CS370 Operating Systems

Colorado State University

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Fall 21 Lecture 4

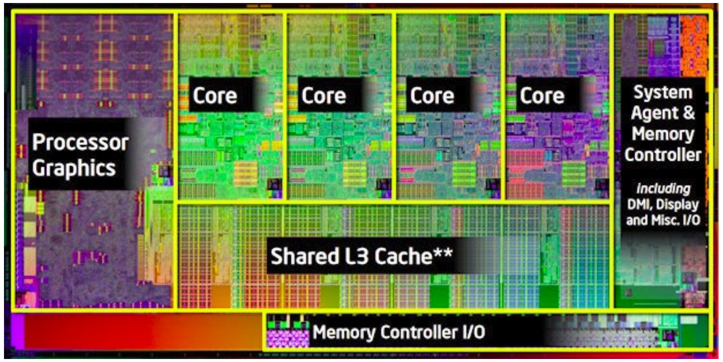
OS Structures/Processes

Slides based on

- Text by Silberschatz, Galvin, Gagne
- Various sources

FAQ

- A **chip** can have one or more **processors** (**CPU, core**) and possibly more components.



- **Kernel vs OS**: Kernel: process/memory/file/IO management, OS can include UI, libraries etc.
- **Why User vs kernel mode**? Because users can't be trusted.
- Where are **registers**, **Cache** and **main memory** , physically?
- Scheduling, Memory management, storage management? Good that you are thinking about these.

Note: TA office hours are available. Help session Slides: Schedule, Video: Teams

Memory & Storage Management

K-scale: Amount of information/storage

Byte (B) = 8 bits (b)

Amount of info:

Kibibyte?

- A **kilobyte**, or **KB**, is 1,024 (or 2^{10}) bytes
- a **megabyte**, or **MB**, is $1{,}024^2$ (or 2^{20}) bytes
- a **gigabyte**, or **GB**, is $1{,}024^3$ bytes
- a **terabyte**, or **TB**, is $1{,}024^4$ bytes
- a **petabyte**, or **PB**, is $1{,}024^5$ bytes

Measures of time

- **Milli**seconds, **micro**seconds, **nano**seconds, **pico**seconds 10^{-3}, 10^{-6}, 10^{-9}, 10^{-12}

Memory Management

Means main memory here

- To execute a program all (or part) of the instructions must be in memory
- All (or part) of the data that is needed by the program must be in memory.
- Memory management determines what is in memory and when
  - Optimizing CPU utilization and computer response to users

CPU scheduling

- Memory management activities
  - Keeping track of which parts of memory are currently being used and by whom
  - Deciding which processes (or parts thereof) and data to move into and out of memory
  - Allocating and deallocating memory space as needed

Storage Management

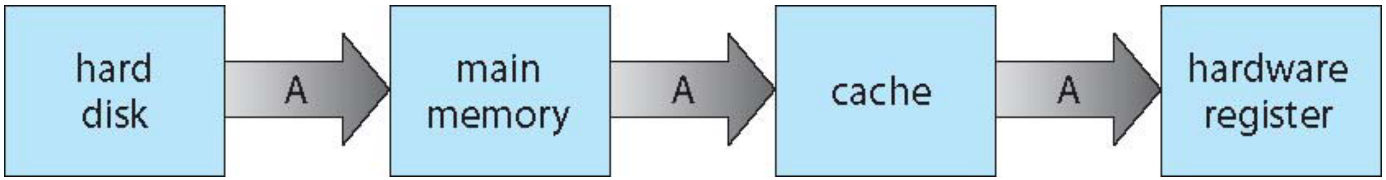
- OS provides uniform, logical view of information storage
  - Abstracts physical properties to logical storage unit - **file**
  - Each medium is controlled by device (i.e., disk drive, tape drive)
    - Varying properties include access speed, capacity, data-transfer rate, access method (sequential or random)
- File-System management
  - Files usually organized into directories
  - Access control on most systems to determine who can access what
  - OS activities include
    - Creating and deleting files and directories
    - Primitives to manipulate files and directories
    - Mapping files onto secondary storage
    - Backup files onto stable (non-volatile) storage media

