Introduction to Operation Systems

2016-17 COMP3230A

Contents

- Purpose and Functions of Operating Systems
- Core Services
- OS Architectures (Implementation design)

Related Learning Outcome

- ILO 1 – [**Fundamentals**] discuss the characteristics of different structures of the Operating Systems (such as microkernel, layered, virtualization, etc.) and identify the core functions of the Operating Systems.

Reading & Reference

- Required Readings
  - Chapter 2, Introduction to Operating Systems, Operating Systems: Three Easy Pieces by Arpaci-Dusseau et. al
    - http://pages.cs.wisc.edu/~remzi/OSTEP/intro.pdf

  - Section 1.10 to 1.13 of Chapter 1 of Operating Systems, 3rd edition by Deitel et. al
    - http://www.deitel.com/books/os3e/os3e_01.pdf

What is an Operating System?

- A PROGRAM that
  - controls the execution of application programs
    - which program runs first? for how long? which program to be swapped out? . . . .
- Two main functions
  - primarily are **resource managers**
    - Managing resources – CPUs, memory, disks, files, . . .
    - Decides between conflicting requests for **efficient** and **fair use** of resources
  - An **interface** between applications and hardware
    - **Separates** applications from the hardware they access
    - OS provides the APIs (Application Program Interfaces) for programs to ask for OS services/resources
      - This greatly simplifies application development

Core Services

- Allow applications to run on the system
- Allow running applications to use memory as well as share the memory
- Allow running applications to interact with each other
- Allow applications to access and share data that stored in persistent storage

The crux of our problem

- How does the operating system support these services?

  - "Note that why the OS does this is not the main question, as the answer should be obvious: it makes the system easier to use. " "Thus, we focus on the how: what **mechanisms and policies** are implemented by the OS to support its services? How does the OS do so **efficiently**? What **hardware support** is needed?"

Process & Processor Management

- A process is basically a **program in execution**
  - Process needs resources to accomplish its task
    - CPU, memory, I/O, files, initial data
  - Process termination requires reclamation of any reusable resources

- Typically system has many processes, some are user processes, some are OS/kernel/system processes, running concurrently on one or more CPUs (cores)

Process & Processor Management

- Responsibilities of OS
  - How to manage and control application processes?
    - There are many processes running in the system
  - How to perform restricted operations?
    - Processes must be allowed to perform I/O and other restricted operations
  - How to provide the illusion of many CPUs?
    - Each given to a process
  - How to regain control of the CPU?
    - Even if processes are not being cooperative
  - How to design an effective and efficient processor scheduler?
    - Even without perfect knowledge of processes' characteristics

Memory Management

- Von Neumann model of computing
  - Instructions & data of a running process must be in physical memory in order to execute
- Main objective
  - With limited memory and many processes are running, determines what should be in memory
    - To optimize **CPU utilization** and computer **response** to users

Memory Management

- Responsibilities of OS
  - How can running processes share the single pool of physical memory?
    - Giving an abstraction of a private memory space for each process
  - How to maintain control over which memory locations an application can access?
    - We don’t want other processes to write to another process’s memory
  - How to run many processes with total memory demand higher than physical limit?
    - Getting help from the larger, slower hard disks
  - How to manage free space? What should OS do if running out of free space?
    - If running out of free space, getting back some memory from running processes

Concurrency

- OS is a concurrent program
  - Many internal kernel data structures may be updated concurrently by multiple execution logics
- Nowadays, multi-core systems and multi-thread programs are prevalent
  - Threads can update shared data simultaneously
- When there are many concurrently tasks running within the same memory space, how can we build a correctly working program?
  - Programs or OS have to carefully access shared data, with the uses of proper synchronization primitives, in order to work correctly

Concurrency

- Responsibilities of OS
  - What primitives are needed for synchronization?
    - We may have to examine different kinds of synchronization and concurrency issues
  - What support do we need from hardware and OS in order to build useful synchronization primitives?
    - We want the primitives to work correctly and efficiently
- How can we use them to solve concurrency problems?

File Management

- The component in OS that manages storage disks is called the file system
  - Responsible for storing any data the user created in a **reliable and efficient** manner on the disks of the system

- File System
  - Provides a uniform, logical view of information storage
  - Abstracts physical properties to logical storage unit - **file**
  - Maps files onto physical media and **provides mechanisms** for applications to manage and access files

