Computer Systems
Operating System Structures & User Interface

Lecture Objective / Overview

In this lecture, we shall see:

- Operating System Services
- System Calls / OS Relationship
- OS Design and Implementation
- Operating System Structure
- User Classes & Interfaces

What is part of an Operating System?

- When you install an OS, what do you get?
  - **System programs** - program loader, command interpreter
  - **Language processors** - C compiler, assembler, linker
  - **Utilities** - text editor, terminal emulator
  - **Subroutine libraries** - standard C library, JVM

Operating System Services

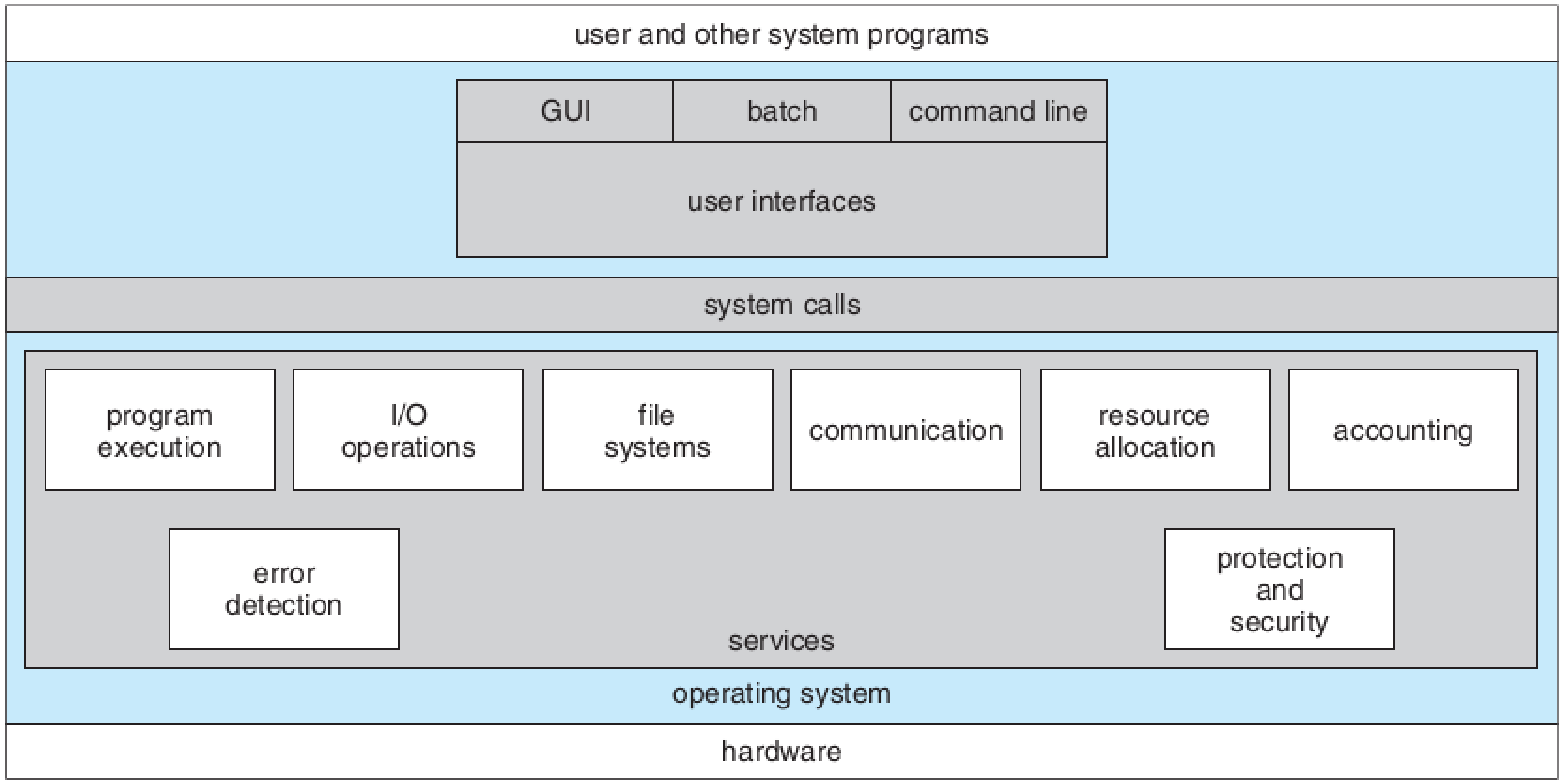
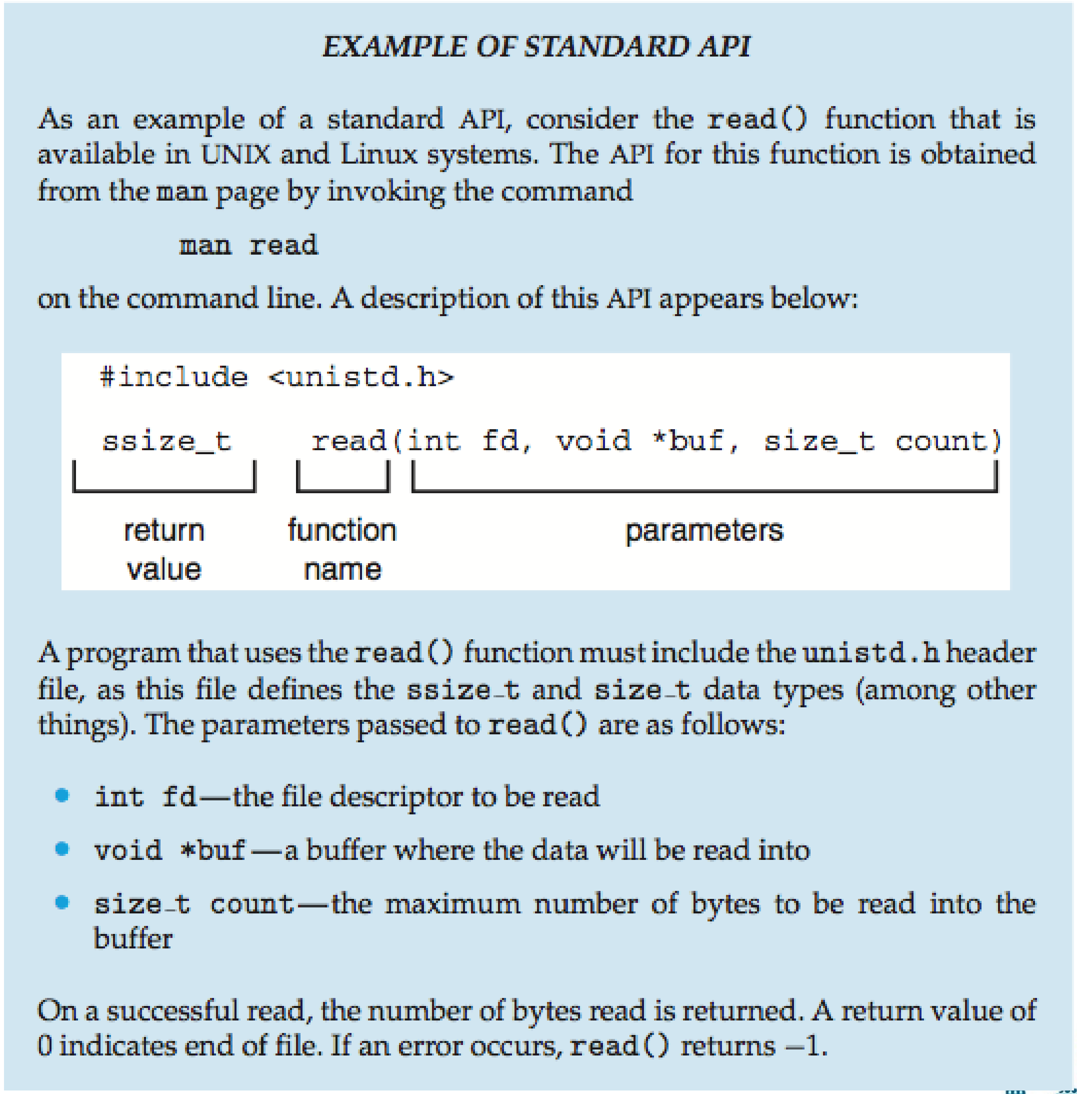


Figure 2.1 A view of operating system services.