Mass-Storage Management

- Usually, disks used to store data that does not fit in main memory or data that must be kept for a "long" period of time
- Entire speed of computer operation hinges on disk subsystem and its algorithms
- OS activities
  - Free-space management
  - Storage allocation
  - Disk scheduling
- Some storage need not be fast
  - Tertiary storage includes optical storage, magnetic tape
  - Still must be managed – by OS or applications
  - Varies between WORM (write-once, read-many-times) and RW (read-write)

Migration of data “A” from Disk to Register

- Multitasking environments must be careful to use most recent value, no matter where it is stored in the storage hierarchy



- Multiprocessor environment must provide **cache coherency** in hardware such that all CPUs have the most recent value in their cache
- Distributed environment situation even more complex
  - Several copies of a datum can exist
  - Various solutions covered in Chapter 19 *(will not get to it)*

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OS Structures

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Chap2: Operating-System Structures

Objectives:

- Services OS provides to users, processes, and other systems
- Structuring an operating system
- How operating systems are designed and customized and how they boot

OS Services for the User 1/3

- Operating systems provide an environment for execution of programs and services to programs and users
  - **User interface** - Almost all operating systems have a user interface (**UI**).
    - Varies between **Command-Line** (**CLI**), **Graphics User Interface** (**GUI**), **Batch**
  - **Program execution** - The system must be able to load a program into memory and to run that program, end execution, either normally or abnormally (indicating error)
  - **I/O operations** - A running program may require I/O, which may involve a file or an I/O device

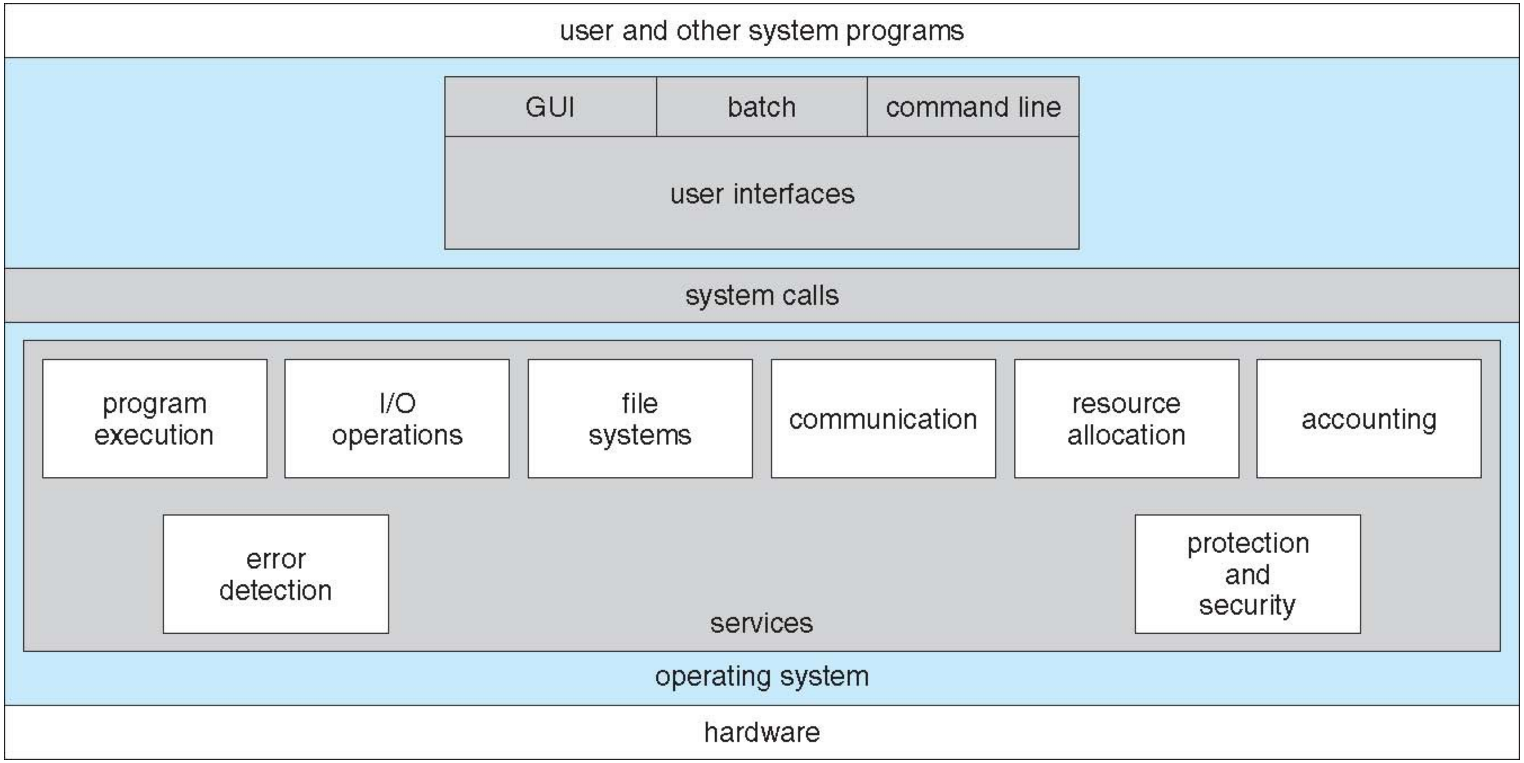
OS services for the User 2/3 (Cont.)