File Management

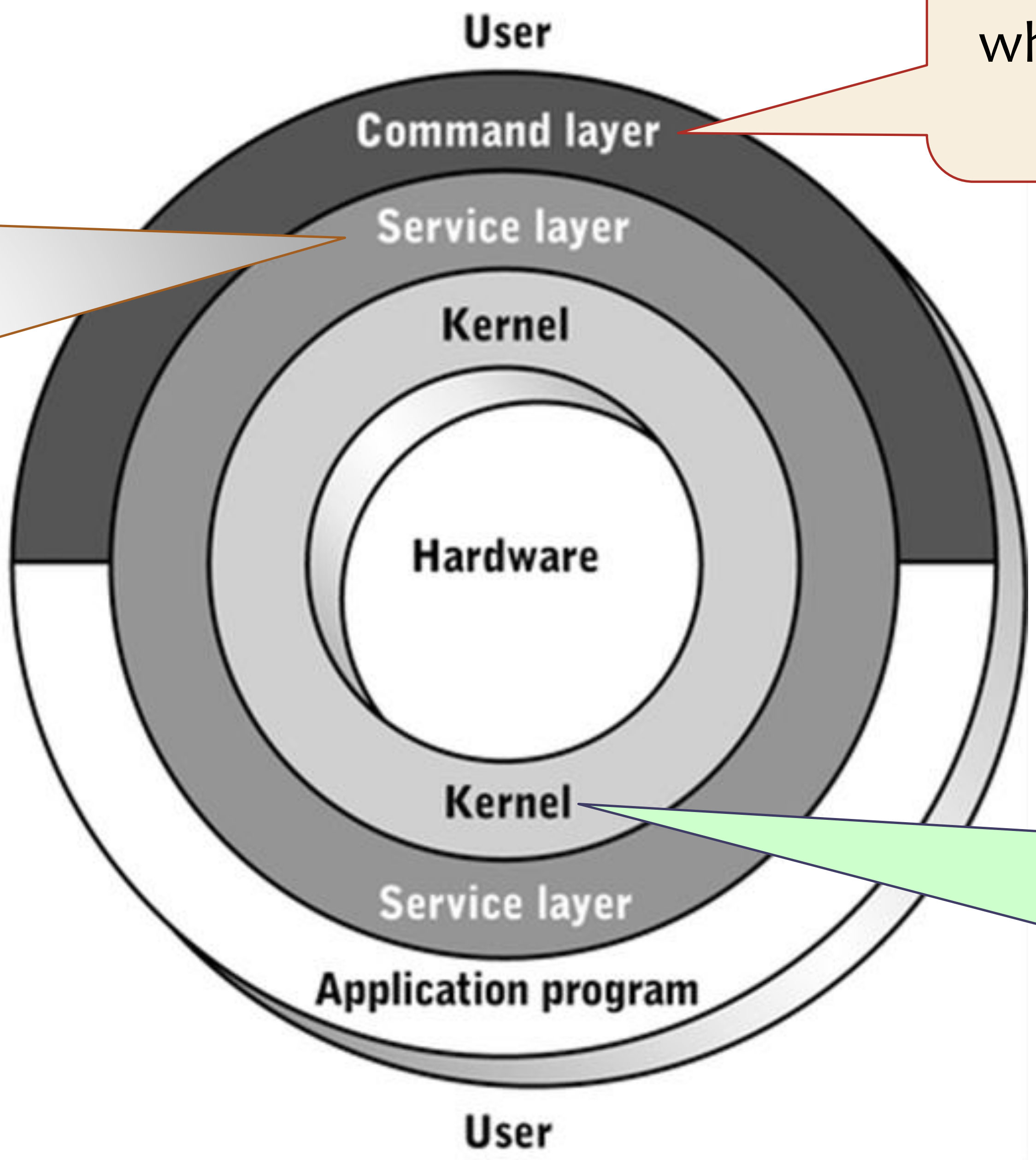
- Responsibilities of OS
  - How to manage a persistent device?
    - For example, where to find suitable storage units for a newly created file? what will happen if deleting a file?
  - How to implement the file system?
    - We need some data structures on the disk for the file system to work correctly and efficiently; e.g., given a file name, how to access the data of the file?
  - How to reduce file system I/O costs?
    - Disk access is slow, is there any way to make file access faster??

Goals of OS

- Makes the system convenient and easy to use
- Provides protection between applications and between OS and applications
- Allows computer system resources to be used in an efficient manner
- Can operate on many hardware configurations
- Provides a high degree of reliability and will not fail due to isolated application/hardware errors
- Protect resources from unauthorized access by users and software

OS Architectures

Operating System Structure



Usually we call it the shell, which is the interface for users to interact with OS

Contains a set of utility functions that will be used or called by application programs and the command layer

Which is the core of OS; it manages resources and directly interacts with computer hardware

Architectures

- Operating Systems tend to be complex
  - Provide many services and support variety of hardware and software
- Operating system architectures help manage this complexity
  - Organize operating system components (functionalities)
  - **Specify privilege** with which each component executes
- Common options
  - Monolithic Architecture
  - Layered Architecture
  - Microkernel Architecture
  - Modular Approach

User Mode / Kernel Mode

- CPU operates in (at least) two modes
  - Kernel mode
    - Also known as privilege mode or supervisor mode
    - CPU is put in *kernel mode* **when** the OS kernel executes
    - It is at the **highest privilege** level and can execute any instruction the machine is capable of executing

  - User mode
    - CPU is put in *user mode* **when** a user application is executing
    - Only a **subset** of the machine instruction is available
    - Ensures that one user program cannot execute instruction that may interfere with operation of other user programs

