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Operating System Structure

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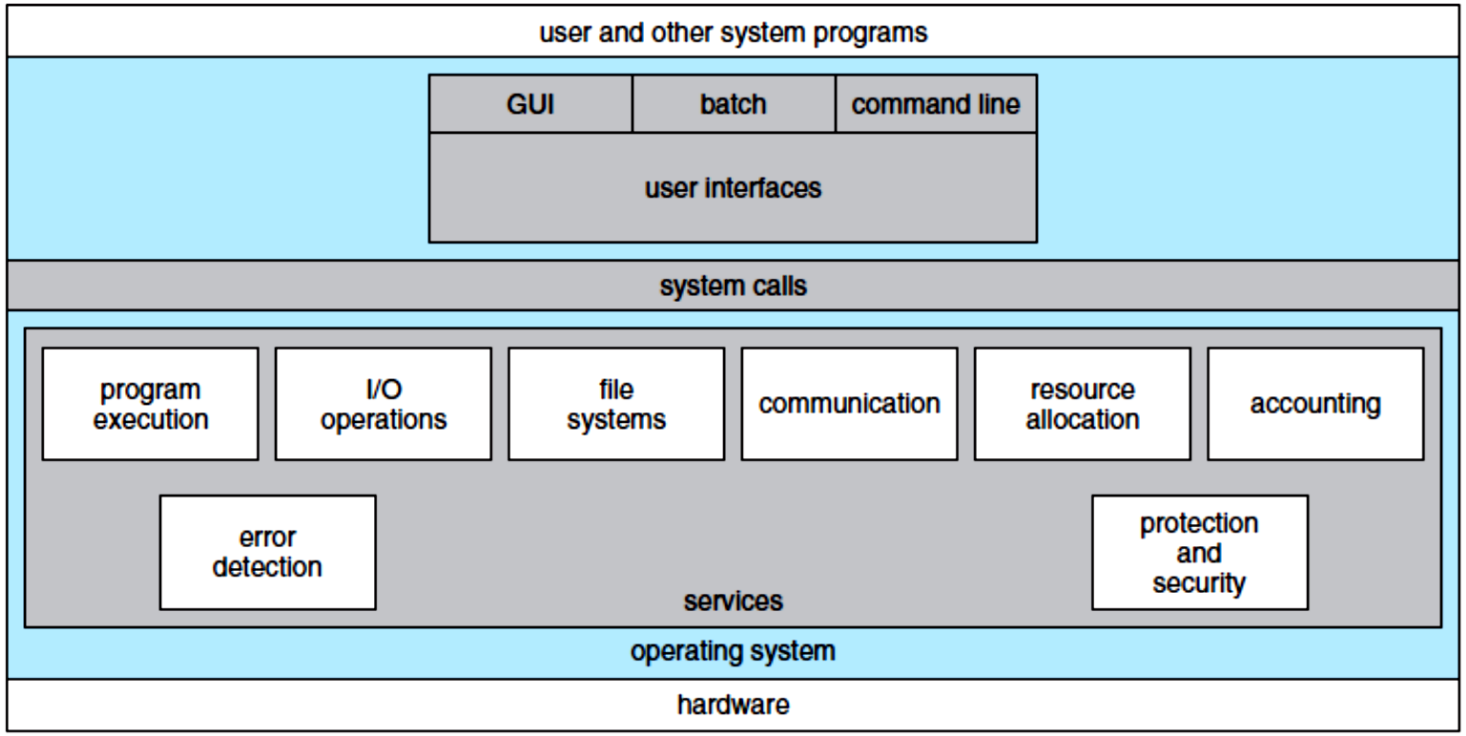
Advantages of OS

- **Different views from OS**
  - Services (predefined comfort routines)
  - Interface to users and programs (interactions)
  - Components & their interconnects (SW architecture)



OS services (helpful to users)

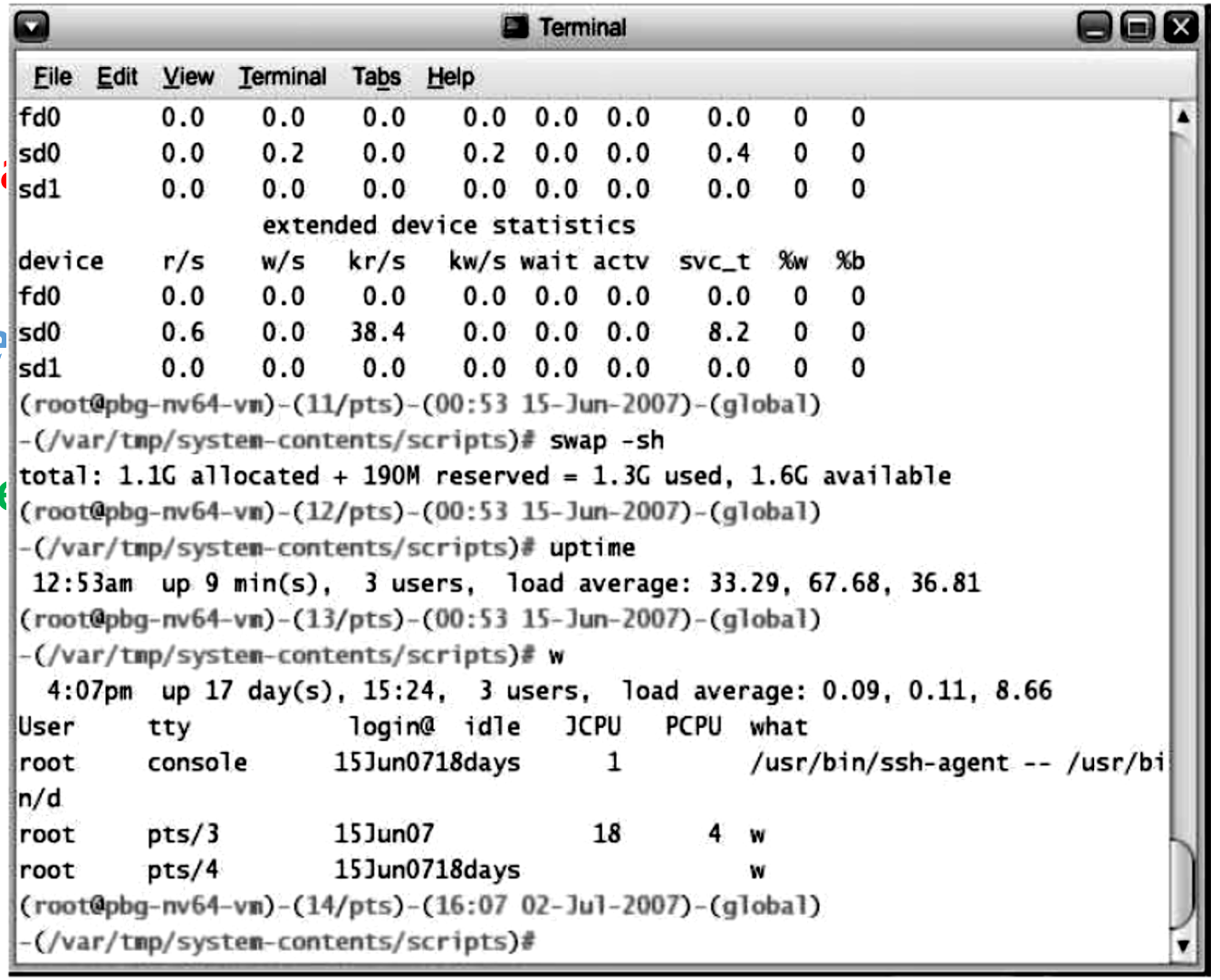
- User interface
  - CLI (Command-line interface)
  - GUI (Graphical user interface)
  - Batch (shell script)
- Program execution
- I/O operations
- File-system manipulation
- Communications
  - Shared memory
  - Message passing
- Error detection

OS services (for efficient operation)

- **Resource allocation**
- **Accounting**
- **Protection & security**

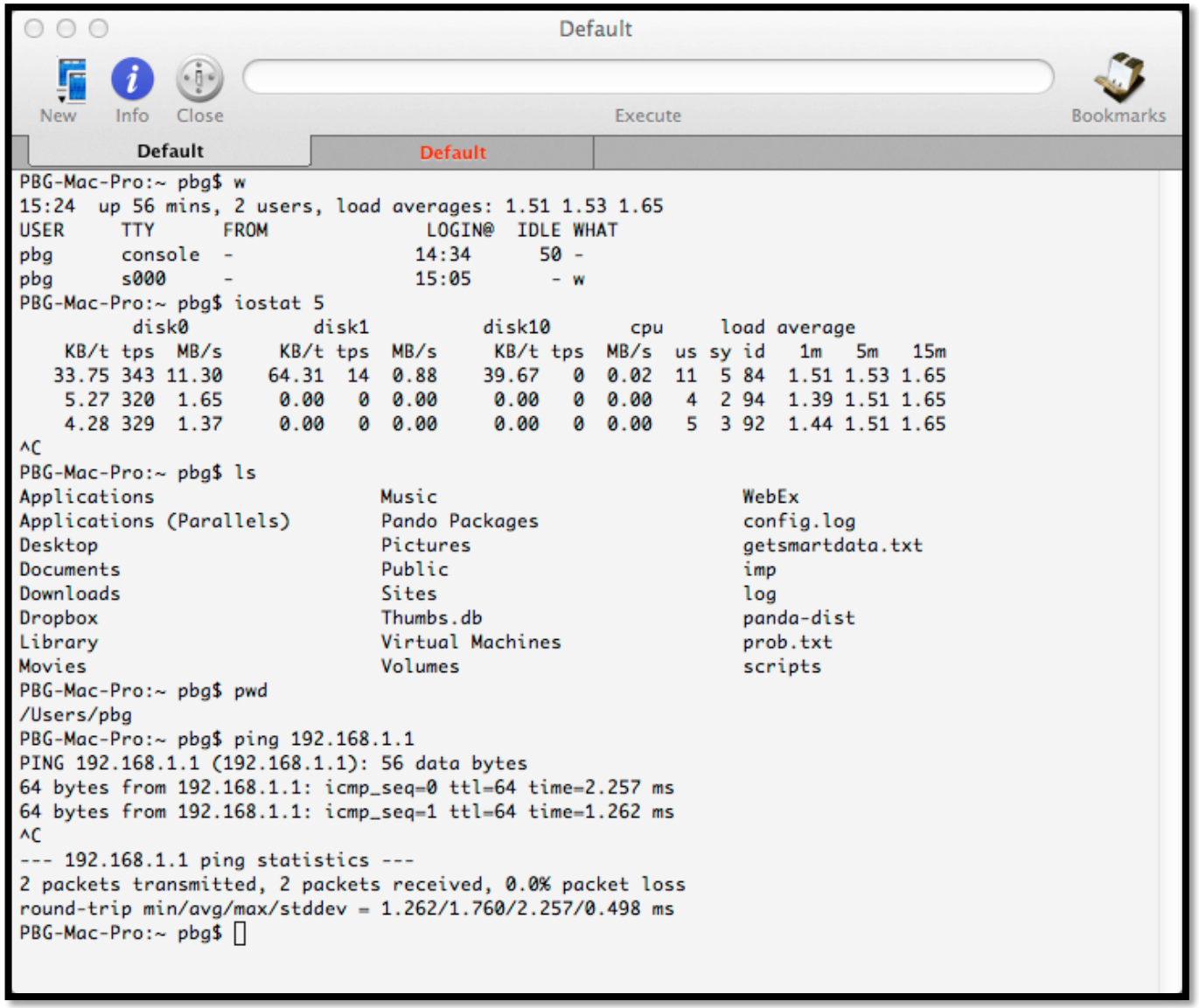
OS interface (command line)