- **File-system operations** - read and write files and directories, create and delete them, search them, list file Information, permission management.
- **Communications** – Processes may exchange information, on the same computer or between computers over a network
  - via shared memory or through message passing (packets moved by the OS)
- **Error detection** – OS needs to be constantly aware of possible errors
  - May occur in the CPU and memory hardware, in I/O devices, in user program
  - For each type of error, OS should take the appropriate action to ensure correct and consistent computing

OS services for system 3/3 (Cont.)

- OS functions for ensuring the efficient resource sharing
  - **Resource allocation** - When multiple users or multiple jobs running concurrently, resources must be allocated to each of them
    - Many types of resources - CPU cycles, main memory, file storage, I/O devices.
  - **Accounting** - To keep track of which users use how much and what kinds of computer resources
  - **Protection and security** - concurrent processes should not interfere with each other
    - **Protection** involves ensuring that all access to system resources is controlled
    - **Security** of the system from outsiders requires user authentication, extends to defending external I/O devices from invalid access attempts

A View of Operating System Services



User Operating System Interface - CLI

CLI or **command interpreter** allows direct command entry

- Sometimes implemented in kernel, sometimes by systems program
- Sometimes multiple flavors implemented – **shells**
- Primarily fetches a command from user and executes it
- Sometimes commands built-in, sometimes just names of programs
  - If the latter, adding new features doesn't require shell modification

