V OPERATING SYSTEM DESIGN AND IMPLEMENTATION

DESIGN GOALS

The first problem in designing a system is to define goals and specifications. At the highest level, the design of the system will be affected by the choice of hardware and the type of system: traditional desktop/laptop, mobile, distributed, or real time. Beyond this highest design level, the requirements may be much harder to specify.

The requirements can, however, be divided into two basic groups:

User goals and **system goals**.

- ❖ User goals

  Convenience and efficiency , Easy to learn , Reliable , Safe and Fast
- ❖ System goals

  Easy to design, implement, and maintain , Flexible, reliable, error-free, and efficient

Mechanisms and Policies

Mechanisms determine ***how*** to do something; policies determine ***what*** will be done.

For example, the timer construct is a mechanism for ensuring CPU protection, but deciding how long the timer is to be set for a particular user is a policy decision.

- Early OS in assembly language, Now C, C++
- Using emulators of the target hardware, particularly if the real hardware is unavailable (e.g. not built yet), or not a suitable platform for development, (e.g. smart phones, game consoles, or other similar devices.)
- Android

  Library : C, C++

  Application Frameworks : JAVA

1. OPERATING SYSTEM STRUCTURE

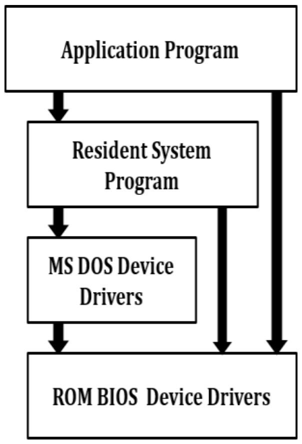
Operating system can be implemented with the help of various structures. The structure of the OS depends mainly on how the various common components of the operating system are interconnected and melded into the kernel.

Depending on this we have following structures of the operating system:

- ❖ Monolithic Structure
- ❖ Layered Approach
- ❖ Microkernels
- ❖ Modules
- ❖ Hybrid Systems
    - ▪ macOS and iOS
    - ▪ Android

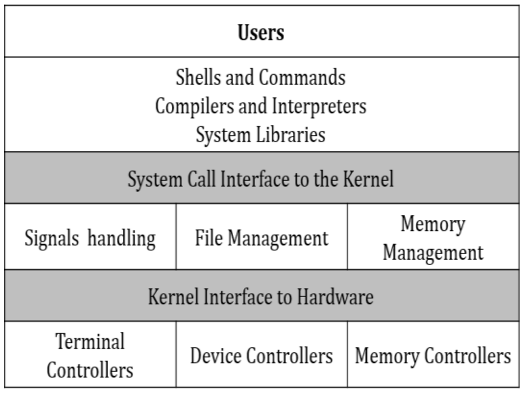
❖ **Monolithic structure:**

Such operating systems do not have well defined structure and are small, simple and limited systems. The interfaces and levels of functionality are not well separated. MS-DOS is an example of such operating system. In MS-DOS application programs are able to access the basic I/O routines. These types of operating system cause the entire system to crash if one of the user programs fails. Diagram of

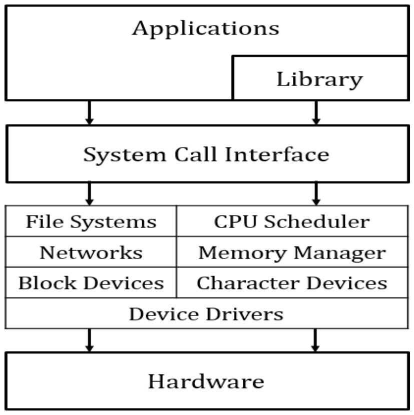


the structure of MS-DOS is shown below.

An example of such limited structuring is the original UNIX operating system, which consists of two separable parts: the kernel and the system programs. The kernel is further separated into a series of interfaces and device drivers, which have been added and expanded over the years as UNIX has evolved. Everything below the system-call interface and above the physical hardware is the kernel. The kernel provides the file system, CPU scheduling, memory management, and other operating system functions through system calls. Taken in sum, that is an enormous amount of functionality to be combined into one single address space. UNIX Structure is shown below



The Linux operating system is based on UNIX shown in the figure below. Applications typically use the glibc standard C library when communicating with the system call interface to the kernel. The Linux kernel is monolithic in that it runs entirely in kernel mode in a single address space, it does have a

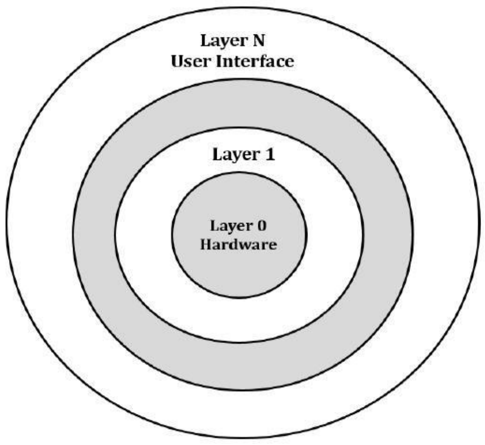


modular design that allows the kernel to be modified during run time.