System Calls

- Programming interface to the services provided by the OS
- Typically written in a high-level language (C or C++)
- Mostly accessed by programs via a high-level Application Programming Interface (API) rather than direct system call use
- Three most common APIs are Win32 API for Windows, POSIX API for POSIX-based systems (including virtually all versions of UNIX, Linux, and Mac OS X), and Java API for the Java virtual machine (JVM)

System Calls – Example

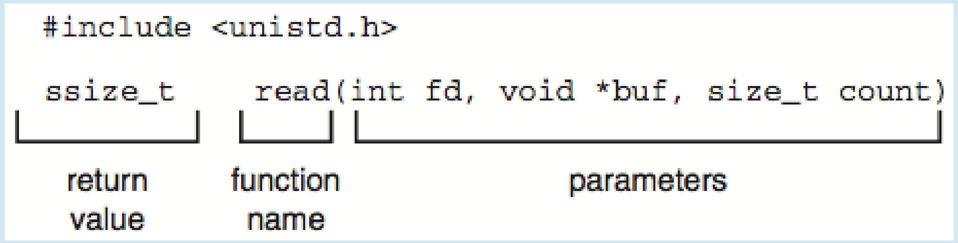


EXAMPLE OF STANDARD API

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)
```

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.

API – System Call – OS Relationship

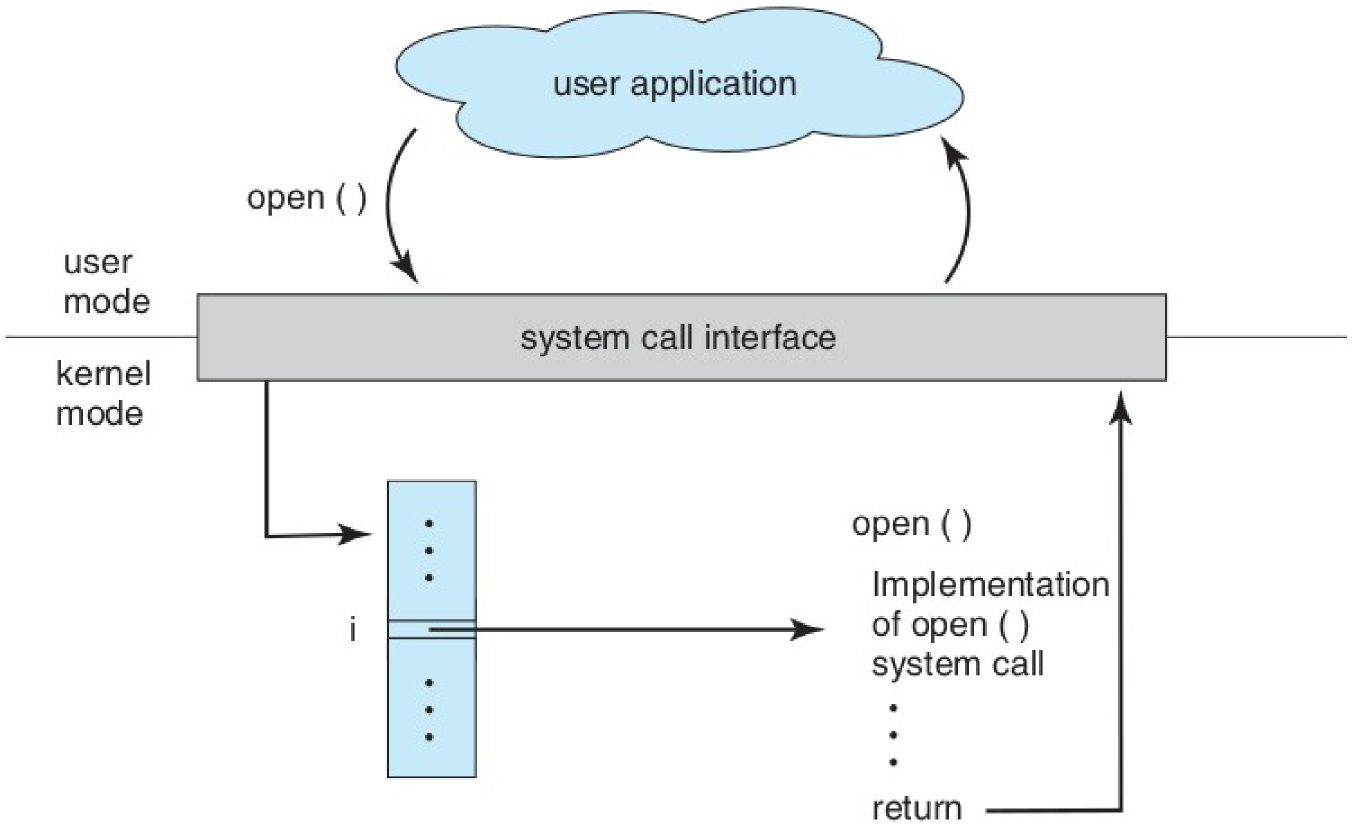
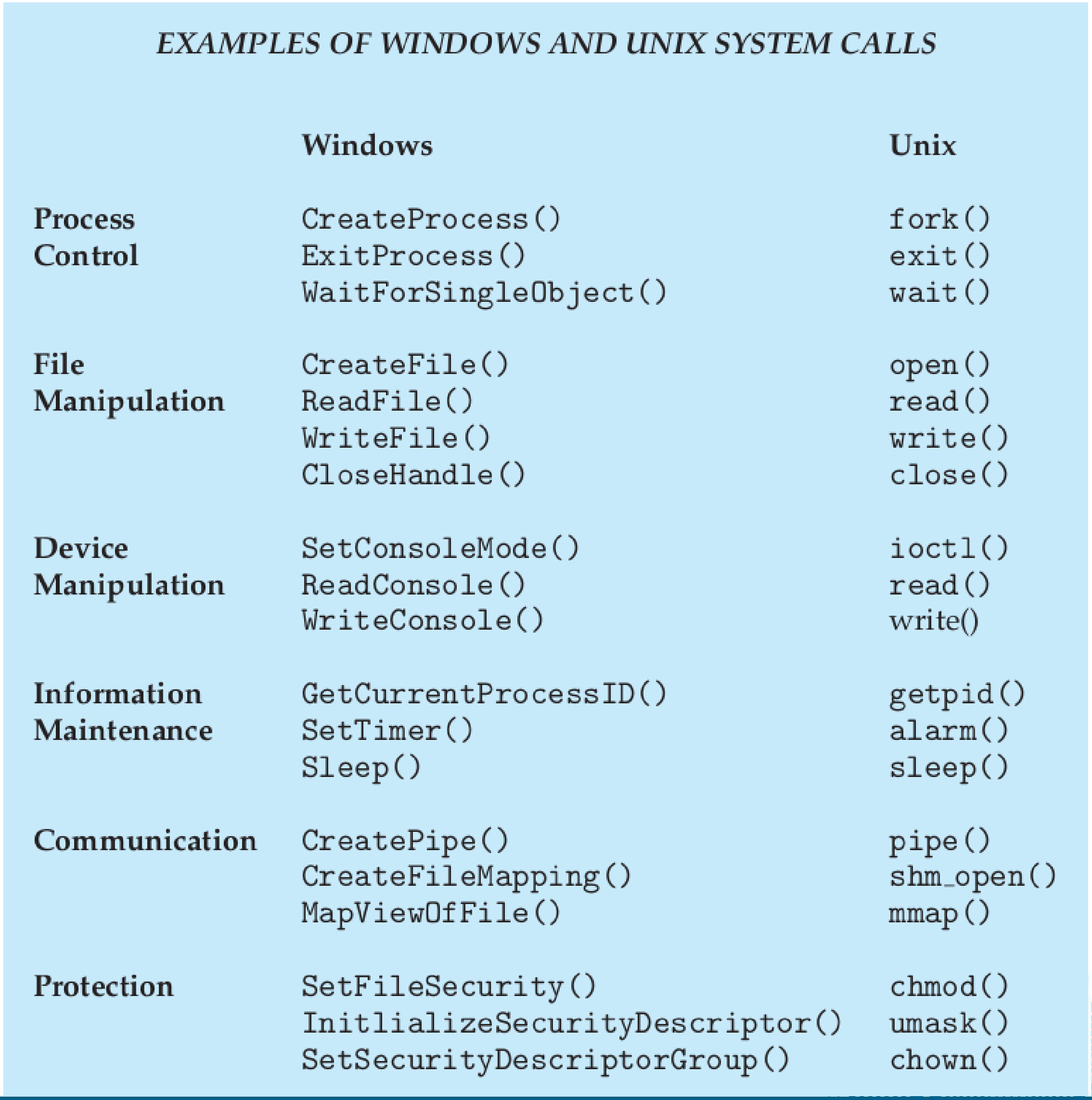


Figure 2.6 The handling of a user application invoking the `open()` system call.

System Call Implementation

- Typically, a number associated with each system call
  - **System-call interface** maintains a table indexed according to these numbers
- The system call interface invokes intended system call in OS kernel and returns status of the system call and any return values
- The caller doesn't need to know implementation details
  - Just needs to obey API and understand what OS will do!
  - Most details of OS interface hidden from programmer by API
  - Managed by run-time support libraries (set of functions built into libraries included with compiler)

Examples of Windows and Unix System Calls