- **Command interpreters**
  - Kernel-based vs. system progr
- **Multiple interpreters, *shell***
  - UNIX, Linux shells: *Bourne she*
  - Third party shell!
  - Similar functionality, user prefe
- **Shell implementations**
  - Internal codes (make jump)
  - System programs (UNIX)
    - rm file.txt



Bourne shell in Solaris 10

Bourne Shell command interpreter



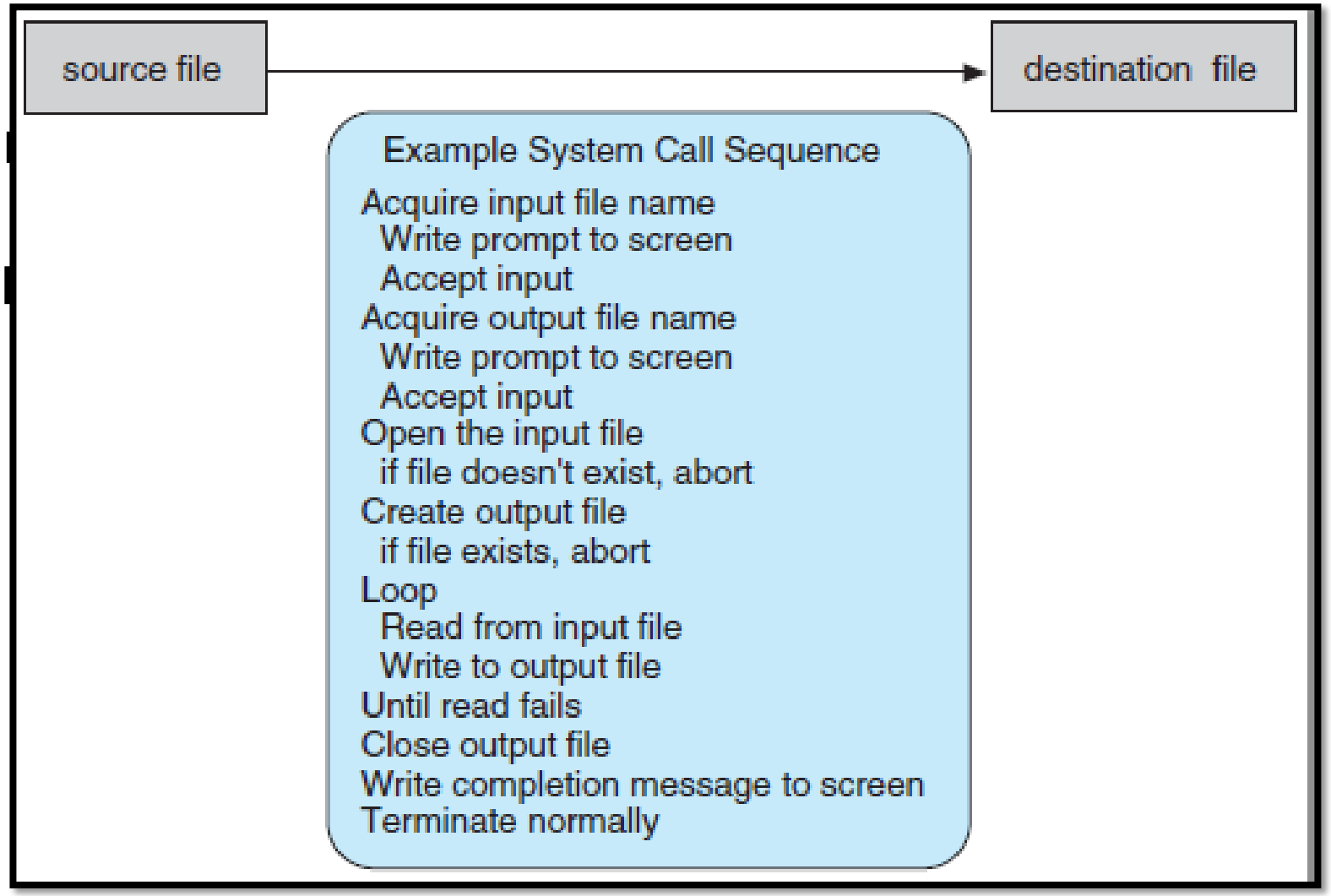
OS interface (GUI)

- Xerox PARC (1970)
- Xerox Alto (1973)
- Apple Macintosh (1980)
- Aqua in Mac OS X
- Microsoft Windows
- UNIX
  - CDE (Common desktop environment)
  - X-Windows
  - KDE (K Desktop environment)
  - GNOME (GNU project)

Choice of interface (The Mac OS X GUI)

System calls

- C, C++, Assembly
- API (Application progra
  - Win API
  - POSIX API (UNIX, Linux, I
  - JAVA API
- Example: Copy file



Example of standard API

As an example of a standard API, consider the `read()` function that is available in UNIX and Linux systems. The API for this function is obtained from the `man` page by invoking the command

```
man read
```

on the command line. A description of this API appears below:

```
#include <unistd.h>

ssize_t    read(int fd, void *buf, size_t count)
```

return value — function name — parameters

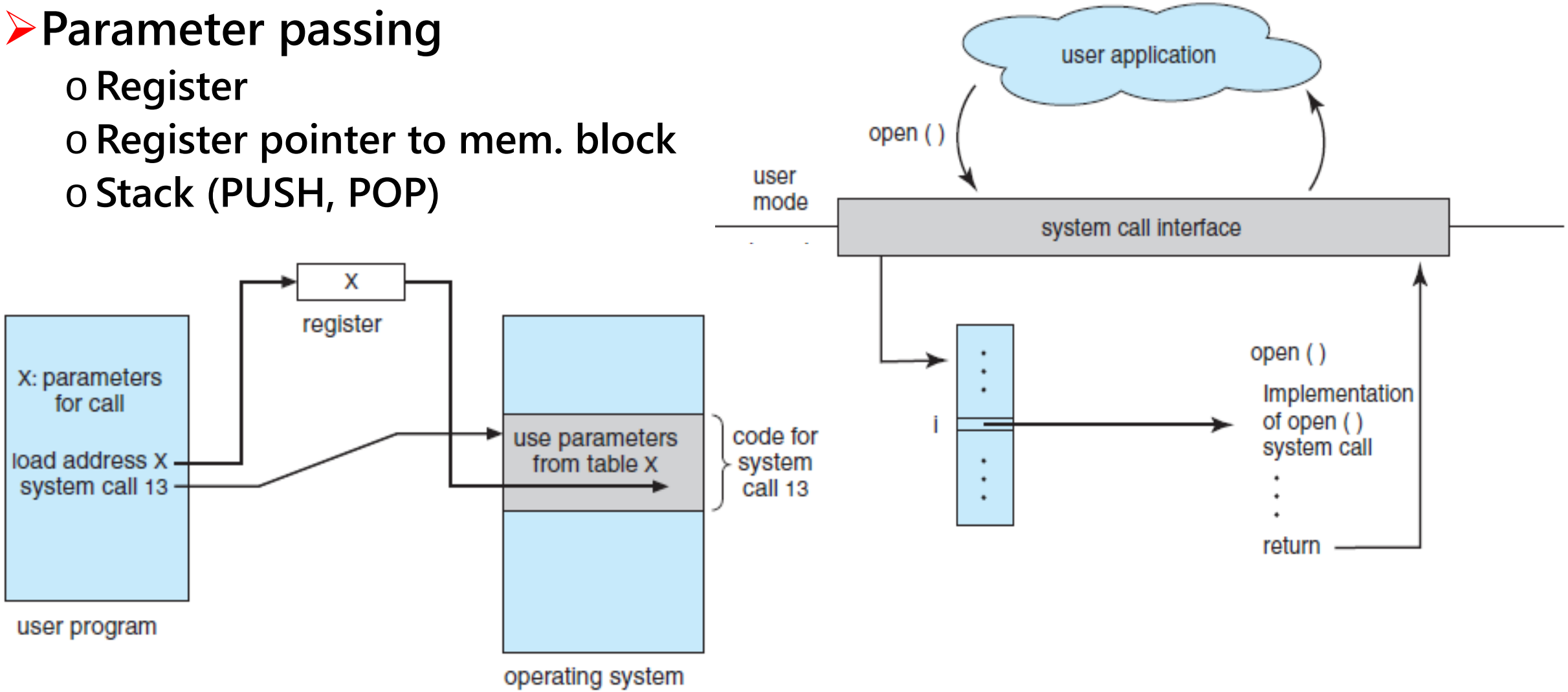
A program that uses the `read()` function must include the `unistd.h` header file, as this file defines the `ssize_t` and `size_t` data types (among other things). The parameters passed to `read()` are as follows:

- `int fd`—the file descriptor to be read
- `void *buf`—a buffer where the data will be read into
- `size_t count`—the maximum number of bytes to be read into the buffer

On a successful read, the number of bytes read is returned. A return value of 0 indicates end of file. If an error occurs, `read()` returns −1.