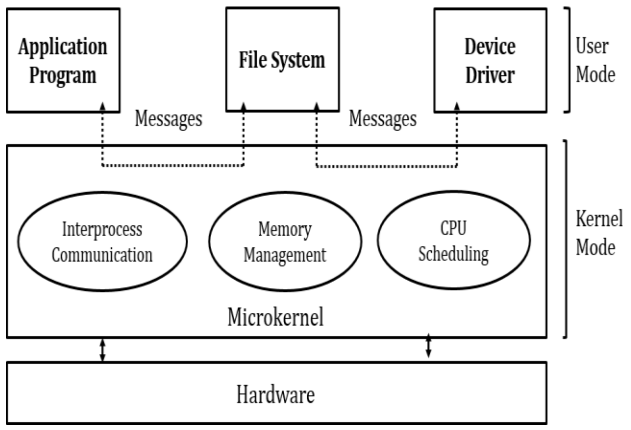
❖ **Layered Approach**

An OS can be broken into pieces and retain much more control on system. In this structure the OS is broken into number of layers (levels). The bottom layer (layer 0) is the hardware and the topmost layer (layer N) is the user interface. These layers are so designed that each layer uses the functions of the lower level layers only. This simplifies the debugging process as if lower level layers are debugged and an error occurs during debugging then the error must be on that layer only as the lower level layers have already been debugged. The main disadvantage of this structure is that at each layer, the data needs to be modified and passed on which adds overhead to the system. Moreover careful planning of the layers is necessary as a layer can use only lower level layers. UNIX is an example of this structure.

❖ **Micro-kernel:**



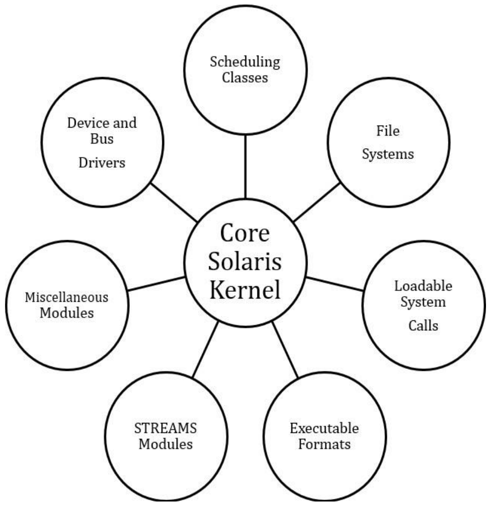
This structure designs the operating system by removing all non-essential components from the kernel and implementing them as system and user programs. This result in a smaller kernel called the micro-kernel.



Advantages of this structure are that all new services need to be added to user space and does not require the kernel to be modified. Thus it is more secure and reliable as if a service fails then rest of the operating system remains untouched. Mac OS is an example of this type of OS.

❖ **Modular structure or approach:**

The best approach for an OS. It involves designing of a modular kernel. The kernel has only set of core components and other services are added as dynamically loadable modules to the kernel either during run time or boot time. It resembles layered structure due to the fact that each kernel has defined and protected interfaces but it is more flexible than the layered structure as a module can call any other module. For example Solaris OS is organized as shown in the figure.



❖ **Hybrid Systems**

The Apple macOS operating system and the two mobile operating systems—iOS and Android.

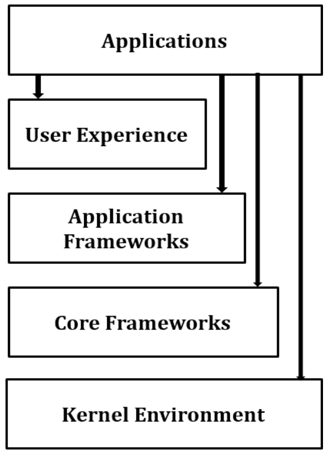
macOS and iOS

Apple's macOS operating system is designed to run primarily on desktop and laptop computer systems, whereas iOS is a mobile operating system designed for the iPhone smartphone and iPad tablet computer. Highlights of the various layers include the following:

- **User experience layer**. This layer defines the software interface that allows users to interact with the computing devices. macOS uses the ***Aqua*** user interface, which is designed for a mouse or trackpad, whereas iOS uses the ***Springboard*** user interface, which is designed for touch devices.

- **Application frameworks layer**. This layer includes the ***Cocoa*** and ***Cocoa Touch*** frameworks, which provide an API for the Objective-C and Swift programming languages. The primary difference between Cocoa and Cocoa Touch is that the former is used for developing macOS applications, and the latter by iOS to provide support for hardware features unique to mobile devices, such as touch screens.
- **Core frameworks**. This layer defines frameworks that support graphics and media including, Quicktime and OpenGL.

- **Kernel environment**. This environment, also known as **Darwin**, includes the Mach microkernel and the BSD UNIX kernel.



Applications can be designed to take advantage of user-experience features or to bypass them and interact directly with either the application framework or the core framework. Additionally, an application can forego frameworks entirely and communicate directly with the kernel environment.