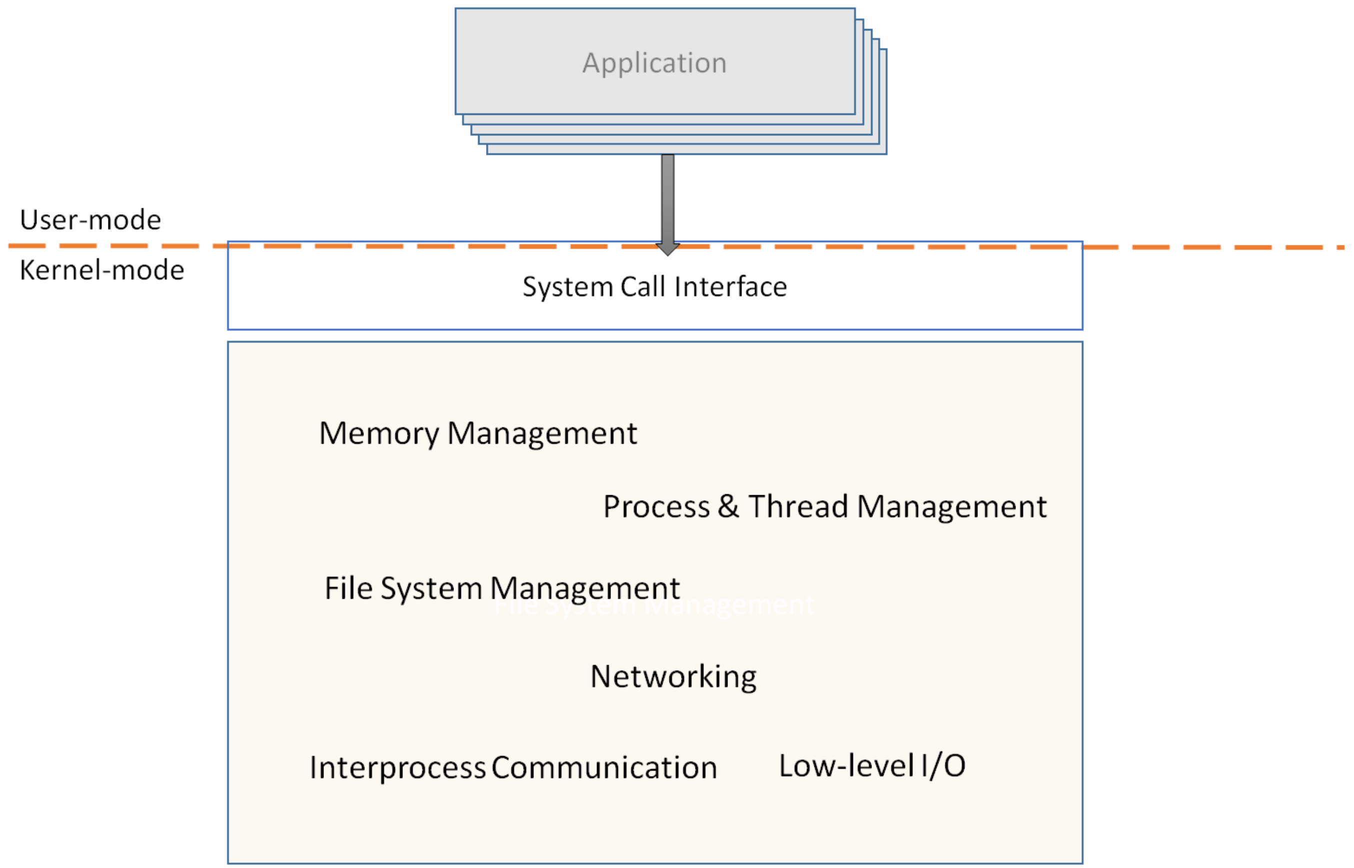
System Calls

- A system call is a request that an application program makes to the OS for requesting resources/services
  - the set of system calls is the **interface (API) to the services** provided by the OS

- When a system call occurs, the system **switches** from **user mode** to **kernel mode** and executes the corresponding kernel's system function
  - We call this *mode switch*
  - This is achieved by special instructions to ***trap*** into the kernel and ***return-from-trap*** back to user mode program

Monolithic

- Every component is contained **in the kernel**
  - Traditionally, OS code **did not** consist of a set of modules with clearly defined interfaces
  - All its components are interwoven into one large program that **runs in privilege mode**
  - Any component (within kernel) can directly communicate with any other (e.g. by using function calls)
  - Data structures are easily shared as all in one program