System call interface

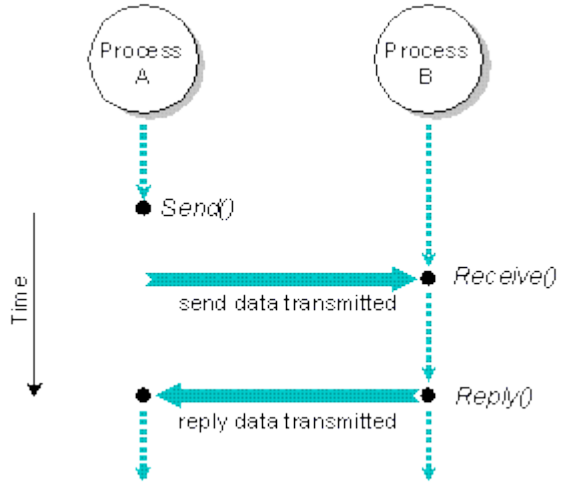
- **Parameter passing**
  - Register
  - Register pointer to mem. block
  - Stack (PUSH, POP)



Communications mechanisms

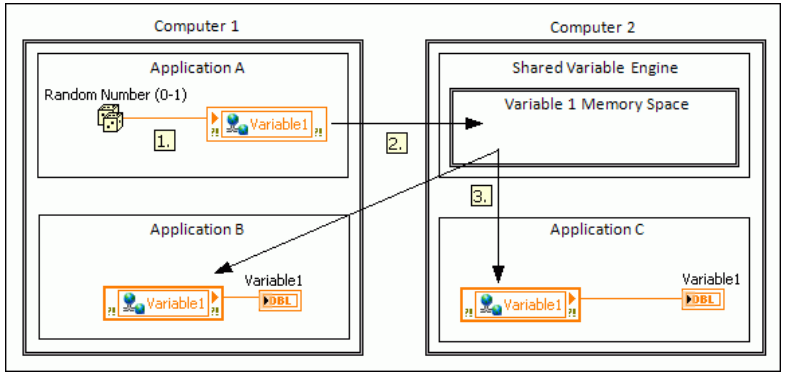
➢Message passing

- o Easy
- o Suitable for low communication rate
- o No interference



➢Shared memory

- o Easy
- o Fast
- o Points of: protection, race condition



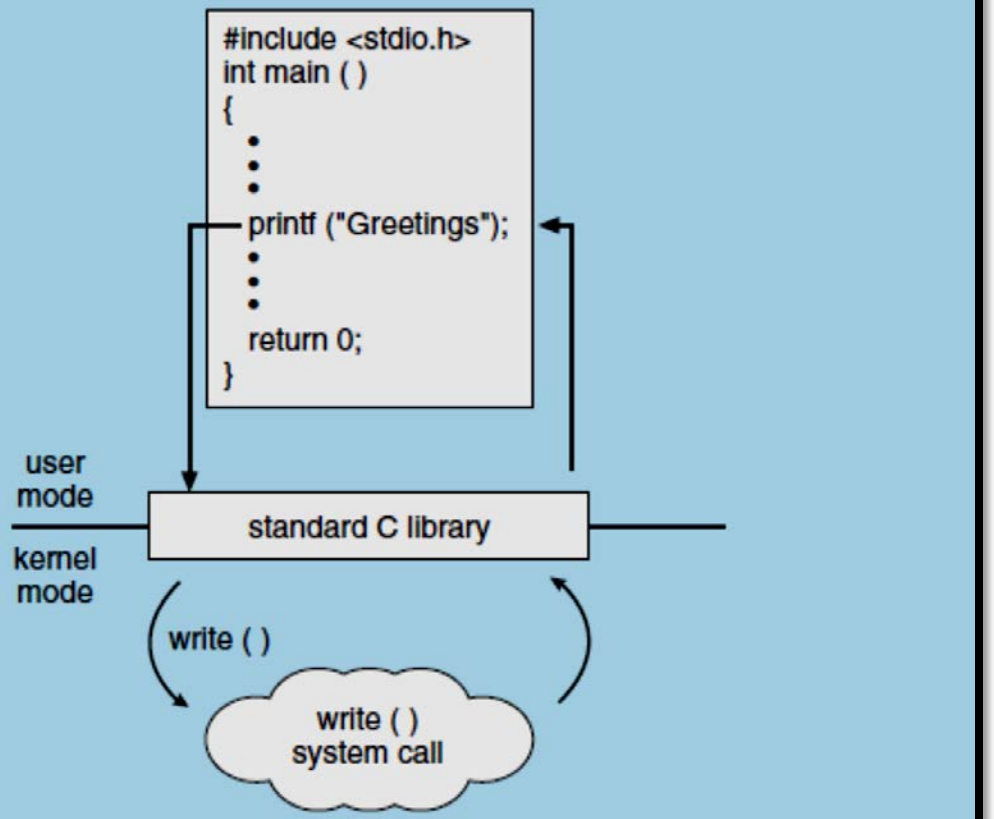
Types of system calls

- Process control
- File manipulation
- Device manipulation
- Information maintenance
- Communications
- Protections

	Windows	Unix
Process Control	CreateProcess() ExitProcess() WaitForSingleObject()	fork() exit() wait()
File Manipulation	CreateFile() ReadFile() WriteFile() CloseHandle()	open() read() write() close()
Device Manipulation	SetConsoleMode() ReadConsole() WriteConsole()	ioctl() read() write()
Information Maintenance	GetCurrentProcessID() SetTimer() Sleep()	getpid() alarm() sleep()
Communication	CreatePipe() CreateFileMapping() MapViewOfFile()	pipe() shm_open() mmap()
Protection	SetFileSecurity() InitlializeSecurityDescriptor() SetSecurityDescriptorGroup()	chmod() umask() chown()

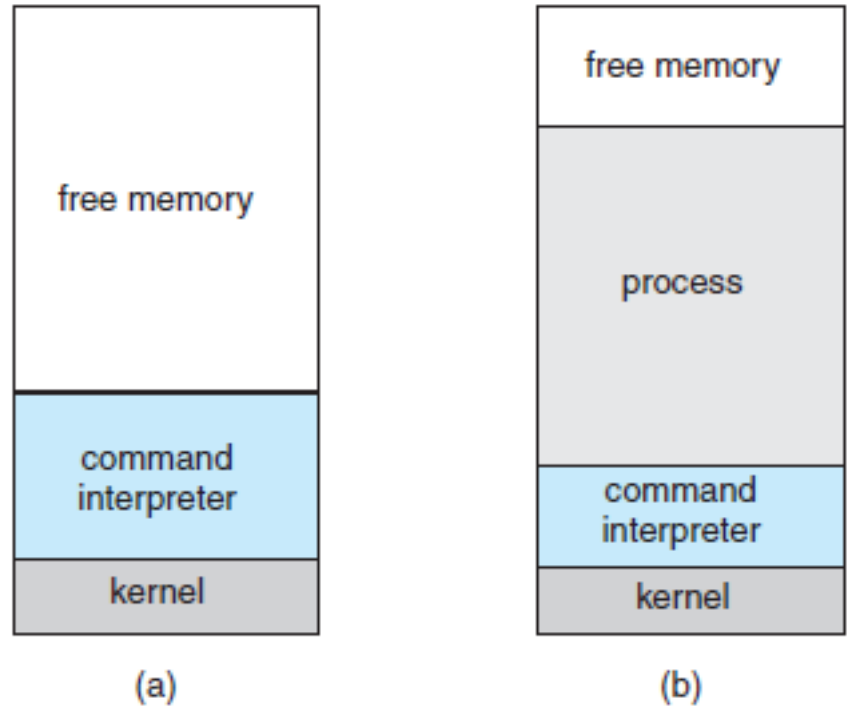
Example of standard C library

The standard C library provides a portion of the system-call interface for many versions of UNIX and Linux. As an example, let's assume a C program invokes the `printf()` statement. The C library intercepts this call and invokes the necessary system call (or calls) in the operating system—in this instance, the `write()` system call. The C library takes the value returned by `write()` and passes it back to the user program. This is shown below:



Example: MS-DOS

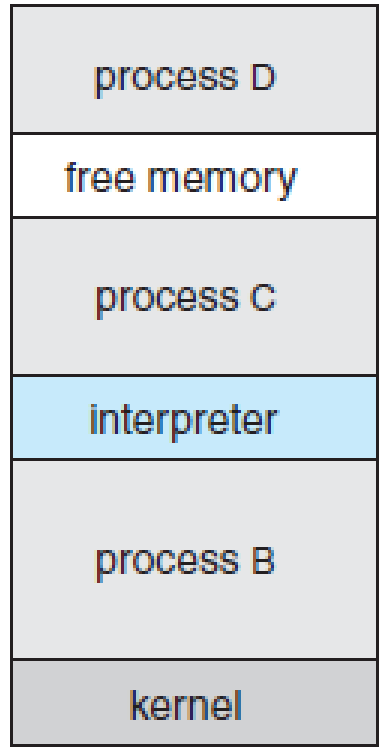
- Single-tasking
- Shell invoked when system booted
- Simple method to run program
  - No process created
- Single memory space
- Loads program into memory, overwriting all but the kernel
- Program exit -> shell reloaded



MS-DOS execution. (a) At system startup. (b) Running a program

Example: FreeBSD

- Unix variant
- Multitasking
- User login -> invoke user's choice of shell
- Shell executes fork() system call to create process
  - Executes exec() to load program into process
  - Shell waits for process to terminate or continues with user commands
- Process exits with code of 0 – no error or > 0 – error code