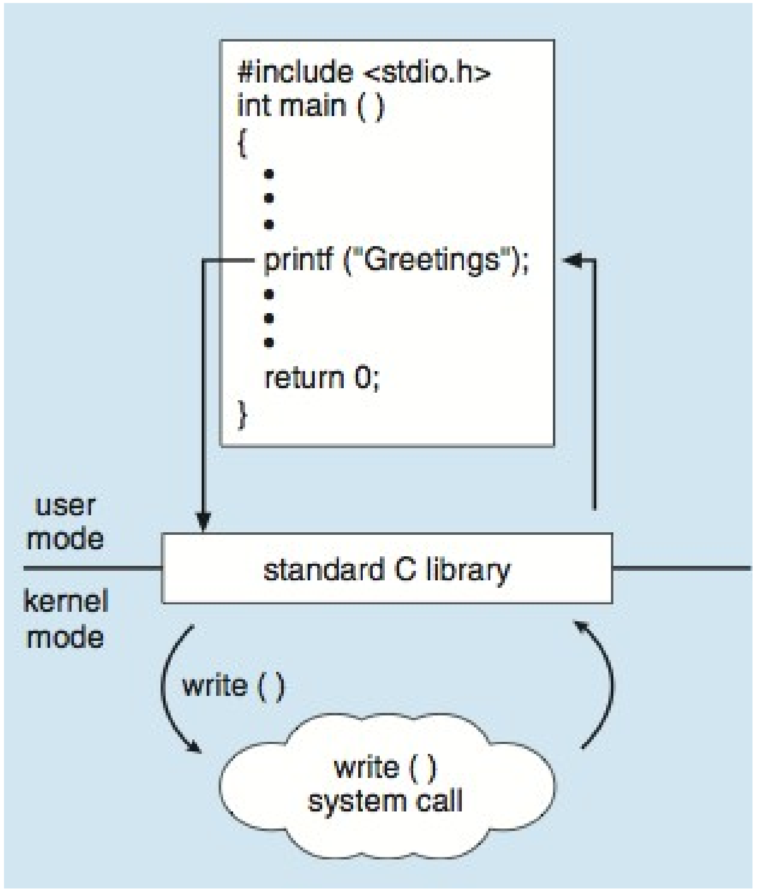


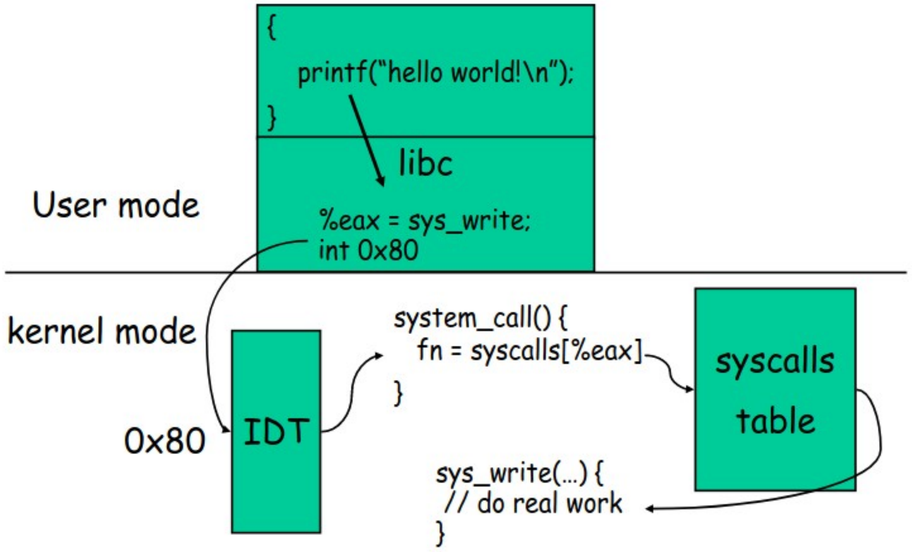
EXAMPLES OF WINDOWS AND UNIX SYSTEM CALLS

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

Standard C Library Example

- C program invoking printf() library call, which calls write() system call





Operating System Design and Implementation

- Design and Implementation of OS not "solvable", but some approaches have proven successful
- Internal structure of Operating Systems can vary widely
- Start the design by defining goals and specifications
- Affected by choice of hardware, type of system
- **User** goals and **System** goals
  - **User goals** – operating system should be convenient to use, easy to learn, reliable, safe, and fast
  - **System goals** – operating system should be easy to design, implement, and maintain, as well as flexible, reliable, error-free, and efficient

Implementation

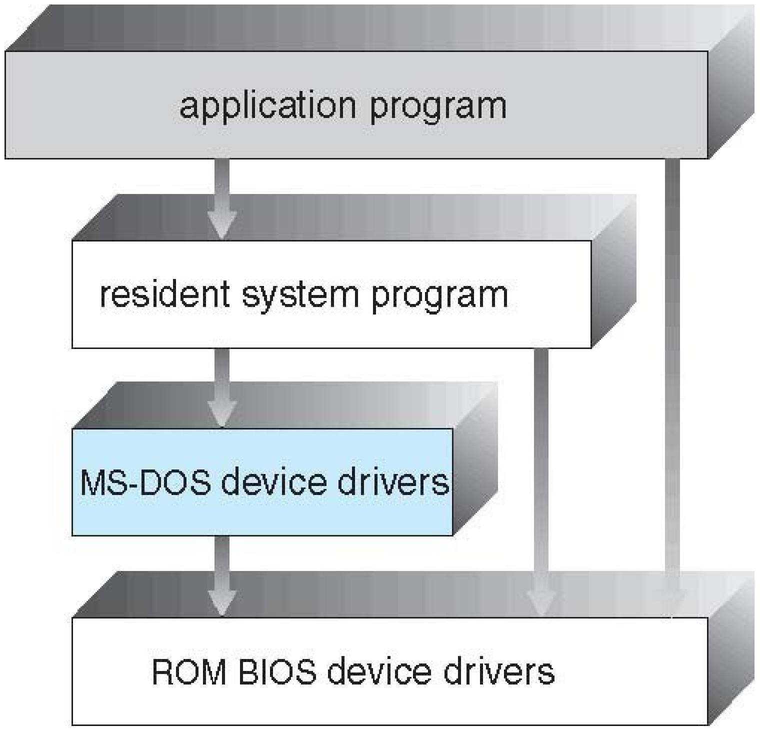
- Much variation
  - Early OSes in assembly language
  - Then system programming languages like Algol, PL/1
  - Now C, C++
- Actually usually a mix of languages
  - Lowest levels in assembly
  - Main body in C
  - Systems programs in C, C++, scripting languages like PERL, Python, shell scripts
- More high-level language easier to **port** to other hardware
  - But slower
- **Emulation** can allow an OS to run on non-native hardware

Operating System Structure

- General-purpose OS is very large program
- Various ways to structure ones
  - Simple structure – MS-DOS