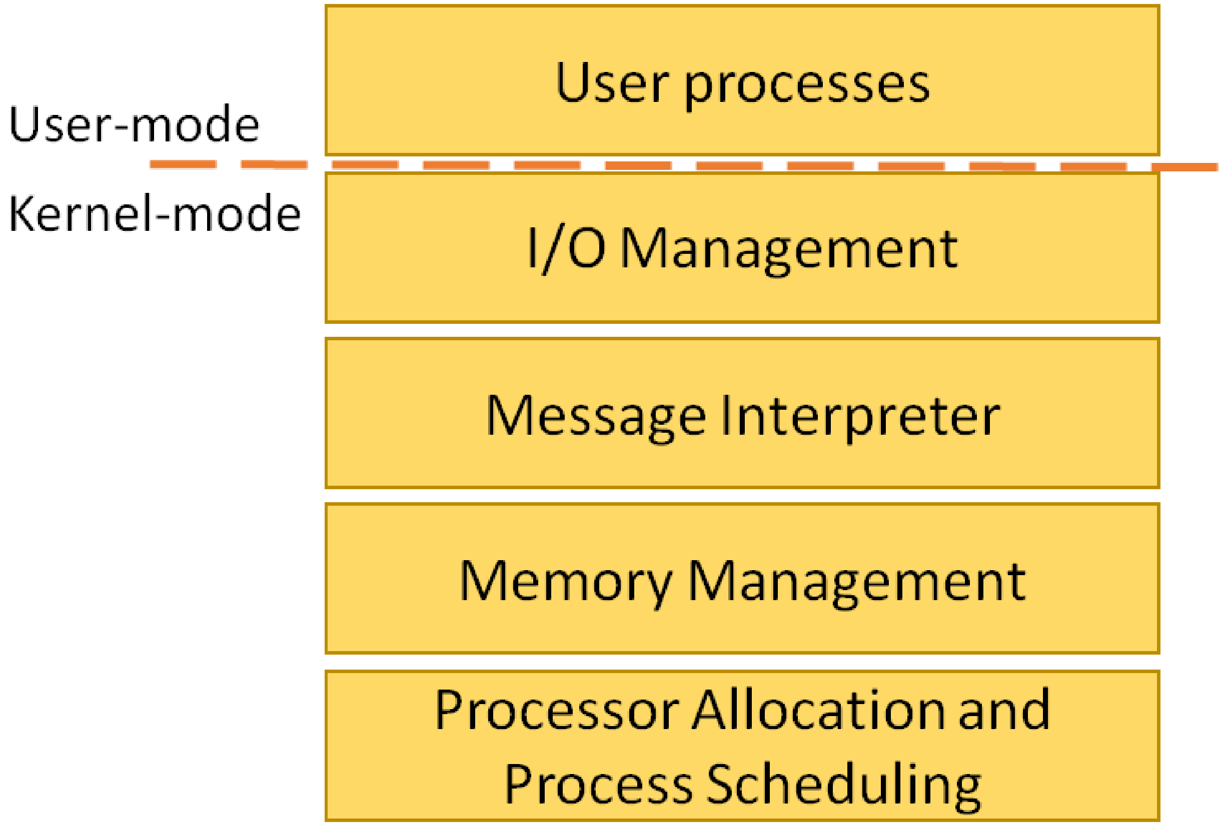
Monolithic

- Adv: Tend to be **highly efficient**
- Disadvantages
  - Components can interact with hardware directly
    - Architecture dependent code was spread throughout the kernel
  - Components can access each other's data and functions directly
    - Changes made in one component could affect other components
    - Bugs in one component can adversely affect another component
      - Difficulty in determining source of subtle errors
    - More susceptible to damage from malicious code (component)

Layered

- Groups components that perform similar function or specific role in a layer and organizes the system into horizontal layers

- With modularity, each layer **communicates only** with layers immediately above and below it
  - Processes' requests might pass through many layers before being serviced
  - **System efficiency can be less** than monolithic kernels

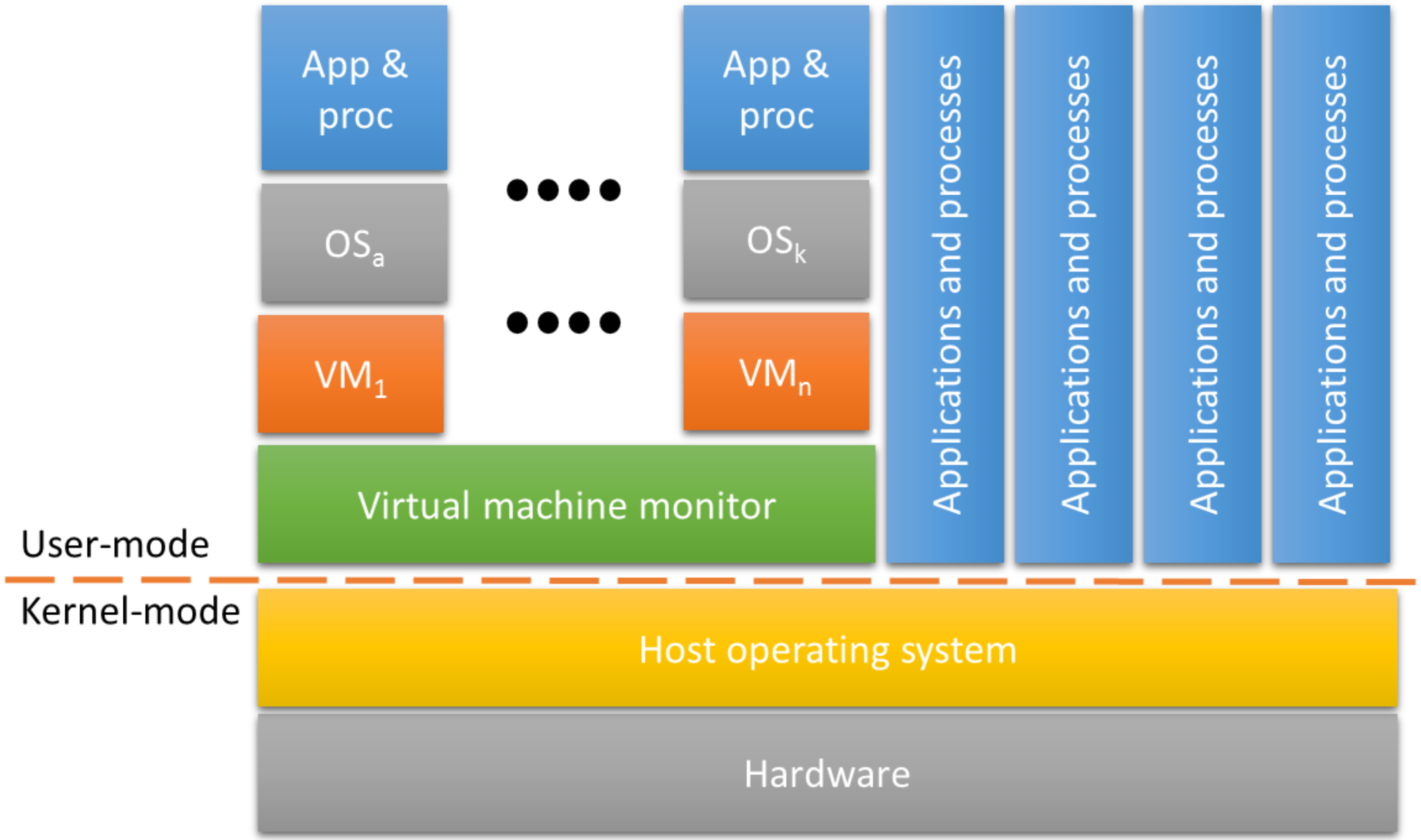


Layered

- Pros
  - Simplicity of construction and debugging
  - **Information hiding** – each layer only knows the interface provided by immediate lower layer

- With the layered approach, the designers have a choice where to draw the kernel-user boundary