FreeBSD running multiple programs

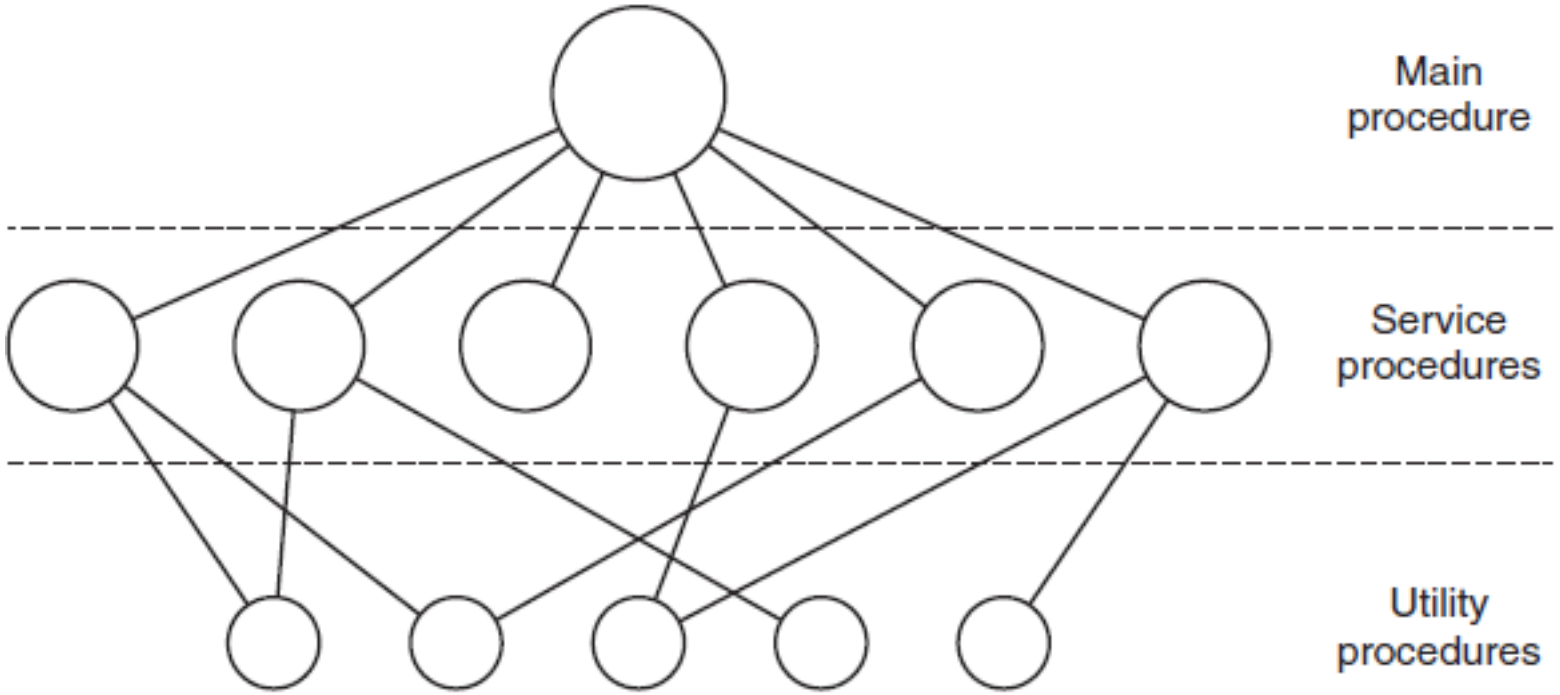
OS design & implementation

- **Goals**
  - User vs. System
- **Mechanisms & policy**
  - how vs. what
- **Implementation**
  - Assembly, C or C++
    - MCP: ALGOL
    - MULTICS: PL/1
    - Linux, Win: C, Assembly
  - C is supported on diff. ISAs, CPUs

OS structure: 1. Simple structure (Monolithic)

- The most common organization
- OS is a single large program in kernel mode

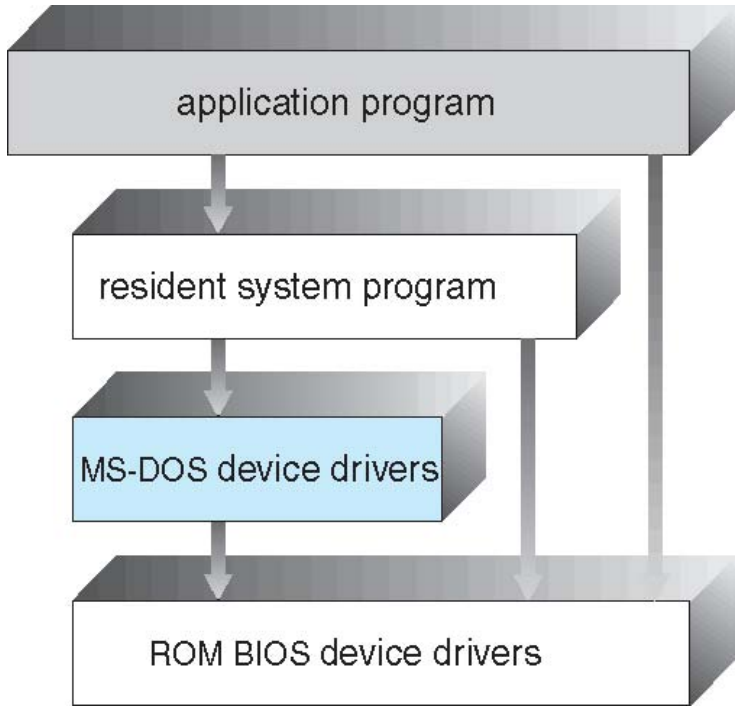
- Problems
  - Crash in called procedures?
  - Unwieldy & difficult to understand



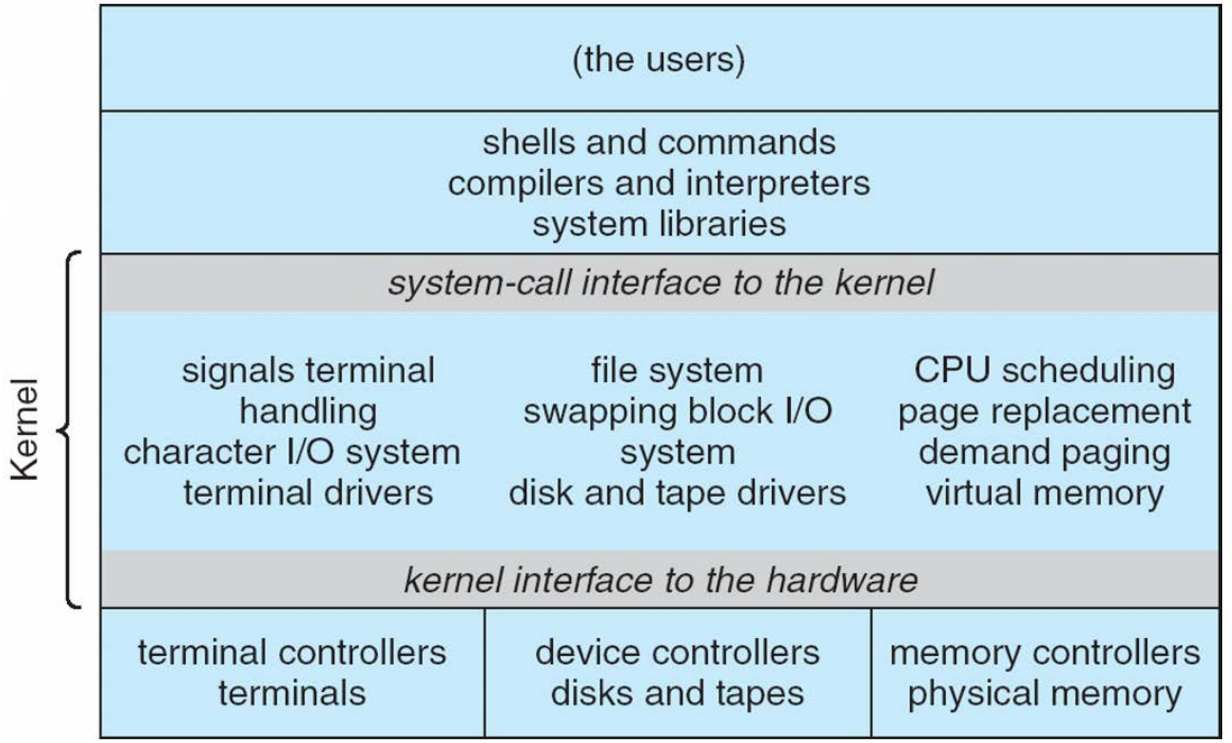
A simple structuring model for a monolithic system