  - More complex – UNIX
  - Layered – An Abstraction
  - Microkernel – Mach OS
  - Modular and Hybrid

Simple Structure – MS DOS

- MS-DOS – written to provide the most functionality in the least space
  - Not divided into modules
  - Although MS-DOS has some structure, its interfaces and levels of functionality are not well separated

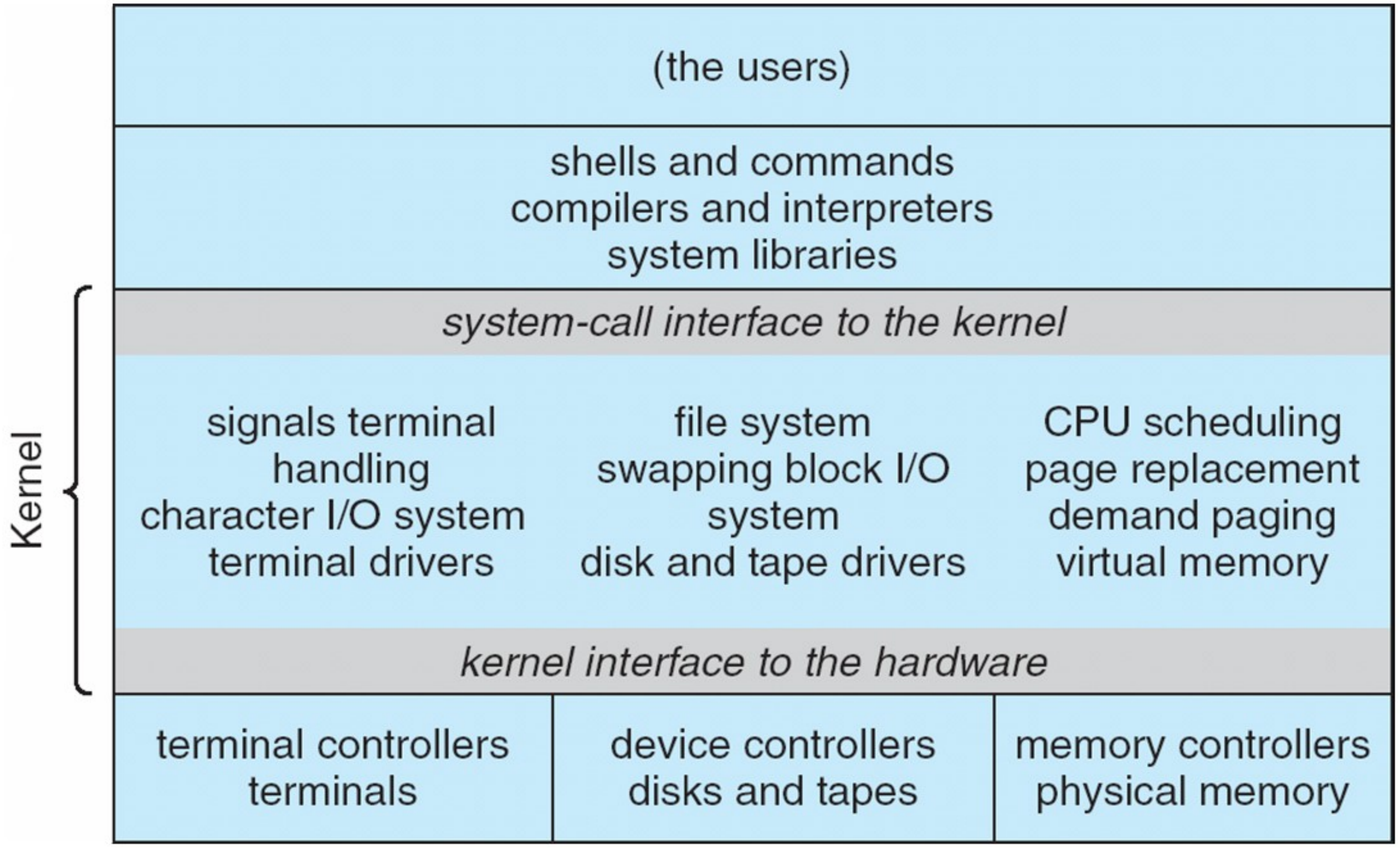


Non Simple Structure – UNIX

- UNIX – limited by hardware functionality, the original UNIX operating system had limited structuring. The UNIX OS consists of two separable parts
  - Systems programs
  - The kernel
    - Consists of everything below the system-call interface and above the physical hardware
    - Provides the file system, CPU scheduling, memory management, and other operating-system functions; a large number of functions for one level

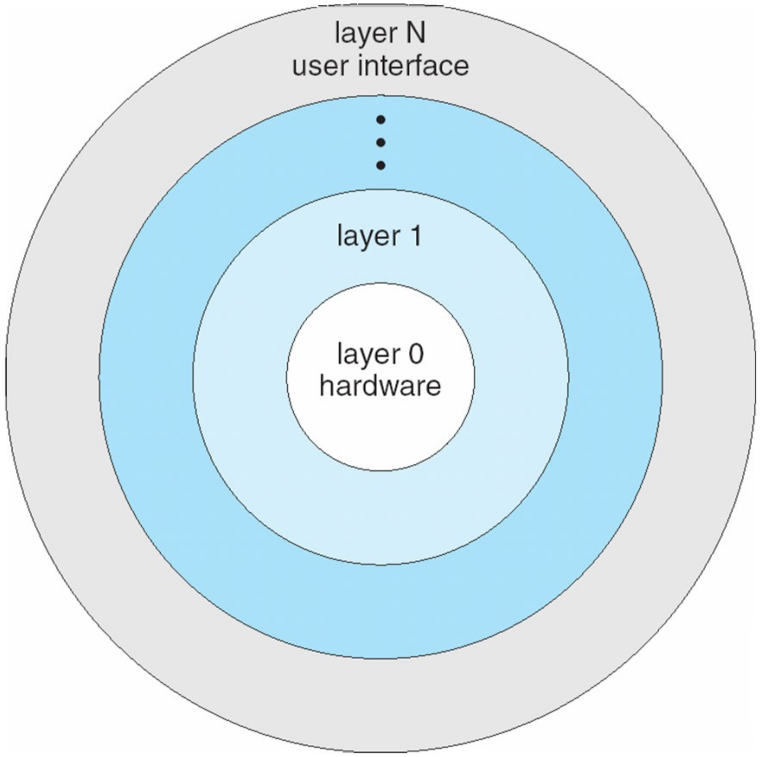
Traditional UNIX System Structure

- Beyond simple but not fully layered!



Layered Approach

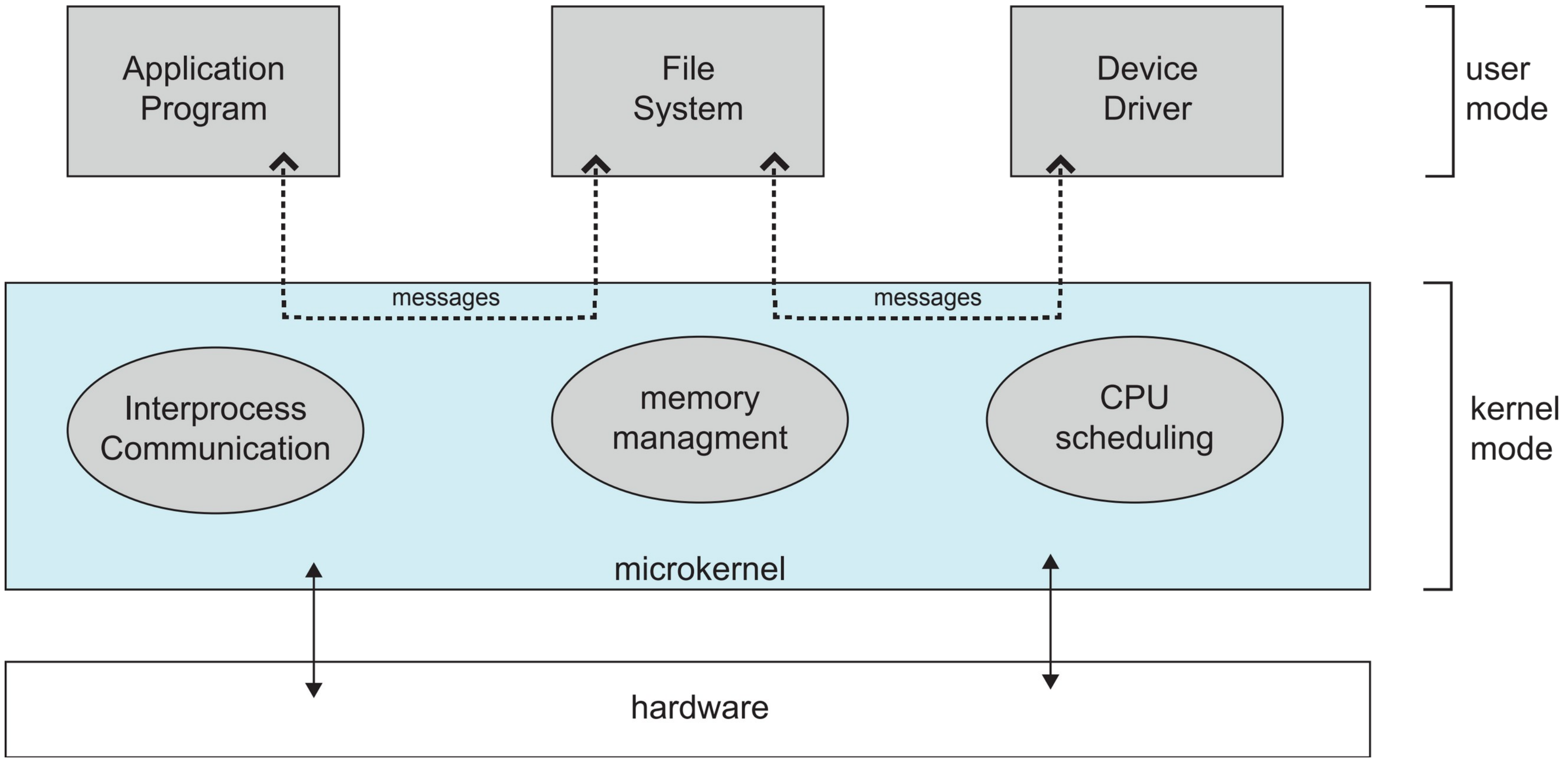
- The operating system is divided into a number of layers (levels), each built on top of lower layers. The bottom layer (layer 0), is the hardware; the highest (layer N) is the user interface.
- With modularity, layers are selected such that each uses functions (operations) and services of only lower-level layers



Microkernel System Structure

- Moves as much from the kernel into user space
- **Mach** example of **microkernel**
  - Mac OS X kernel (**Darwin**) partly based on Mach