Ex:
Windows: command prompt
Linux: bash

Shell Command Interpreter

A bash session

ymalaiya — -bash — 81×35

```
Last login: Sat Aug 27 22:09:08 on ttys000
Ys-MacBook-Air:~ ymalaiya$ echo $0
-bash
Ys-MacBook-Air:~ ymalaiya$ pwd
/Users/ymalaiya
Ys-MacBook-Air:~ ymalaiya$ ls
270             Desktop         Downloads       Music           android-sdks
Applications    Dialcom         Library         Pictures
DLID Books      Documents       Movies          Public
Ys-MacBook-Air:~ ymalaiya$ w
22:14  up  1:12, 2 users, load averages: 1.15 1.25 1.27
USER     TTY      FROM              LOGIN@  IDLE WHAT
ymalaiya console  -                21:02    1:11 -
ymalaiya s000     -                22:14       - w
Ys-MacBook-Air:~ ymalaiya$ ps
  PID TTY           TIME CMD
  594 ttys000    0:00.02 -bash
Ys-MacBook-Air:~ ymalaiya$ iostat 5
          disk0       cpu     load average
    KB/t tps  MB/s  us sy id   1m   5m   15m
   36.76  17  0.60   5  3 92  1.42 1.31 1.28
^C
Ys-MacBook-Air:~ ymalaiya$ ping colostate.edu
PING colostate.edu (129.82.103.93): 56 data bytes
64 bytes from 129.82.103.93: icmp_seq=0 ttl=116 time=46.069 ms
64 bytes from 129.82.103.93: icmp_seq=1 ttl=116 time=41.327 ms
64 bytes from 129.82.103.93: icmp_seq=2 ttl=116 time=58.673 ms
64 bytes from 129.82.103.93: icmp_seq=3 ttl=116 time=44.750 ms
64 bytes from 129.82.103.93: icmp_seq=4 ttl=116 time=48.336 ms
^C
--- colostate.edu ping statistics ---
5 packets transmitted, 5 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 41.327/47.831/58.673/5.877 ms
Ys-MacBook-Air:~ ymalaiya$
```

Common bash commands 1/2

pwd	print Working directory	
ls -l	Files in the working dir –long format	
cd dirpath	Change to dirpath dir	
. .. ~username /	This dir , upper, usename's home, root	
cp f1 d1	Copy f1 to dir d1	
mv f1 d1	Move f1 to d1	
rm f1 f2	Remove f1, f2	
mkdir d1	Create directory d1	
which x1	Path for executable file x1	
man cm help cm	Manual entry or help with command cm	
ls > f.txt	Redirect command std output to f.txt, >> to append	
sort < list.txt	Std input from file	
ls –l | less	Pipe first command into second	

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Common bash commands 2/2

echo $((expression))	Evaluate expression	
echo $PATH	Show PATH	
echo $SHELL	Show default shell	
chmod 755 dir	Change dir permissions to 755	
jobs ps	List jobs for current shell, processes in the system	
kill id	Kill job or process with given id	
cmd &	Start job in background	
fg id	Bring job id to foreground	
ctrl-z followed by bg or fg	Suspend job and put it in background	
w who	Who is logged on	
ping ipadd	Get a ping from ipadd	
ssh user@host	Connect to host as user	
grep pattern files	Search for pattern in files	
Ctrl-c	Halt current command	

User Operating System Interface - GUI

- User-friendly **desktop** metaphor interface
  - Usually mouse, keyboard, and monitor
  - **Icons** represent files, programs, actions, etc
  - Various mouse buttons over objects in the interface cause various actions (provide information, options, execute function, open directory (known as a **folder**)
  - Invented at Xerox PARC in 1973
- Most systems now include both CLI and GUI interfaces
  - Microsoft Windows is GUI with CLI "command" shell
  - Apple Mac OS X is "Aqua" GUI interface with UNIX kernel underneath and shells available
  - Unix and Linux have CLI with optional GUI interfaces (CDE, KDE, GNOME)