Samples

- **Simple structure**
  - **MS-DOS, UNIX (Traditional)**



MS-DOS layer structure

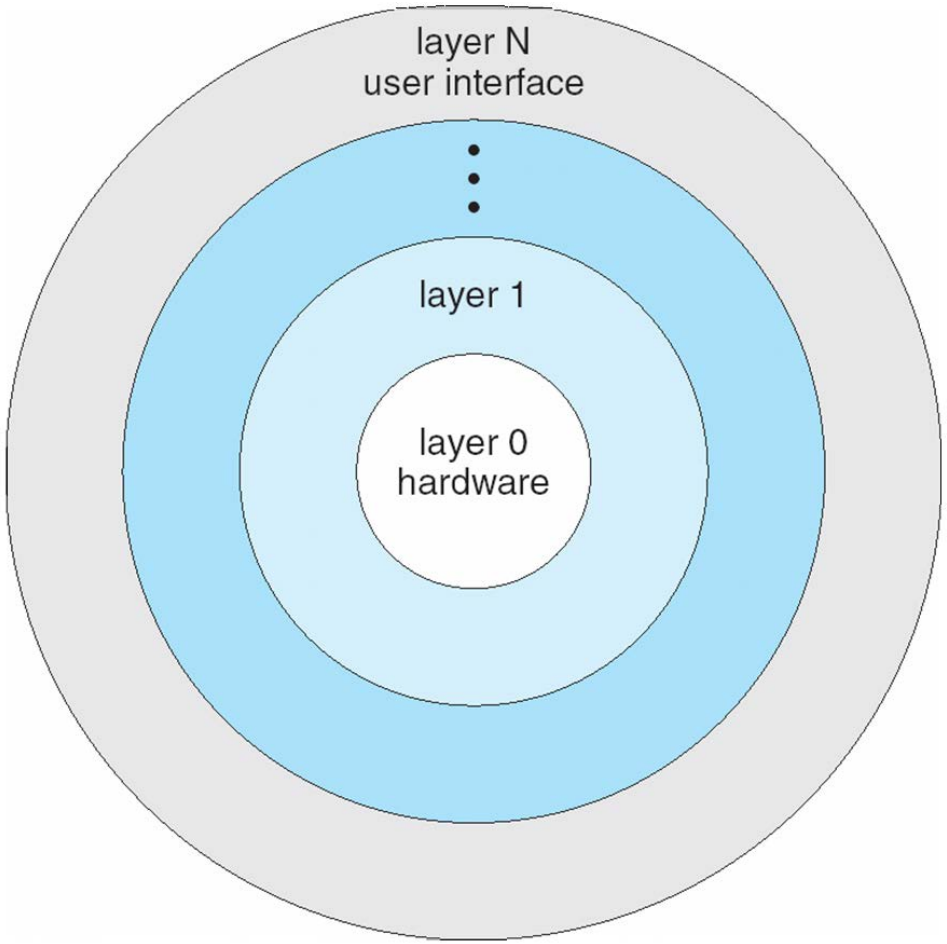


Traditional UNIX system structure

Beyond simple but not fully layered

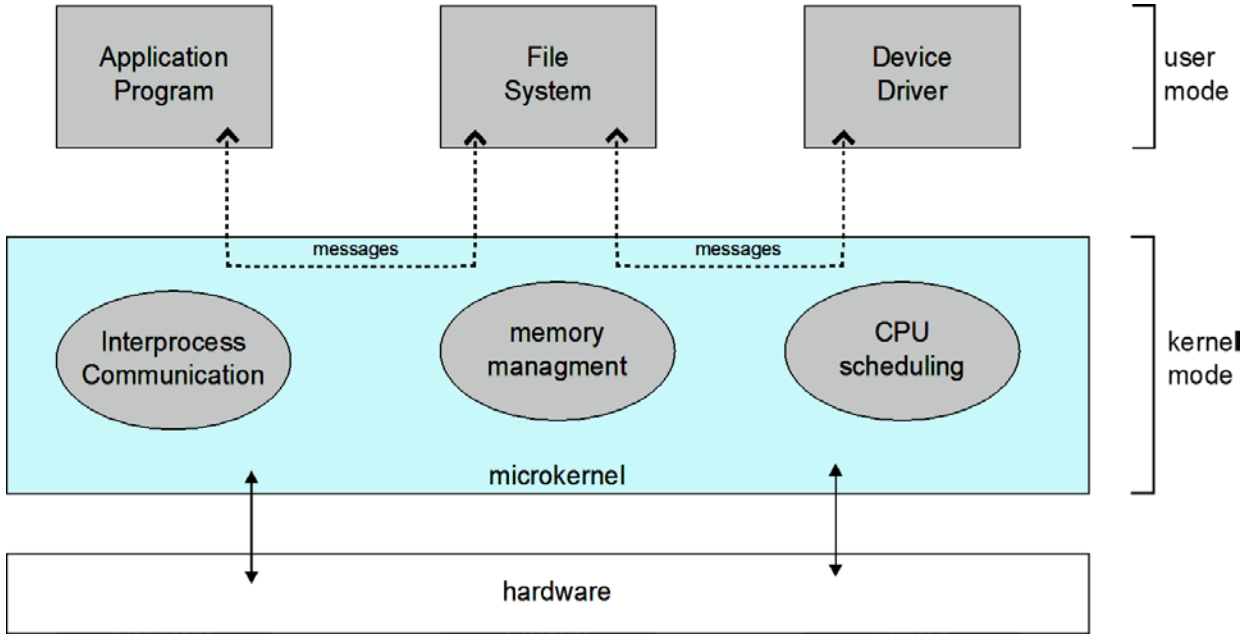
OS structure: 2. Layered approach

- **Layered approach**
  - **abstractions**
  - **adv.**
    - Simplicity
      - ✓ Construction
      - ✓ Debugging
    - Functions and operations of low layers
  - **dis. adv.**
    - Layer definition problem
      - ✓ MMU, backing store, scheduler (?)
    - Less efficient

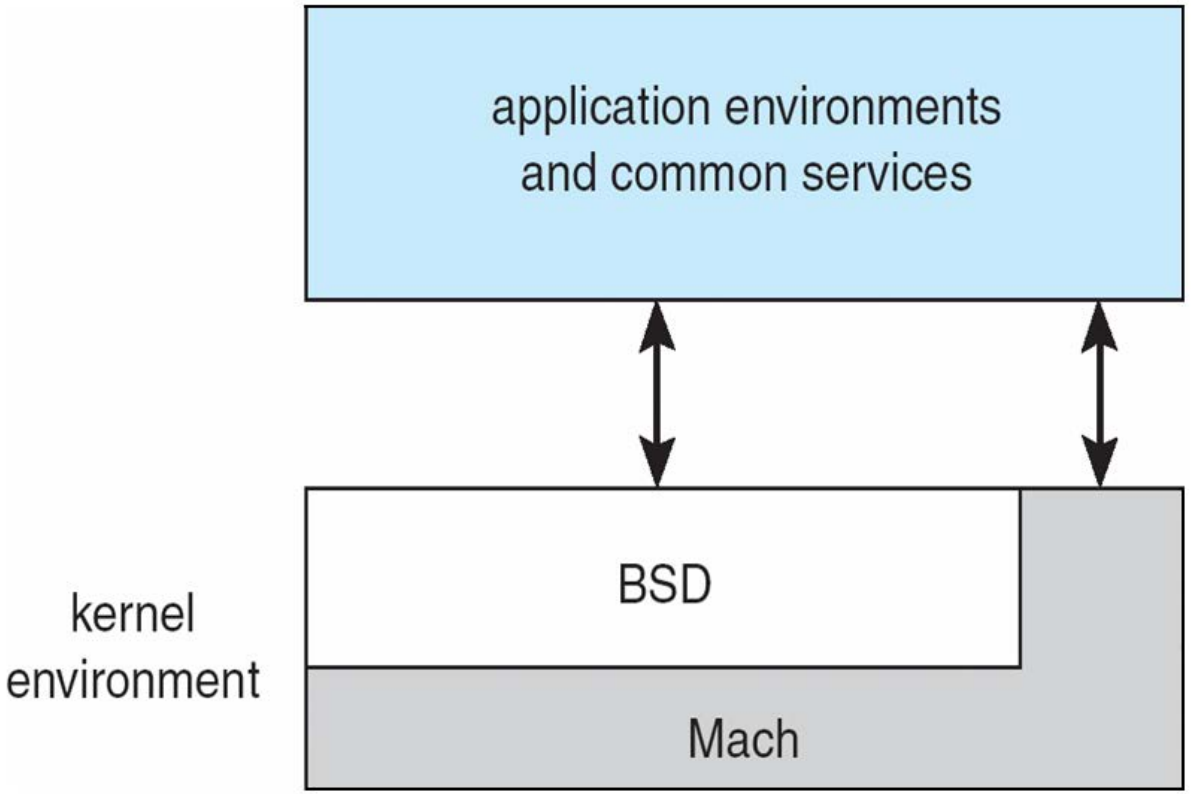


OS structure: 3. Microkernel

- Microkernel
  - Moves as much from the kernel into "*user*" space
  - Communication takes place between user modules using message passing
- Examples
  - Mach (CMU)
  - Mac OS X kernel (Darwin)
- Benefits:
  - Easier to extend a microkernel
  - Easier to port the operating system to new architectures
  - More reliable (less code is running in kernel mode)
  - More secure
- Detriments:
  - Performance overhead of user space to kernel space communication
  - Windows NT 4 (microkernel) slow!
    - vs. Windows XP (monolithic) fast!