- Communication takes place between user modules using **message passing**
- 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

Microkernel System Structure



Modules

- Many modern operating systems implement **loadable 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
- Overall, similar to layers but with more flexible
  - Linux, Solaris, etc

Solaris Modular Approach

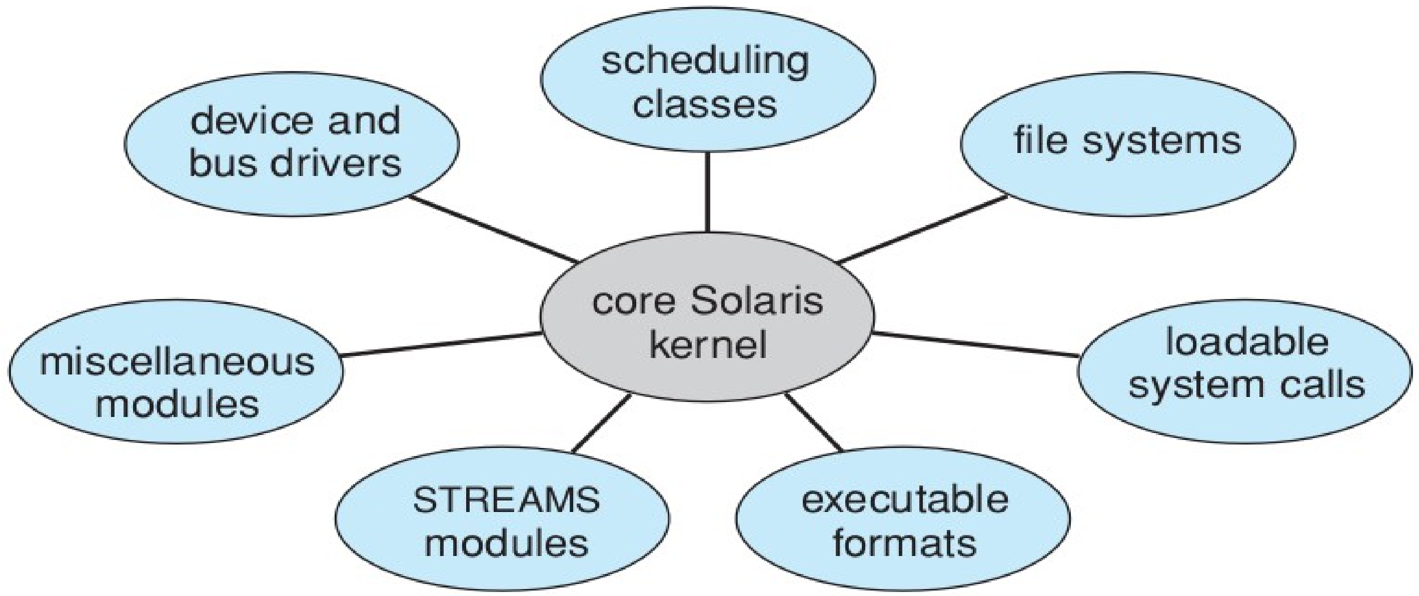
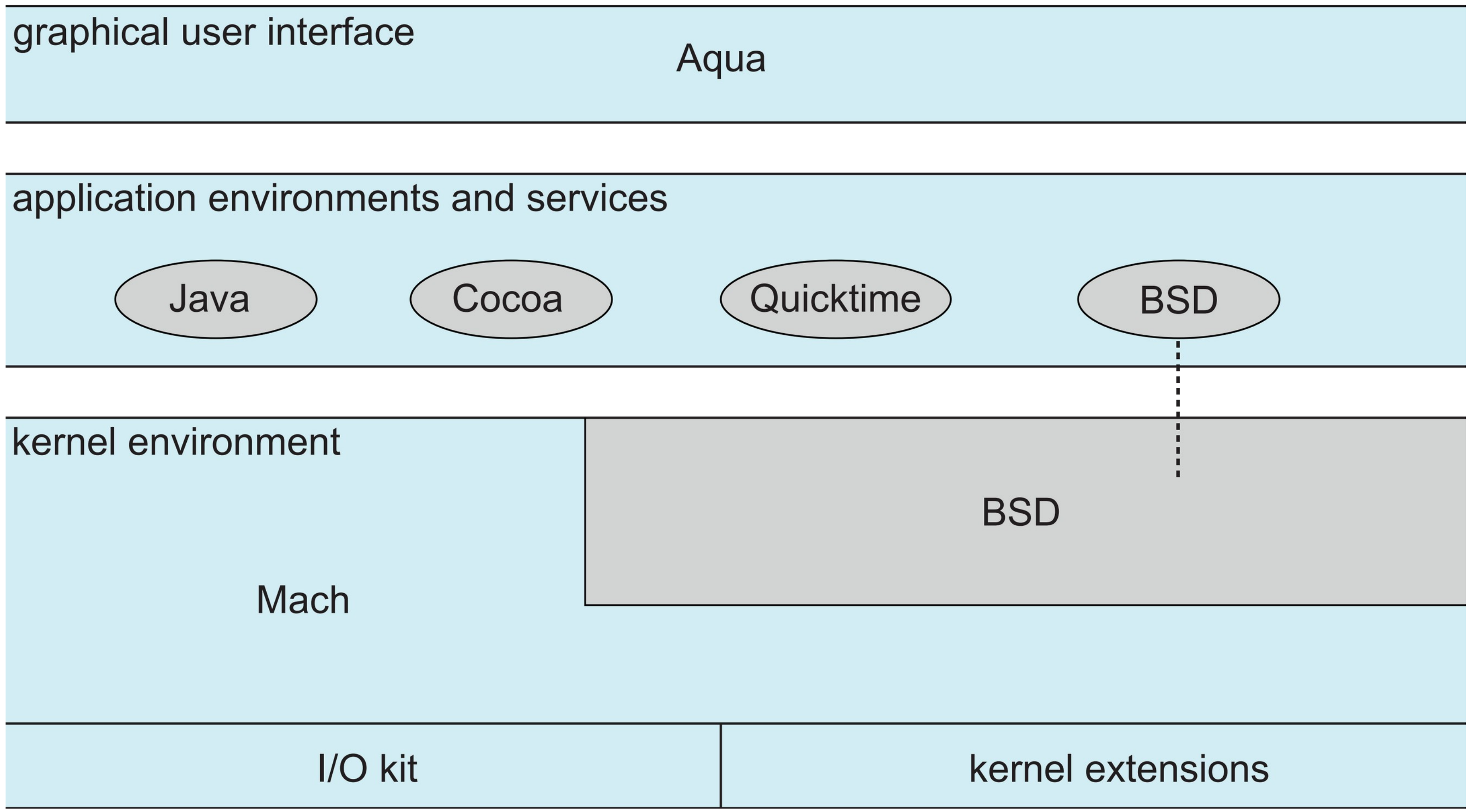


Figure 2.15 Solaris loadable modules.

Hybrid Systems

- Most modern operating systems are actually not one pure model
  - Hybrid combines multiple approaches to address performance, security, usability needs
  - Linux and Solaris kernels in kernel address space, so monolithic, plus modular for dynamic loading of functionality
  - Windows mostly monolithic, plus microkernel for different subsystem ***personalities***
- Apple Mac OS X hybrid, layered, **Aqua** UI plus **Cocoa** programming environment
  - Next slides shows a kernel consisting of Mach microkernel and BSD Unix parts, plus I/O kit and dynamically loadable modules (called **kernel extensions**)

Mac OS X Structure



User Interfaces

Almost all operating systems have a user interface.

This interface can take several forms.

- Command-line Interface (CLI)
- Batch Interface - commands and directives entered into files, which are then executed
- Graphical User Interface (GUI)

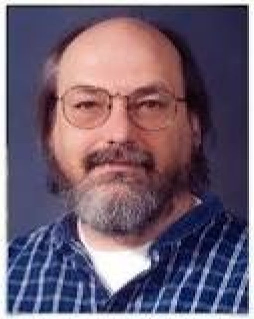
User Interfaces – Key Information