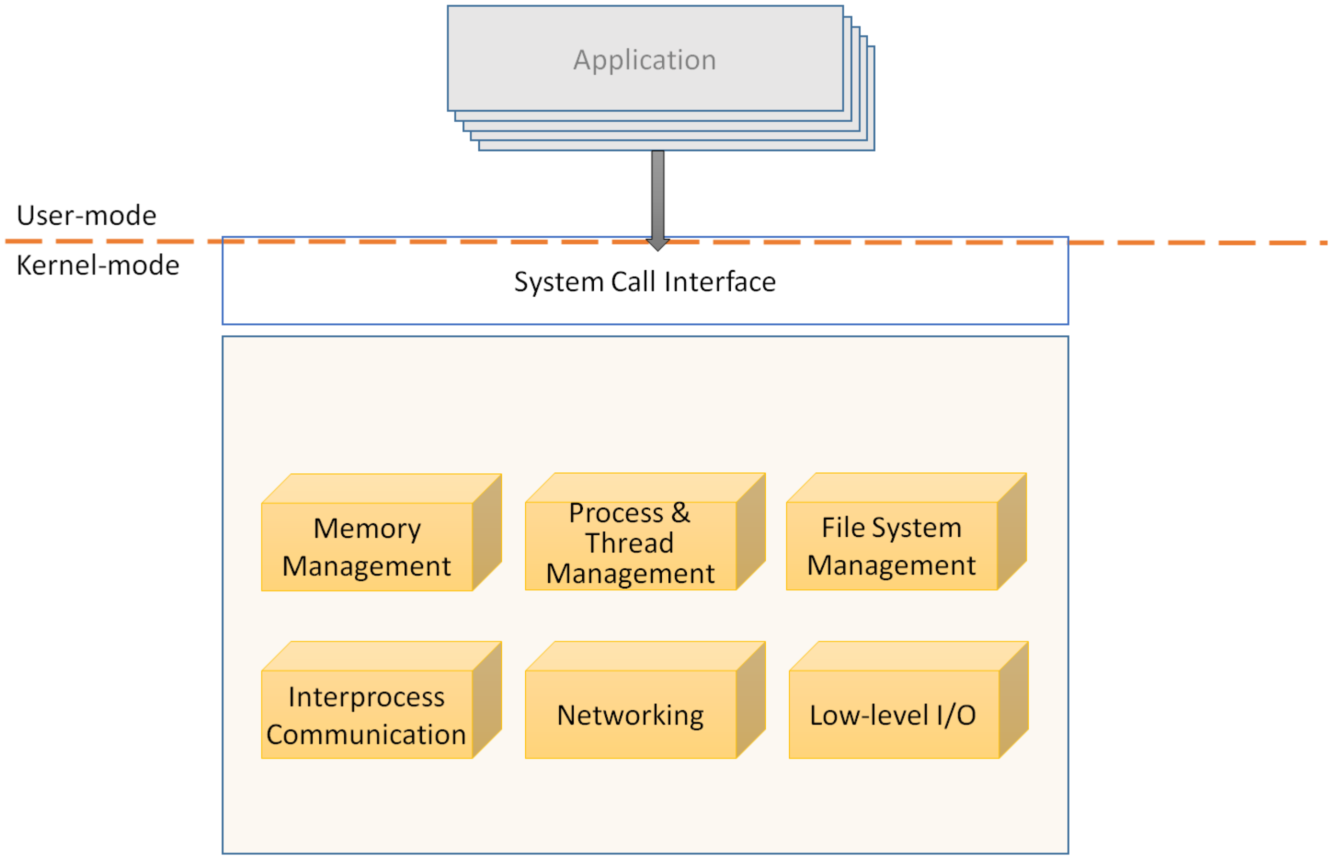
Virtual Machine – An Example of Layered Approach



- Virtual machine monitor
  - Also named as ***hypervisor***
  - Runs on top of host OS – in user mode OR incorporated into host OS – kernel mode
  - Virtualizing the hardware resources and giving the illusion to each running OS that it controls the machine (which is a virtual machine)
  - In essence, it serves as an OS for OSs.

Modular

- Most modern operating systems implement kernel modules
  - Each core component is separated and implemented as module
  - The whole kernel is a collection of modules