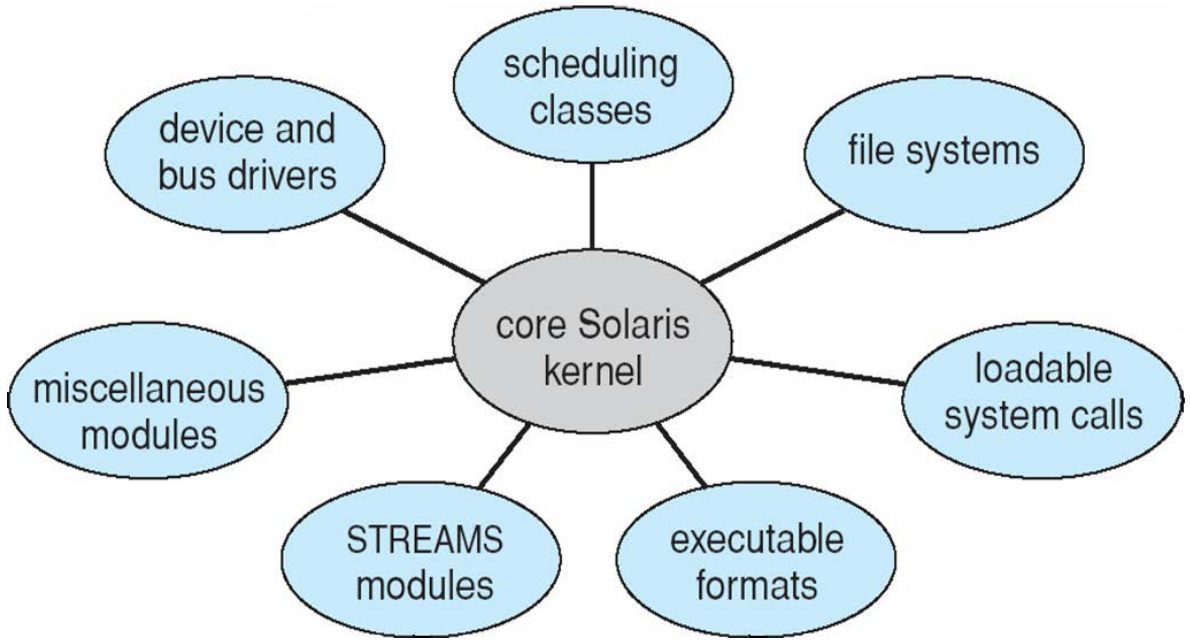
Mac OS X structure



OS structure: 4. Modules

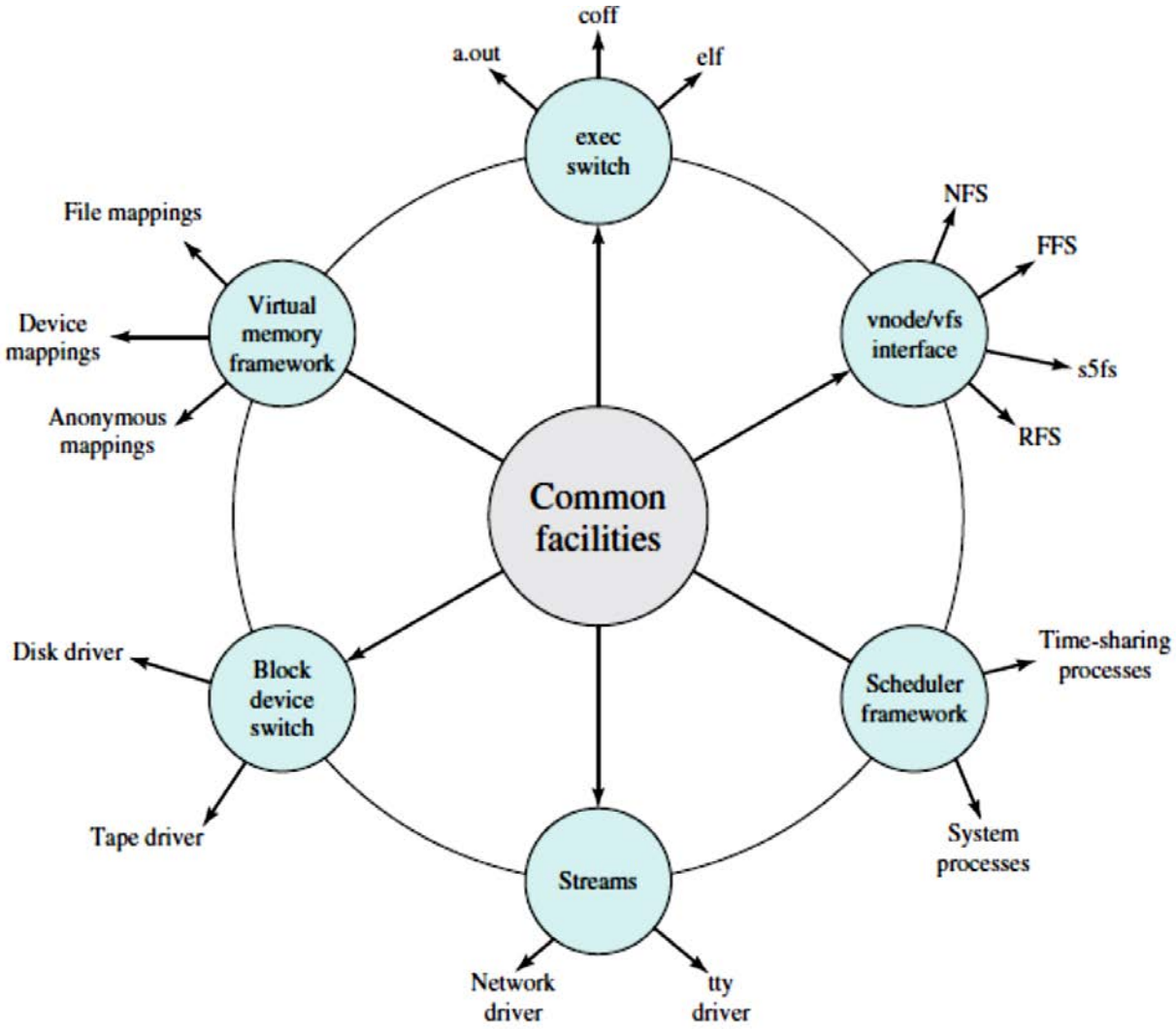
Modules

- Most modern operating systems implement kernel modules
  - Uses object-oriented approach
  - Each core component is separate
  - Each talks to the others over known interfaces
  - Each is loadable as needed within the kernel
  - Faster than microkernel
    - ✓ No need of message passing
  - Better than layered
    - ✓ Direct module communications
- Overall, similar to layers but with more flexible
  - Linux, Solaris, etc



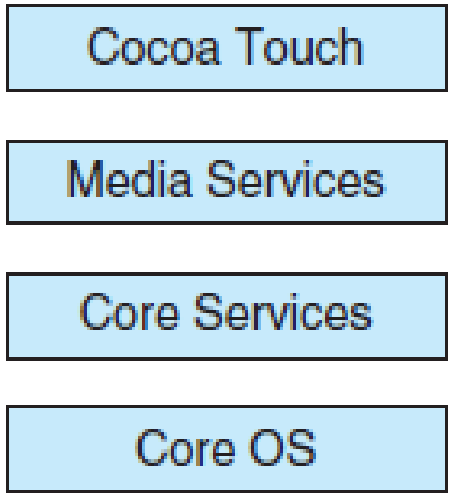
Solaris loadable modules

Modern Unix kernel

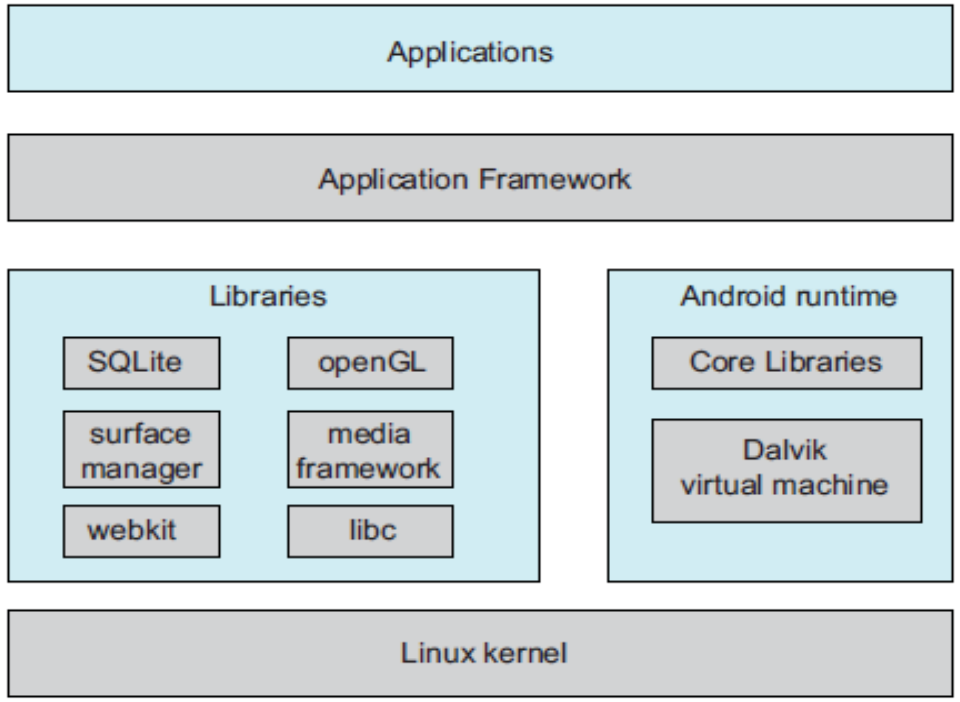


OS structure: 5. Hybrid

- **Hybrid systems**
  - Most modern operating systems
    - Mac OS
    - iOS
    - Android
  - Better to address
    - Reliability
    - Security
    - Usability
  - Examples
    - Linux & Solaris
      - ✓ kernel: monolithic
      - ✓ +feature: loadable
    - Windows
      - ✓ monolithic+microkernel

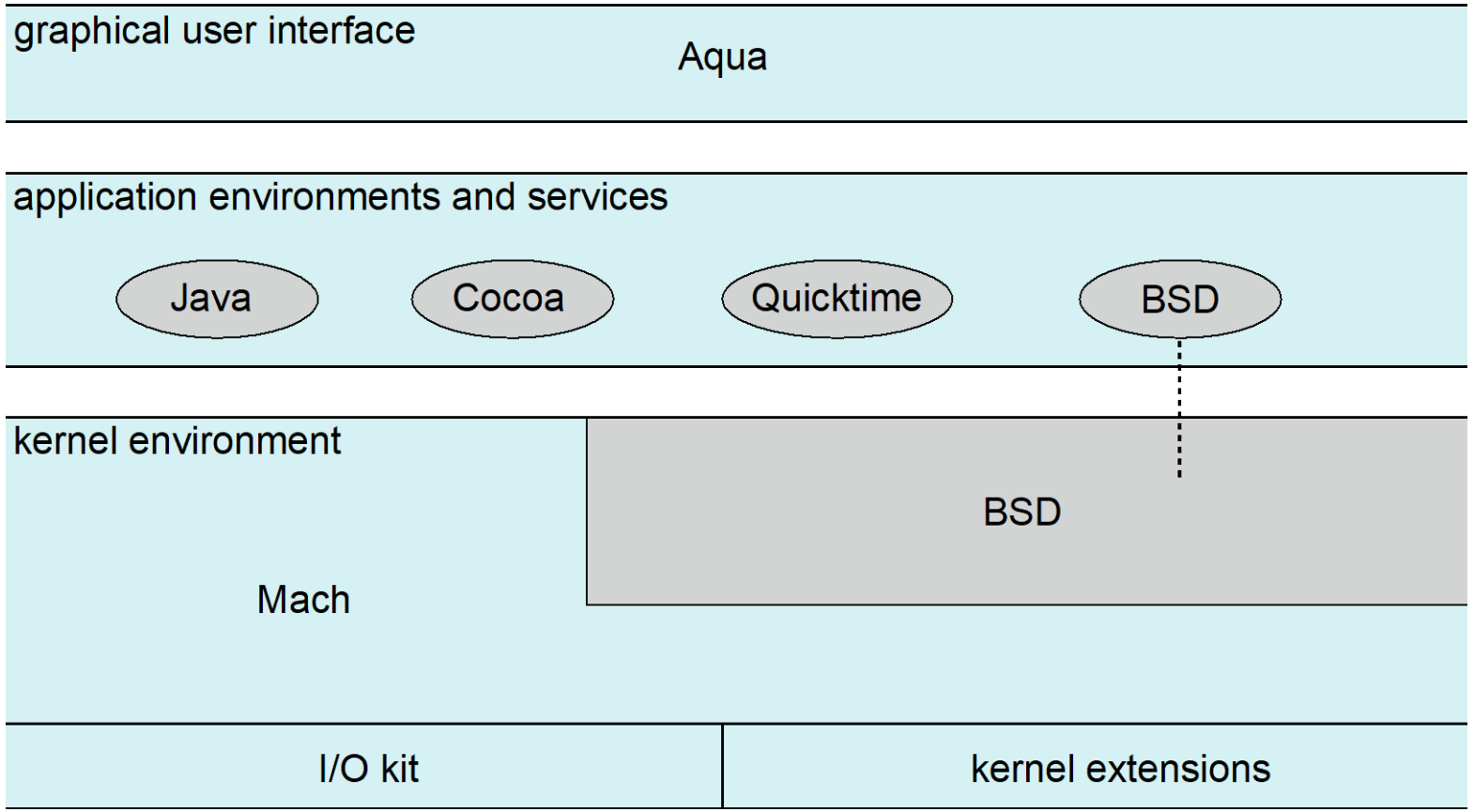


Architecture of Apple's iOS



Architecture of Google's Android

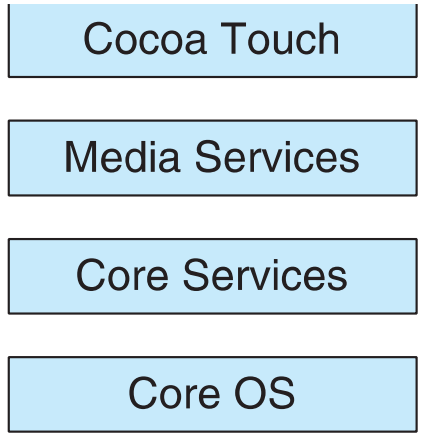
Mac OS X structure



- Top is layered
- Below is kernel consisting of Mach microkernel and BSD Unix parts, plus I/O kit and dynamically loadable modules (called kernel extensions)