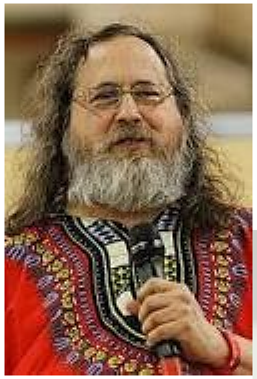
- Any UI requires a software link to hardware
  - This link may be buried under other software
- Most OS’s provide a set of system calls that invoke low level operating system functions
- System calls can be invoked directly, but are often hidden from user

User Classes

1) Programmers

- Produce system or application software (and drink a lot of coffee)
  - System programmer = Operating Systems, compilers, devices drivers etc.
    - Require low level access to machine facilities e.g. System calls.
  - Application programmer = Spreadsheets, DBs, Mobile / Web Apps etc.





User Classes

2) Operational (Admins)

- Concerned with provision, operation and management of computing facilities

User Classes

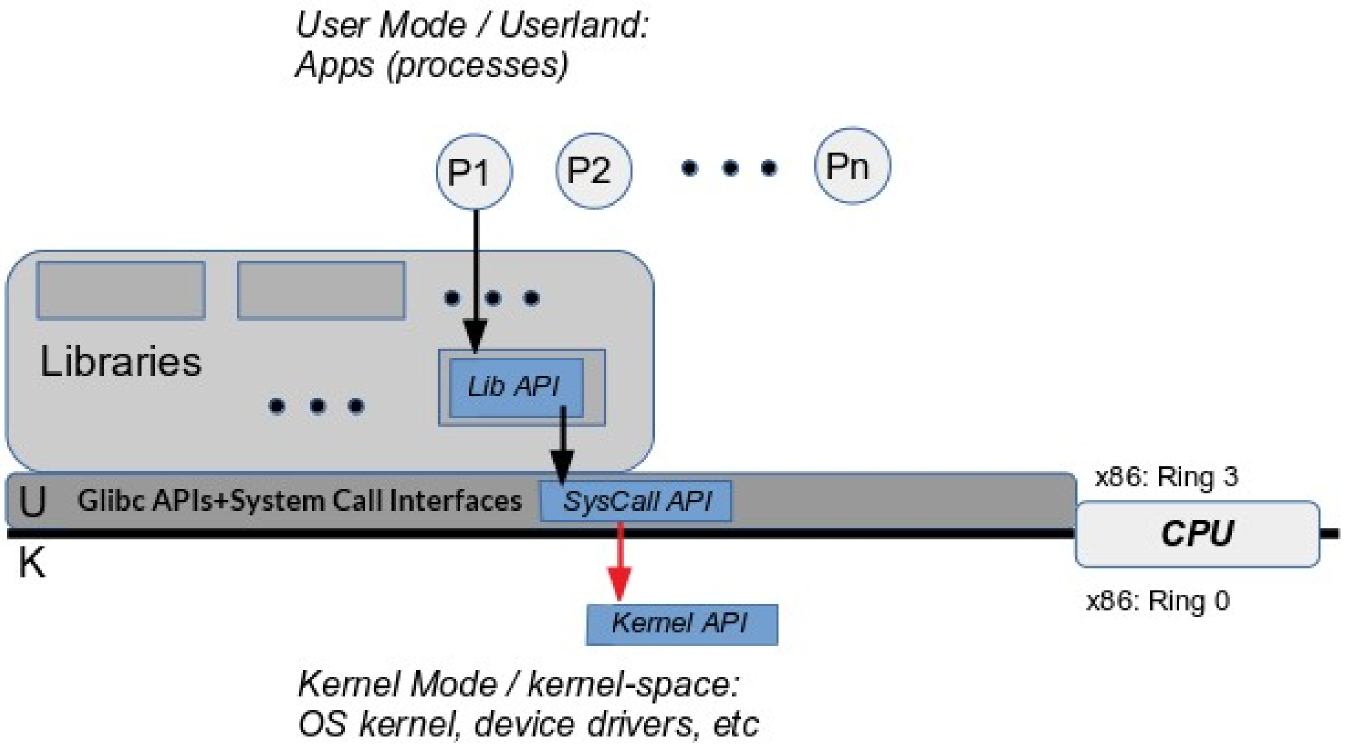
3) End-users

- Someone who applies software to some problem area. Two extremes:
  - Unaware they’re interacting with a computer
  - Substantial understanding of computer

Types of Interface

1) System Calls:

- All interaction with hardware has to go though system call
- OS provides layer of subroutines called an API

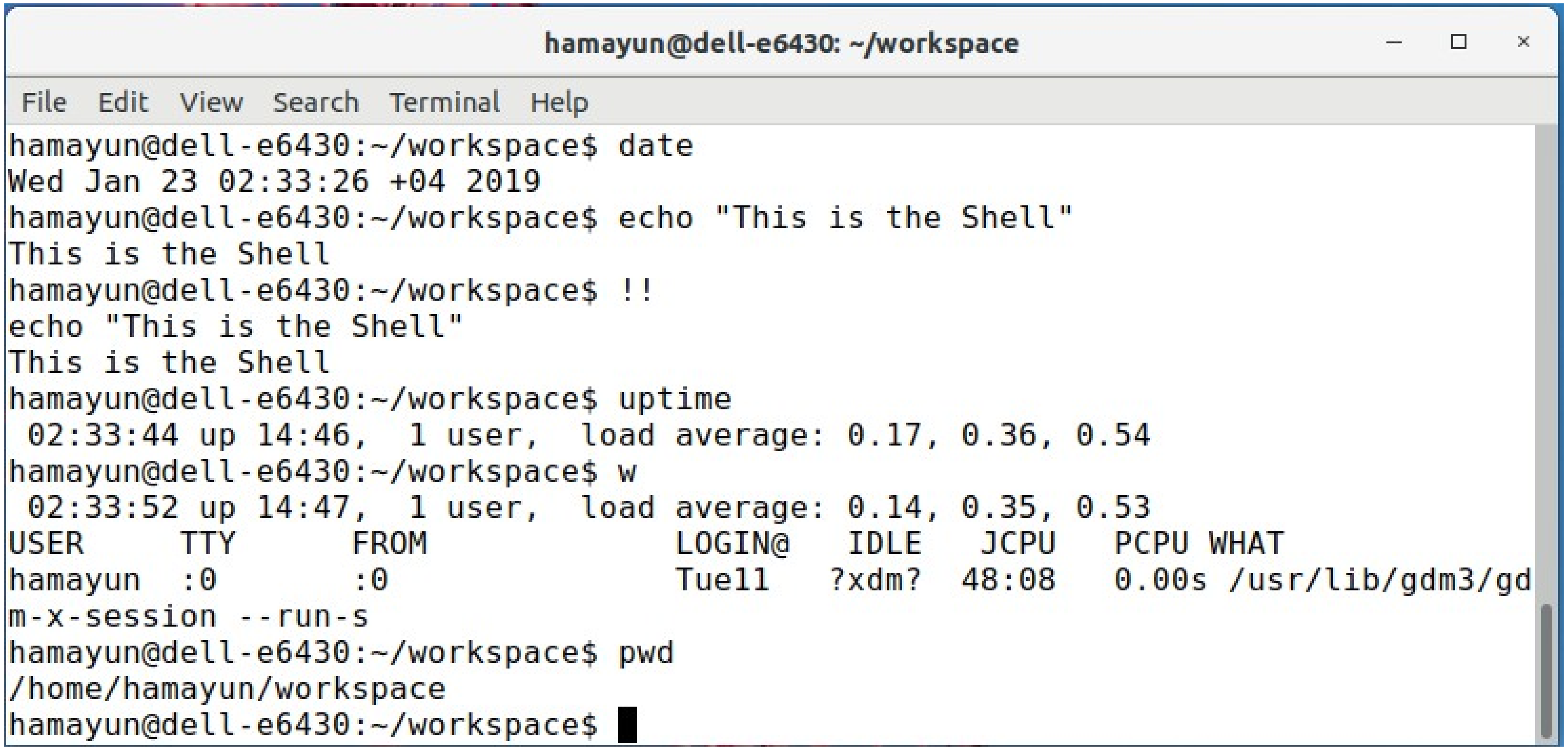


Types of Interface

2) Command Language:

- Most OS’s provide an interactive terminal
- Commands can be entered here
- Used to imitate programs
- Perform housekeeping control routines on system
- UNIX provides shell programs

Types of Interface

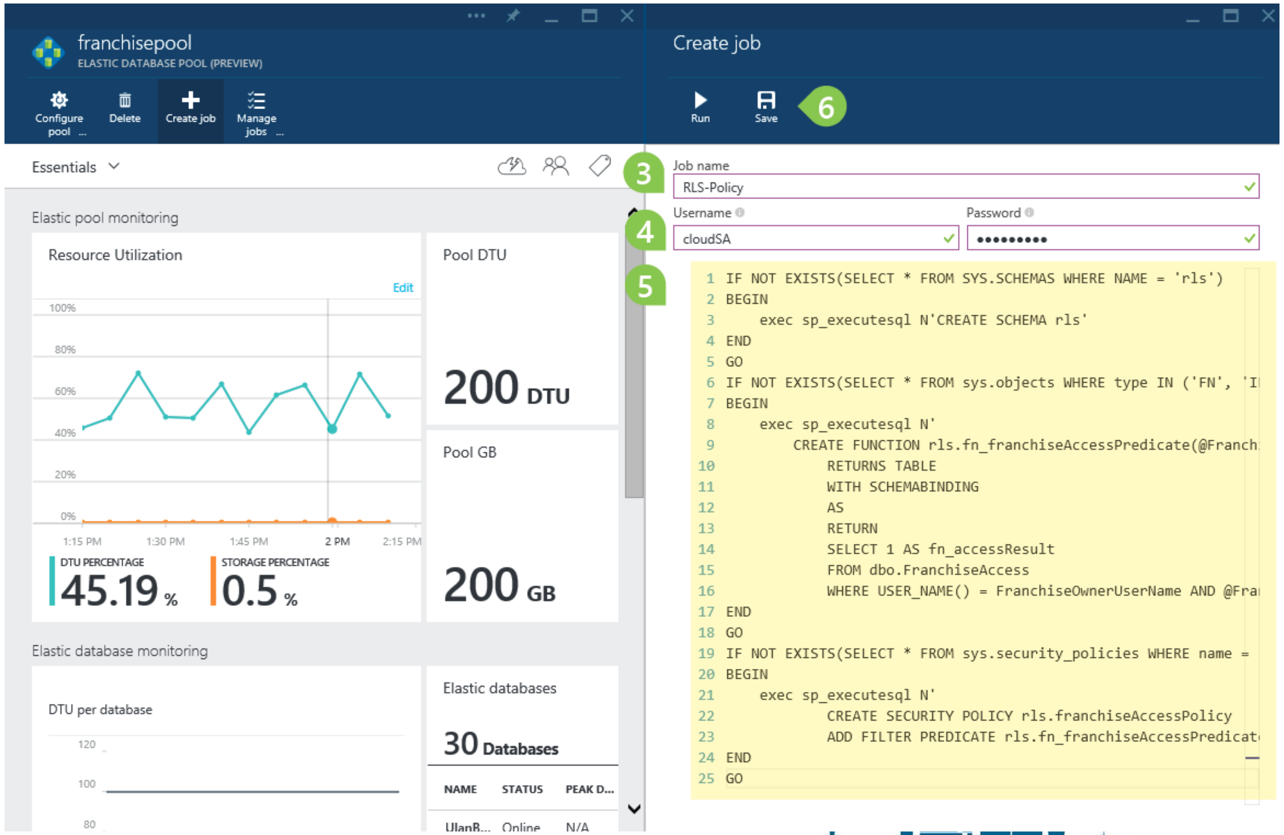

hamayun@dell-e6430: ~/workspace
File Edit View Search Terminal Help