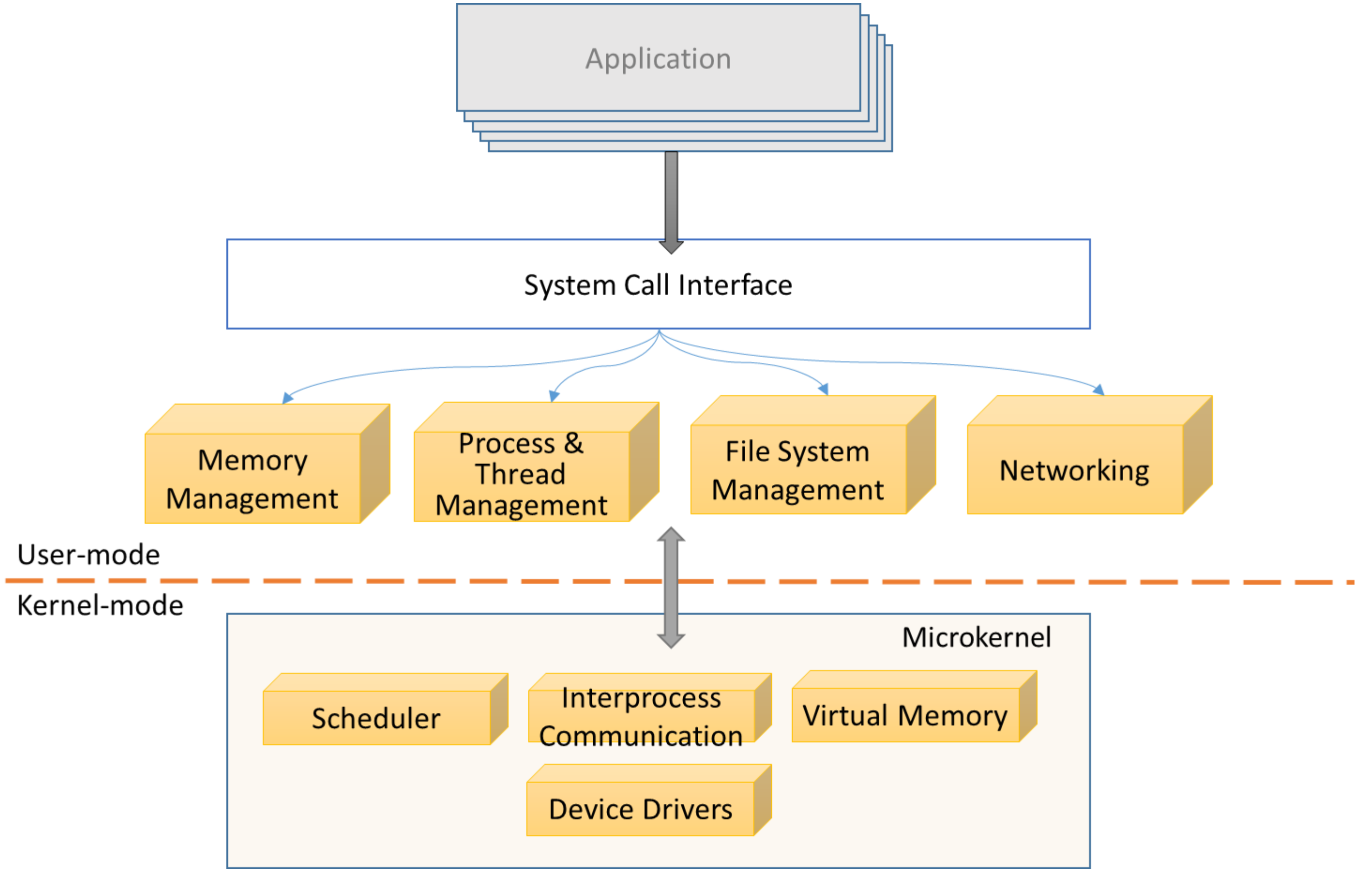


Modular

- Overall, similar to layers but is more flexible and efficient as
  - each kernel module has well-defined, **protected interfaces**; any module can call any other module
  - more efficient to communicate between modules as they are all in kernel
  - allows certain features to be implemented dynamically and loaded as needed (dynamically loadable modules)
    - Memory is conserved as only required modules are loaded in memory
  - more extensible as kernel modules can be modified separately and new modules can be added easily
- Examples: Solaris, Linux, and Mac OS X

Microkernel

- Moves as much functionalities from the kernel space into user space processes (being called as servers)
  - Attempt to keep kernel small
  - the system becomes more stable as only the bare essentials are running in kernel mode
  - More easy to extend and port to other platforms



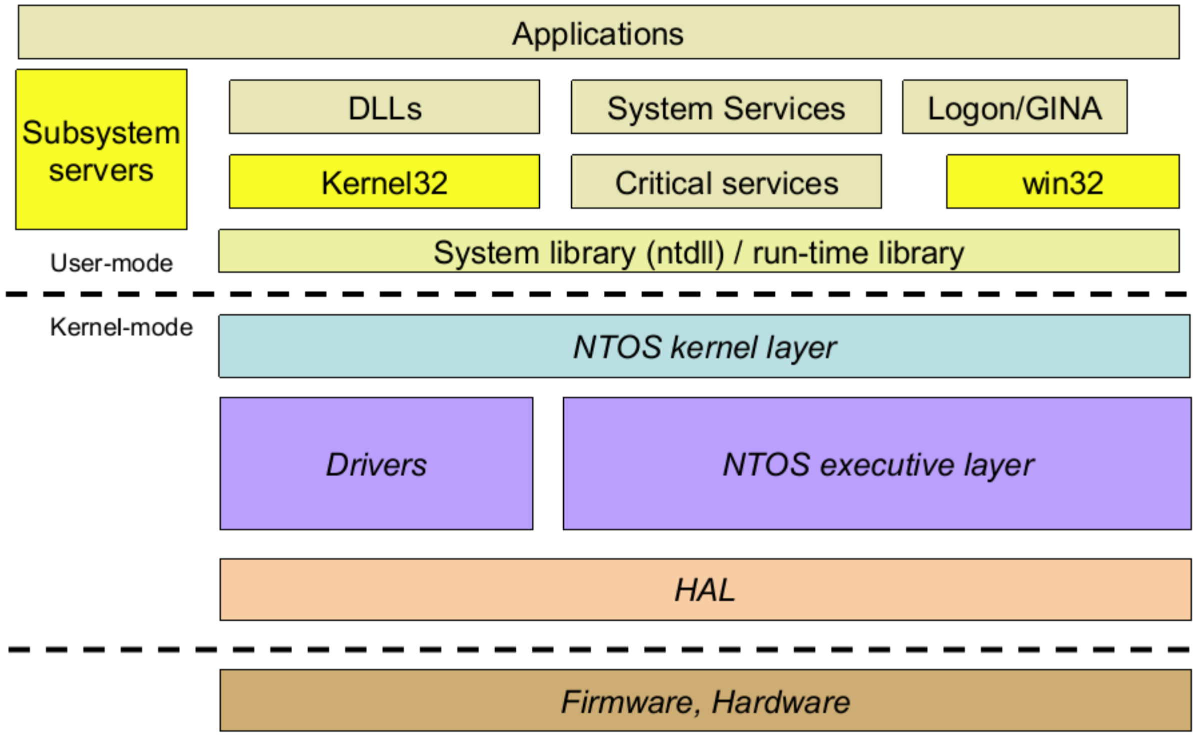
Microkernel

- Pros
  - Extensible, portable and scalable
  - More secure & reliable (less code is running in kernel mode)