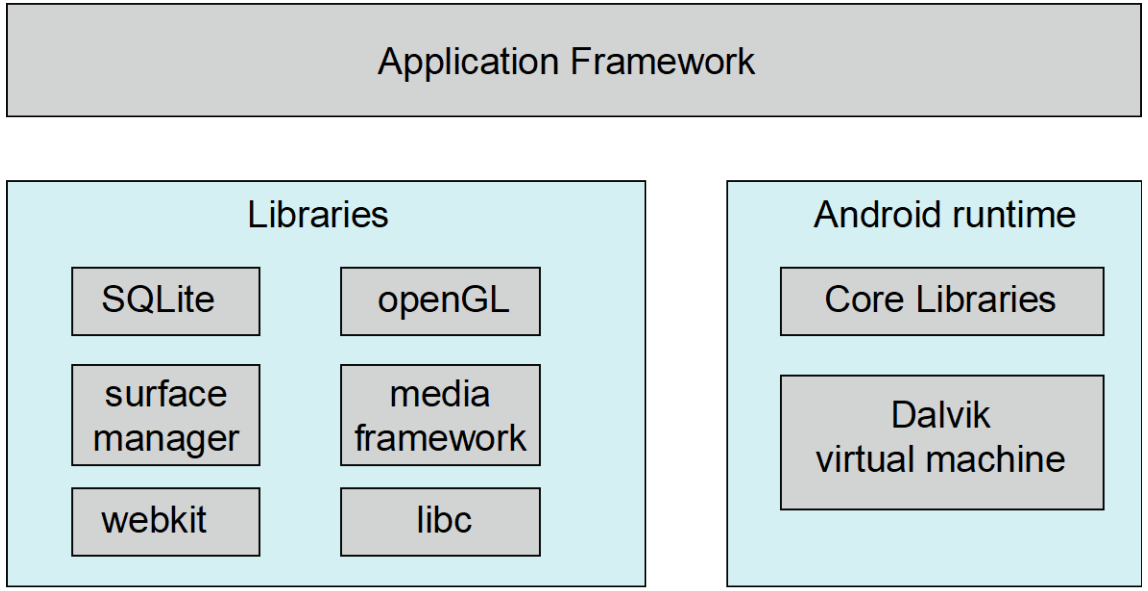
iOS

- Apple mobile OS for *iPhone*, *iPad*
  - Structured on Mac OS X, added functionality
  - Does not run OS X applications natively
    - Also runs on different CPU architecture (ARM vs. Intel)
  - Cocoa Touch Objective-C API for developing apps
  - Media services layer for graphics, audio, video
  - Core services provides cloud computing, databases
  - Core operating system, based on Mac OS X kernel

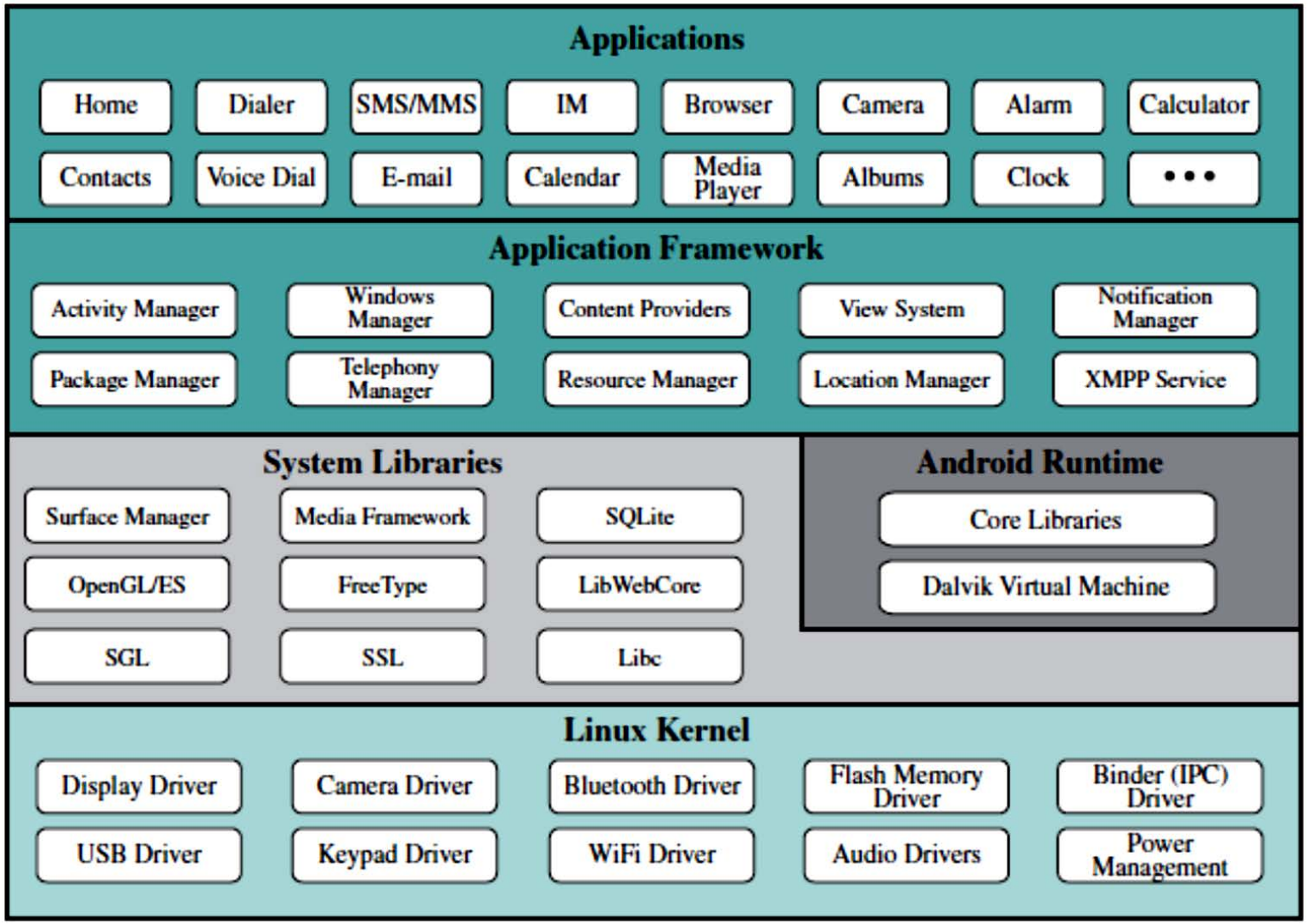


Android

- Developed by Open Handset Alliance (mostly Google)
  - Open Source
- Similar stack to IOS
- Based on Linux kernel but modified
  - Provides process, memory, device-driver management
  - Adds power management
- Runtime environment includes core set of libraries and Dalvik virtual machine
  - Apps developed in Java plus Android API
    - Java class files compiled to Java bytecode then translated to executable than runs in Dalvik VM
- Libraries include frameworks for web browser (webkit), database (SQLite), multimedia, smaller libc



Android SW architecture (detail)