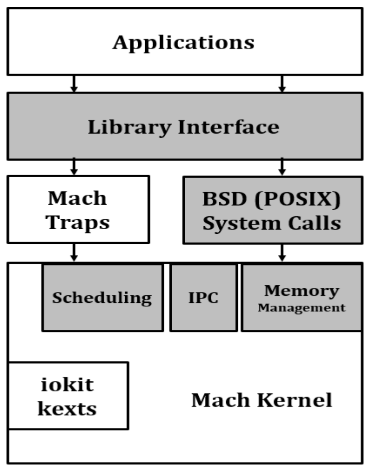
Some significant distinctions between macOS and iOS include the following:

- Because macOS is intended for desktop and laptop computer systems, it is compiled to run on Intel architectures. iOS is designed for mobile devices and thus is compiled for ARM-based architectures. Similarly, the iOS kernel has been modified somewhat to address specific features and needs of mobile systems, such as power management and aggressive memory management. Additionally, iOS has more stringent security settings than macOS.
- The iOS operating system is generally much more restricted to developers than macOS and may even be closed to developers. For example, iOS restricts access to POSIX and BSD APIs on iOS, whereas they are openly available to developers on macOS.

Darwin OS

Darwin OS is a layered system that consists primarily of the Mach microkernel and the BSD UNIX kernel. Darwin's structure is shown below

Darwin provides ***two*** system-call interfaces: Mach system calls (known as **traps**) and BSD system calls (which provide POSIX functionality). The interface to these system calls is a rich set of libraries that includes not only the standard C library but also libraries that provide networking, security, and programming language support.



Beneath the system-call interface, Mach provides fundamental operating system services, including memory management, CPU scheduling, and inter process communication (IPC) facilities such as message passing and remote procedure calls (RPCs). Much of the functionality provided by Mach is available through **kernel abstractions**, which include tasks (a Mach process), threads, memory objects, and ports (used for IPC). As an example, an application may create a new process using the BSD POSIX fork() system call. Mach will, in turn, use a task kernel abstraction to represent the process in the kernel.

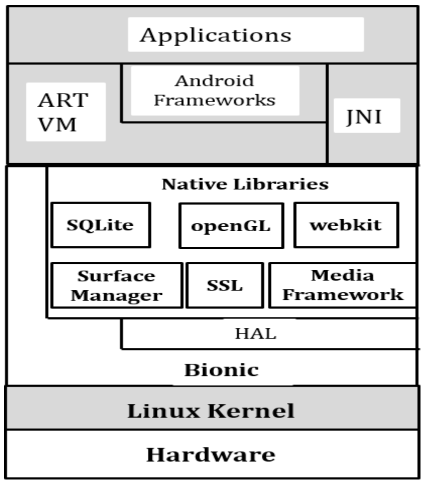
In addition to Mach and BSD, the kernel environment provides an I/O kit for development of device drivers and dynamically loadable modules (which macOS refers to as **kernel extensions**, or **kexts**).

Android

Developed for Android smartphones and tablet computers. Whereas iOS is designed to run on Apple mobile devices and is close-sourced, Android runs on a variety of mobile platforms and is open sourced, partly explaining its rapid rise in popularity. Android is similar to iOS in that it is a layered stack of software that provides a rich set of frameworks supporting graphics, audio, and hardware features. These features, in turn, provide a platform for developing mobile applications that run on a multitude of Android-enabled devices.

Software designers for Android devices develop applications in the Java language, but they do not generally use the standard Java API. Google has designed a separate Android API for Java development. Java applications are compiled into a form that can execute on the Android RunTime ART, a virtual machine designed for Android and optimized for mobile devices with limited memory and CPU processing capabilities. Java programs are first compiled to a Java bytecode .class file and then translated into an executable .dex file. Whereas many Java virtual machines perform just-in-time (JIT) compilation to improve application efficiency, ART performs **ahead-of- time** (**AOT**) compilation

The structure of Android appears is shown below



.dex files are compiled into native machine code when they are installed on a device, from which they can execute on the ART. AOT compilation allows more efficient application execution as well as reduced power consumption, features that are crucial for mobile systems.

Programs written using Java native interface JNI are generally not portable from one hardware device to another. The set of native libraries available for Android applications includes frameworks for developing web browsers (webkit), database support (SQLite), and network support, such as secure sockets (SSLs). Android can run on an almost unlimited number of hardware devices, Google has chosen to abstract the physical hardware through the hardware abstraction layer, or HAL. By abstracting all hardware, such as the camera, GPS chip, and other sensors, the HAL provides applications with a consistent view independent of specific hardware. This feature, of course, allows developers to write programs that are portable across different hardware platforms.

The standard C library used by Linux systems is the GNU C library (glibc). Google instead developed the **Bionic** standard C library for Android. Not only does Bionic have a smaller memory footprint than glibc, but it also has been designed for the slower CPUs that characterize mobile devices. At the bottom of Android's software stack is the Linux kernel. Google has modified the Linux kernel used in Android in a variety of areas to support the special needs of mobile systems, such as power management. It has also made changes in memory management and allocation.