- Con
  - Server processes (in user space) are interacting by means of message exchanges, which need the helps from kernel
    - **Induce significant performance overhead** because of communications have to go through kernel

Examples

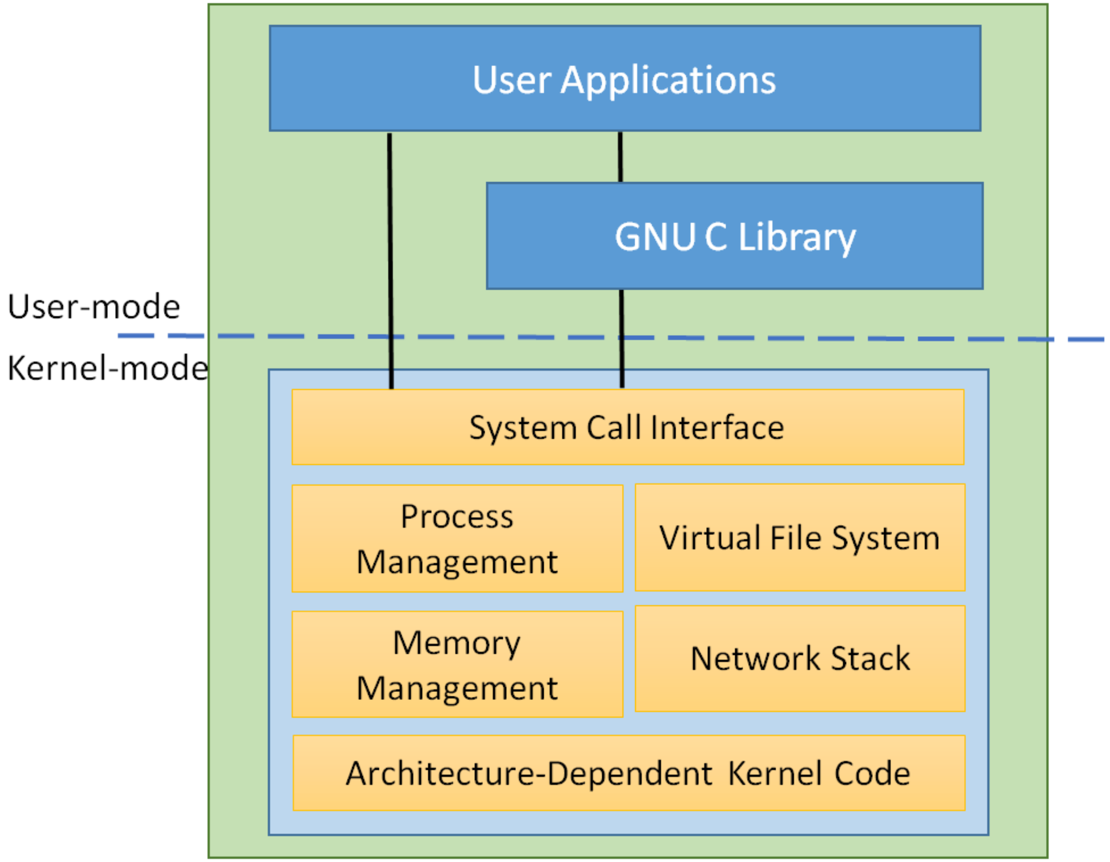
Windows System Architecture



(Source: Windows Kernel Internals by Dave Probert)