```
hamayun@dell-e6430:~/workspace$ date
Wed Jan 23 02:33:26 +04 2019
hamayun@dell-e6430:~/workspace$ echo "This is the Shell"
This is the Shell
hamayun@dell-e6430:~/workspace$ !!
echo "This is the Shell"
This is the Shell
hamayun@dell-e6430:~/workspace$ uptime
 02:33:44 up 14:46,  1 user,  load average: 0.17, 0.36, 0.54
hamayun@dell-e6430:~/workspace$ w
 02:33:52 up 14:47,  1 user,  load average: 0.14, 0.35, 0.53
USER     TTY      FROM             LOGIN@   IDLE   JCPU   PCPU WHAT
hamayun  :0       :0               Tue11   ?xdm?  48:08   0.00s /usr/lib/gdm3/gd
m-x-session --run-s
hamayun@dell-e6430:~/workspace$ pwd
/home/hamayun/workspace
hamayun@dell-e6430:~/workspace$ 
```

Types of Interface

3) Job Control Language:

- Define requirements for work submitted to a batch system
- Used for DBs



Job name: RLS-Policy

Username: cloudSA

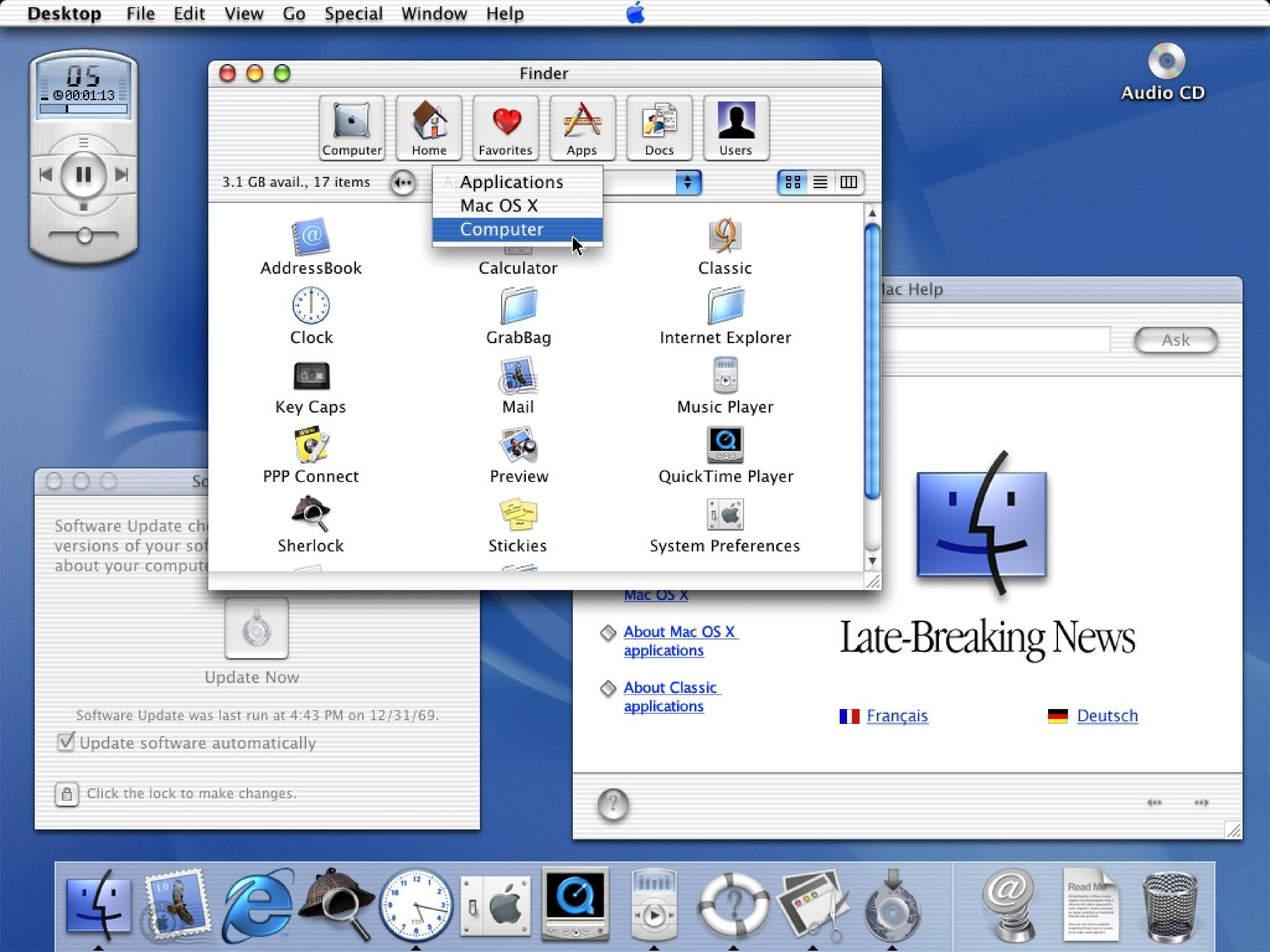
Password: ●●●●●●●●●