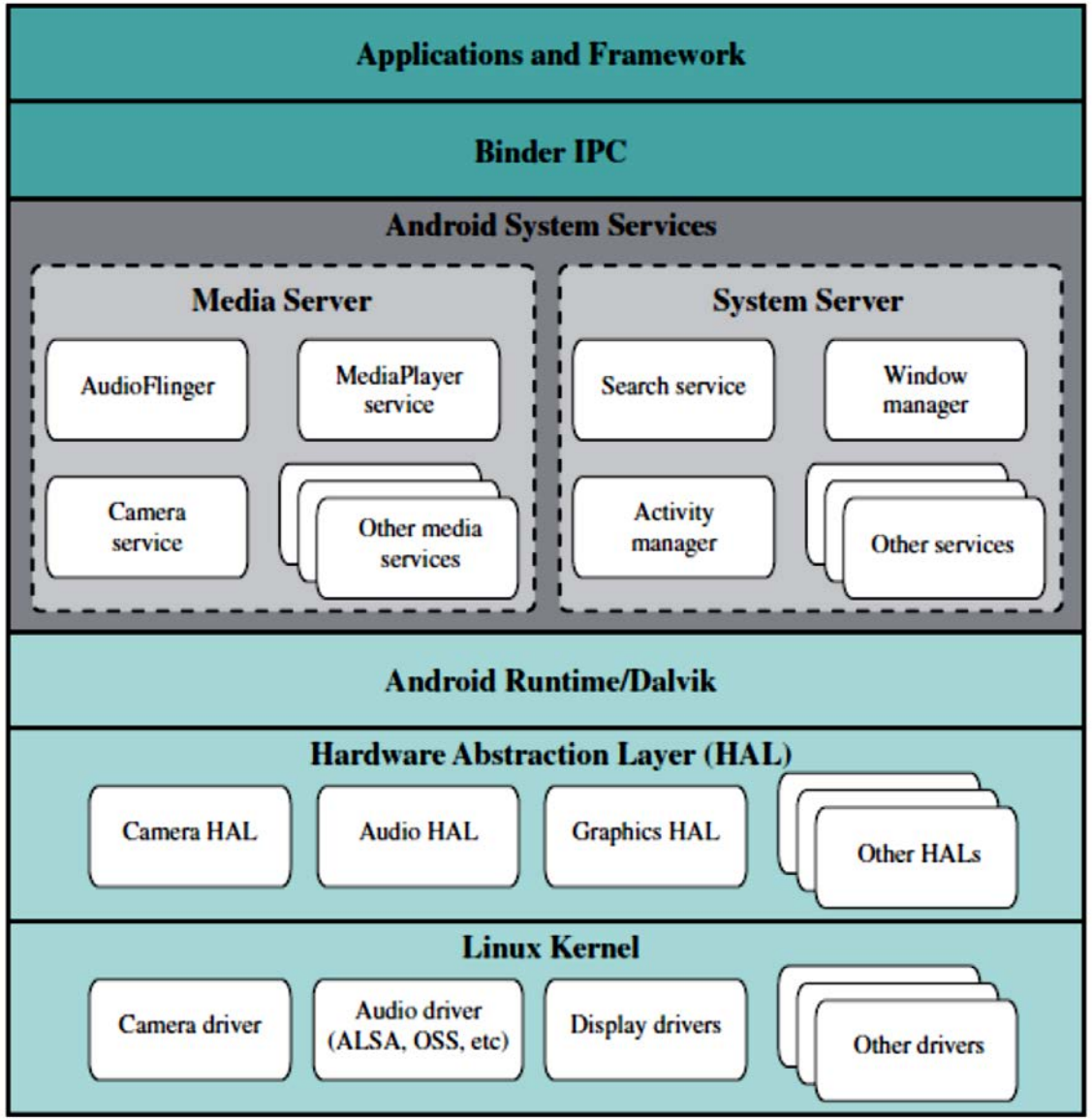


Applications, Application Framework: Java

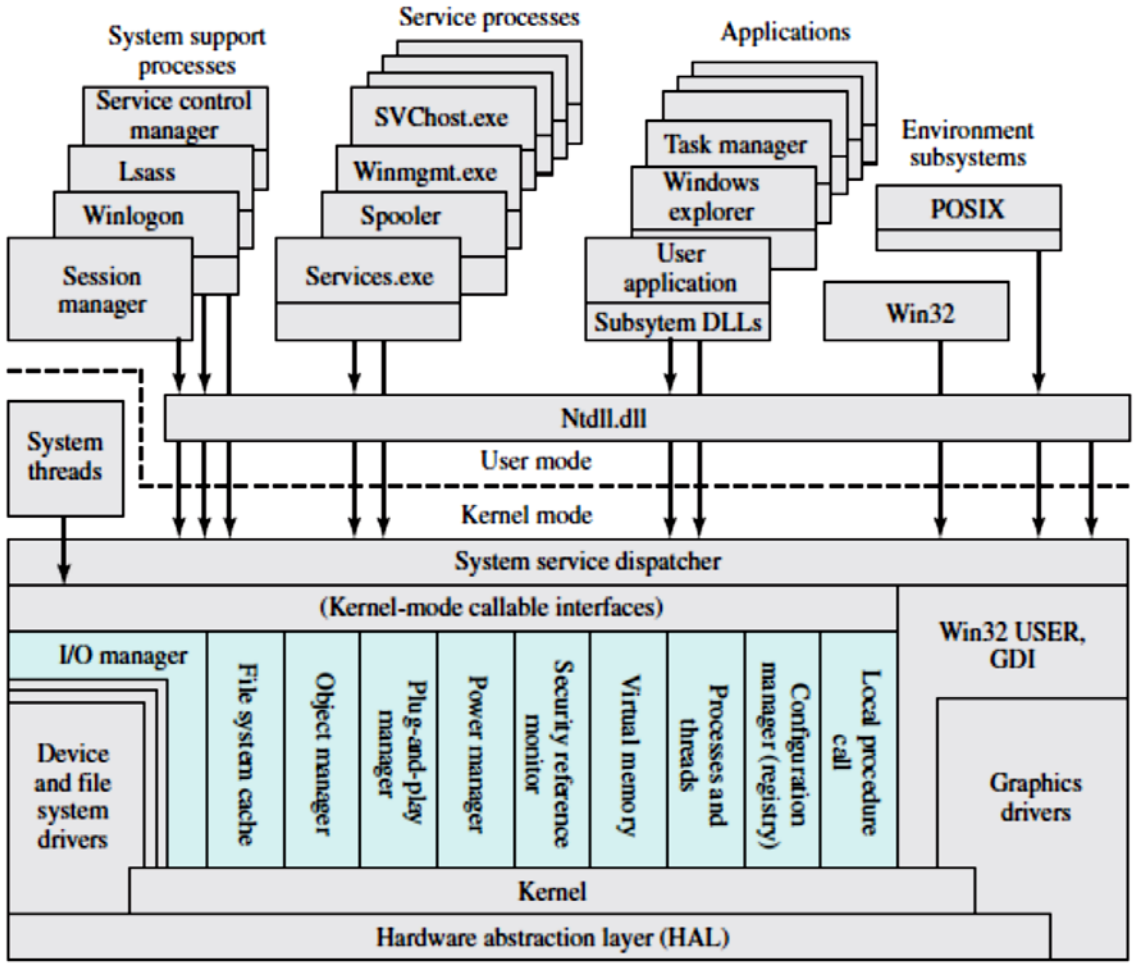
System Libraries, Android Runtime: C and C++

Linux Kernel: C

Android sys. architecture



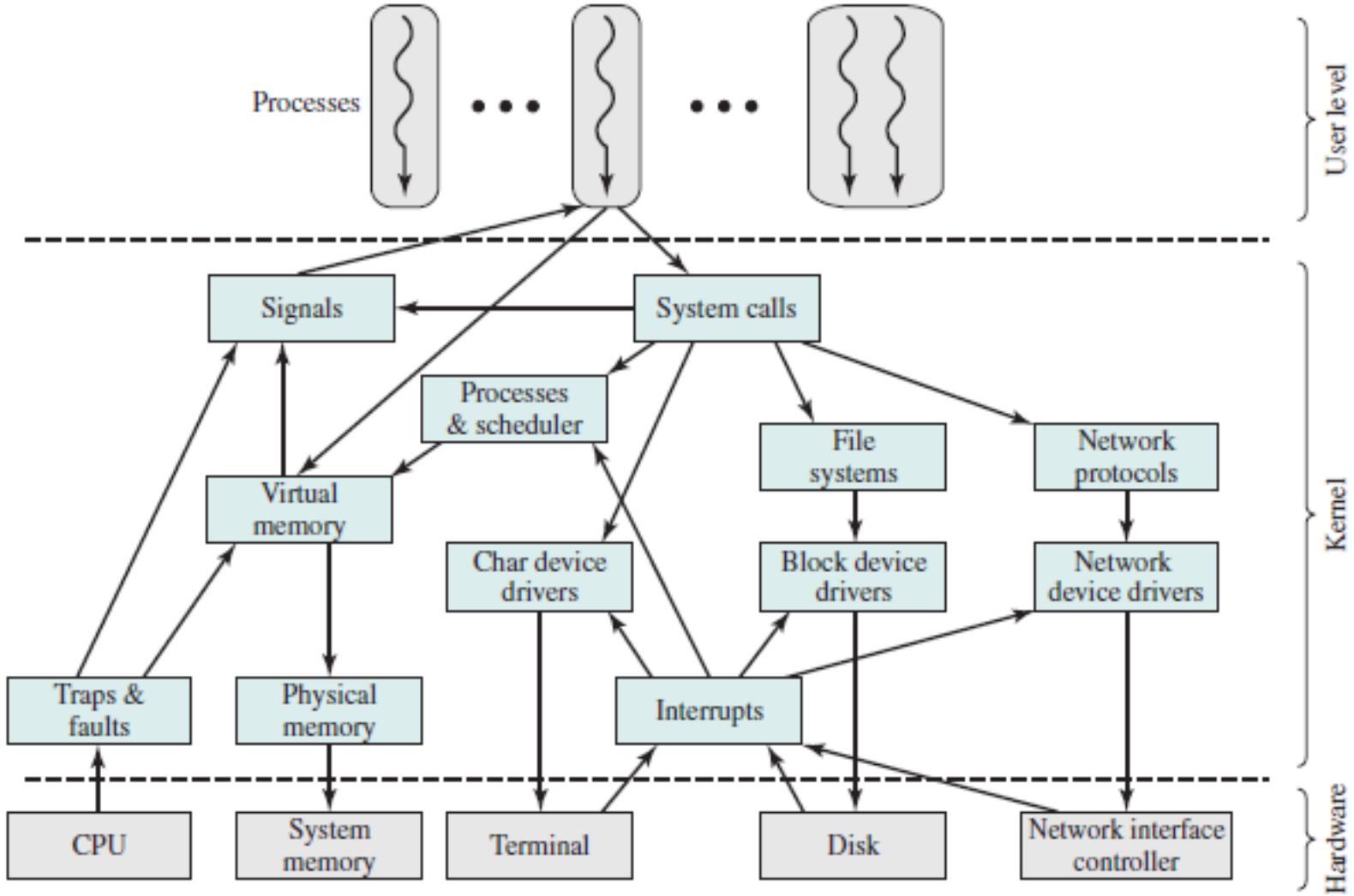
Windows internal architecture



Lsass = local security authentication server
POSIX = portable operating system interface
GDI = graphics device interface
DLL = dynamic link libraries

Colored area indicates Executive

Linux kernel components



OS debugging

- Debugging is finding and fixing errors, or bugs
- OSes generate log files containing error information
- Failure of an application can generate core dump file capturing memory of the process
- Operating system failure can generate crash dump file containing kernel memory
- Beyond crashes, performance tuning can optimize system performance
- Kernighan's Law: "Debugging is twice as hard as writing the code in the first place. Therefore, if you write the code as cleverly as possible, you are, by definition, not smart enough to debug it."
- DTrace tool in Solaris, FreeBSD, Mac OS X allows live instrumentation on production systems
  - Probes fire when code is executed, capturing state data and sending it to consumers of those probes

Solaris 10 *dtrace* Following System Call

```
# ./all.d 'pgrep xclock' XEventsQueued
dtrace: script './all.d' matched 52377 probes
CPU FUNCTION
  0 -> XEventsQueued                       U
  0   -> _XEventsQueued                    U
  0     -> _X11TransBytesReadable          U
  0     <- _X11TransBytesReadable          U
  0     -> _X11TransSocketBytesReadable    U
  0     <- _X11TransSocketBytesreadable    U
  0     -> ioctl                           U
  0       -> ioctl                         K
  0         -> getf                        K
  0           -> set_active_fd             K
  0           <- set_active_fd             K
  0         <- getf                        K
  0         -> get_udatamodel              K
  0         <- get_udatamodel              K
...
  0         -> releasef                    K
  0           -> clear_active_fd           K
  0           <- clear_active_fd           K
  0           -> cv_broadcast              K
  0           <- cv_broadcast              K
  0         <- releasef                    K
  0       <- ioctl                         K
  0     <- ioctl                           U
  0   <- _XEventsQueued                    U
  0 <- XEventsQueued                       U
```

Questions?