A monolithic kernel with modular design principles

Linux System Architecture

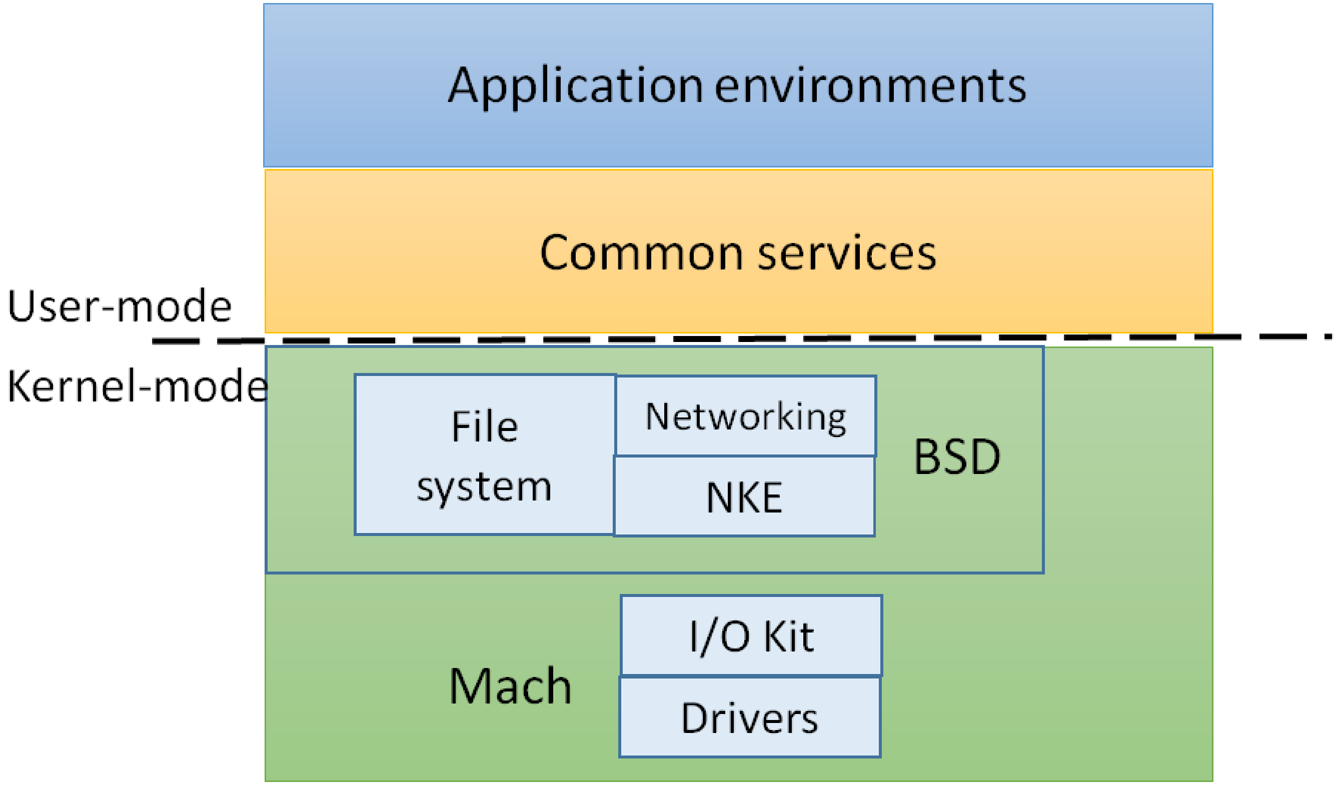


(Source: Anatomy of the Linux Kernel by M. Tim Jones)

A monolithic approach with the support of loadable kernel modules

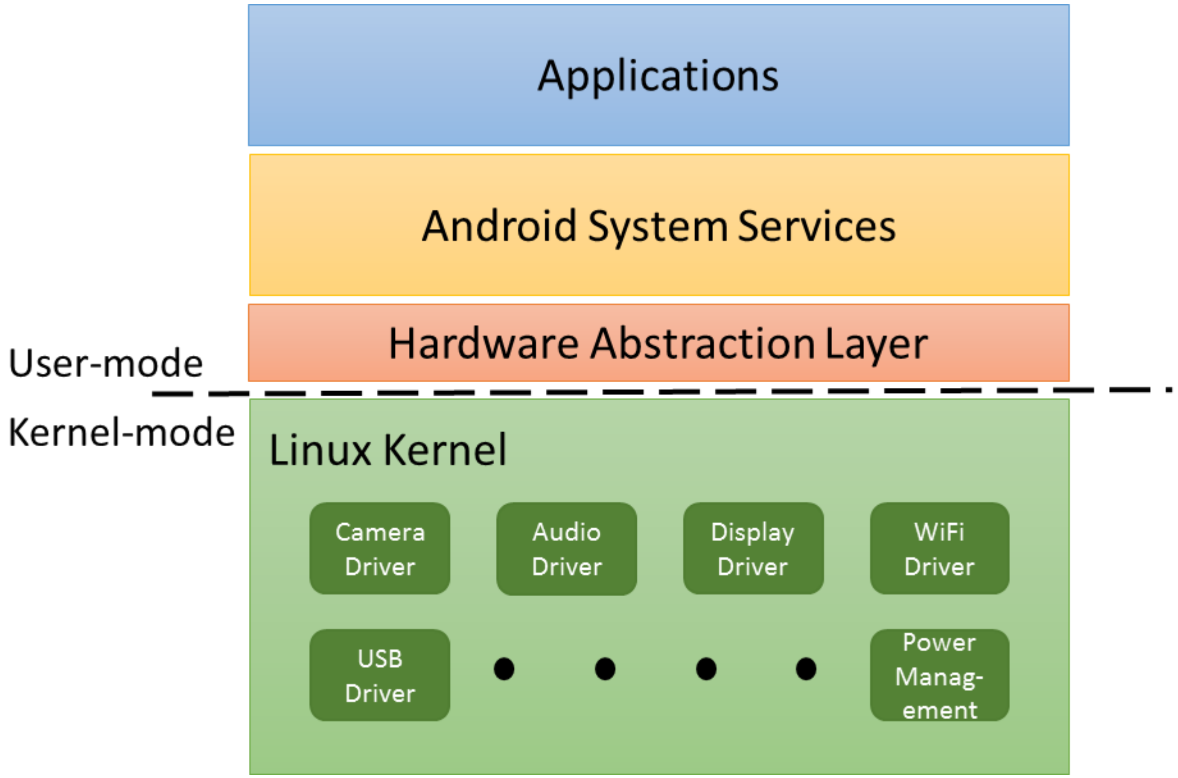
Examples

Mac OS X Architecture



(Source: Kernel Programming Guide by Apple)

Android System Architecture



(Source: Android Open Source Project)

A monolithic approach with the support of loadable kernel extensions

Summary

- What is OS? It is a resource manager that manage & coordinate the use of resources amongst users, and it also provides an abstractive view on the computer to users.

- Different OS architectures have their advantages and disadvantages; however, modern OSs tend to use the monolithic approach with layers and kernel modules for extensibility.

- Next week: We shall talk about processes and how to represent and manage processes