```
IF NOT EXISTS(SELECT * FROM SYS.SCHEMAS WHERE NAME = 'rls')
BEGIN
    exec sp_executesql N'CREATE SCHEMA rls'
END
GO
IF NOT EXISTS(SELECT * FROM sys.objects WHERE type IN ('FN', 'I
BEGIN
    exec sp_executesql N'
        CREATE FUNCTION rls.fn_franchiseAccessPredicate(@Franch
            RETURNS TABLE
            WITH SCHEMABINDING
            AS
            RETURN
            SELECT 1 AS fn_accessResult
            FROM dbo.FranchiseAccess
            WHERE USER_NAME() = FranchiseOwnerUserName AND @Fra
END
GO
IF NOT EXISTS(SELECT * FROM sys.security_policies WHERE name =
BEGIN
    exec sp_executesql N'
            CREATE SECURITY POLICY rls.franchiseAccessPolicy
            ADD FILTER PREDICATE rls.fn_franchiseAccessPredicat
END
GO
```

Types of Interface

4) Graphical User Interface

- Interaction via windows and mouse driven environment
- Desktop, Icons, GUI APIs - Java X Windows
- Programmer’s Perspective
  - Slightly more complex than shell script, but more rewarding
  - Event driven programming - responsive to user actions
- User viewpoint - friendlier?
- Increased processing load



Software Update ch
versions of your sof
about your compute

Software Update was last run at 4:43 PM on 12/31/69.

[✓] Update software automatically

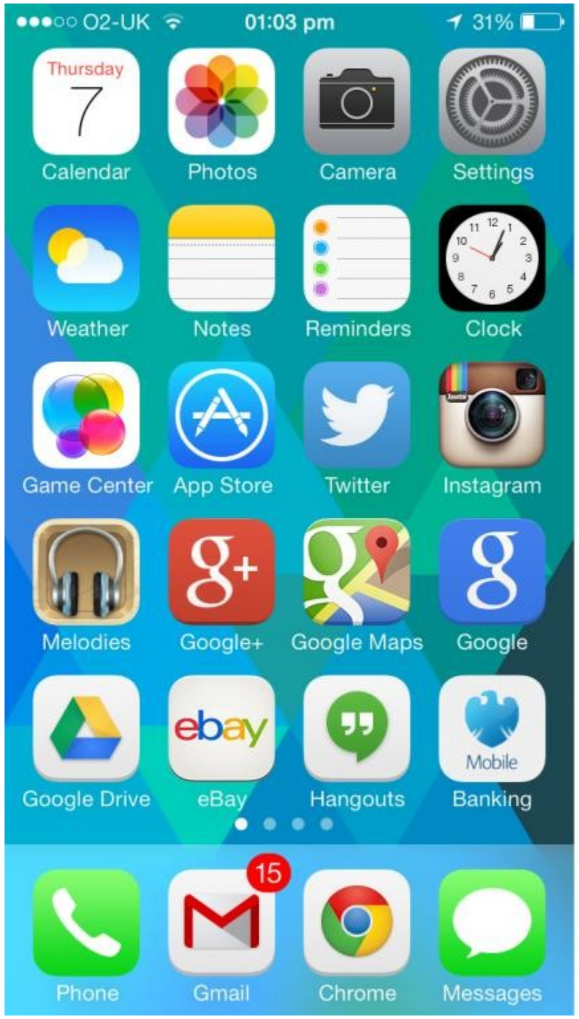
Click the lock to make changes.

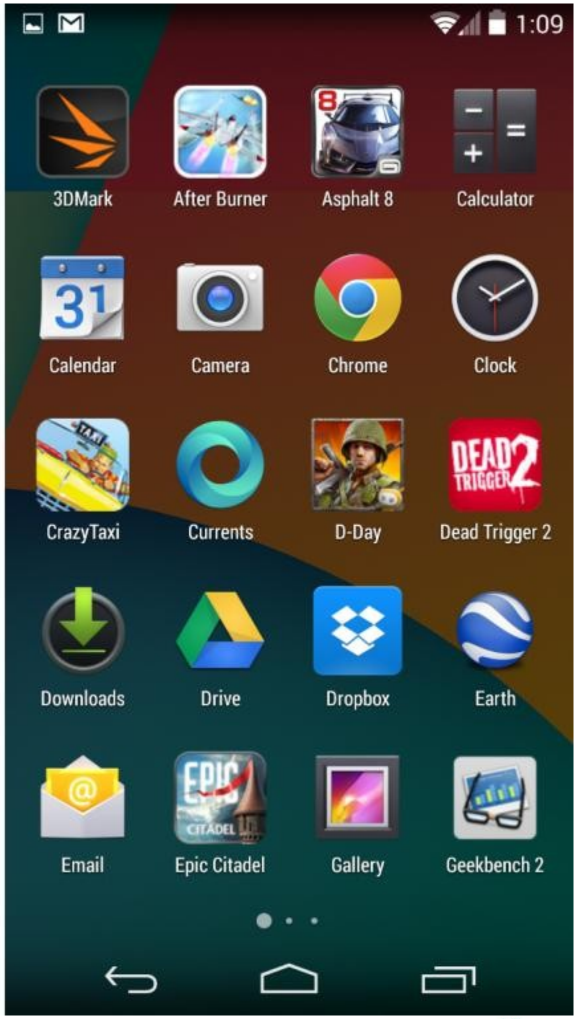
Types of Interface

5) Touchscreen Interfaces

- Touchscreen devices require new interfaces
- Mouse not possible or not desired
- Actions and selection based on gestures
- Virtual keyboard for text entry

Types of Interface





Summary

What elements of a computer system have we looked at:

- Operating System Services
- System Calls / OS Relationship
- OS Design and Implementation
- Operating System Structure
- User Classes & Interfaces

References / Links

- Chapter # 2: **Operating System Concepts** (9th edition) by Silberschatz, Galvin & Gagne