Touchscreen Interfaces

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

The Mac OS X GUI

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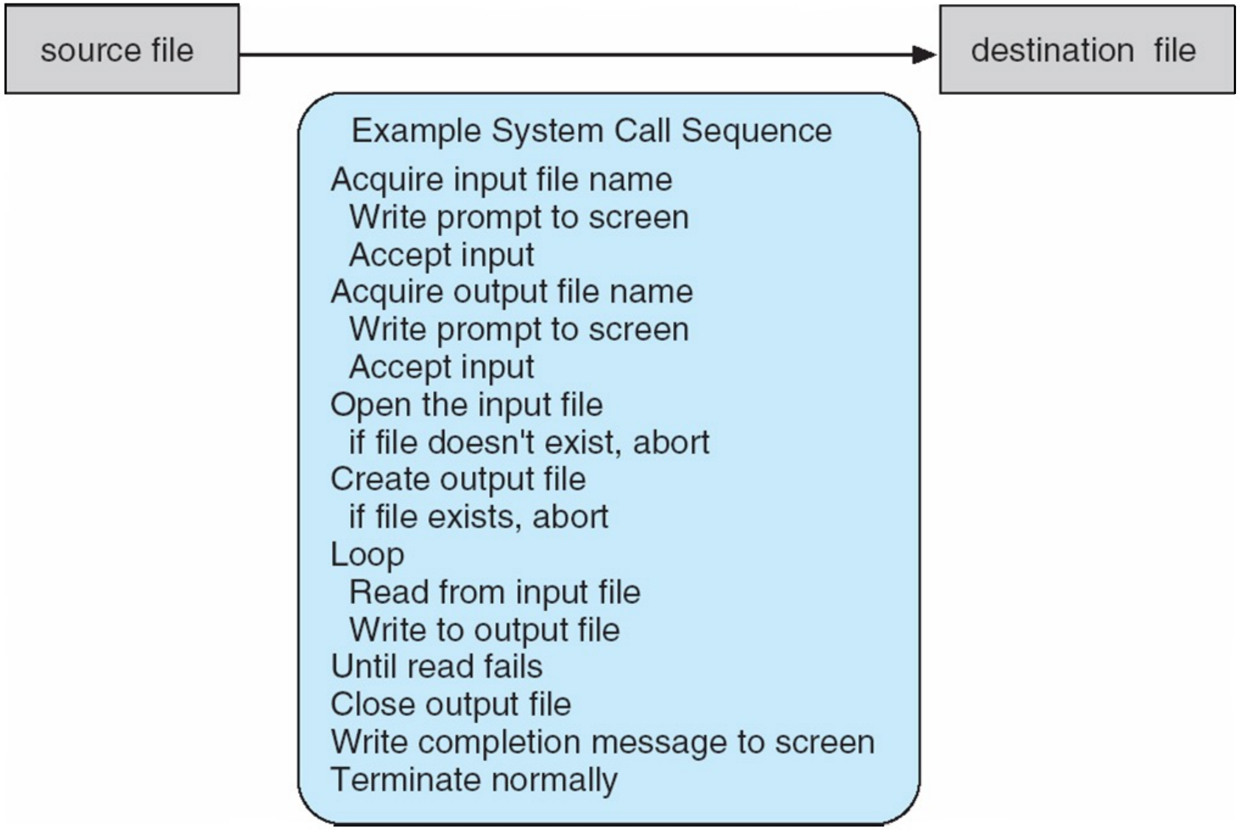
System Calls

- 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)

Note that the system-call names used throughout our text are generic.

Example of System Calls

- System call sequence to copy the contents of one file to another file



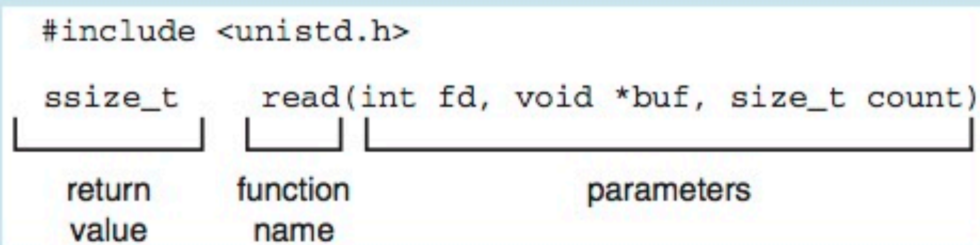
Example of Standard API

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:



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.

unistd.h header file provides access to the POSIX API

System Call Implementation

- The caller need know nothing about how the system call is implemented
  - Just needs to obey API and understand what OS will do as a result call
  - Most details of OS interface hidden from programmer by API
    - Managed by run-time support library (set of functions built into libraries included with compiler)
- System call implementation examples:
  - LC-3 Trap x21 (OUT) code in Patt & Patel (see slide 22)
  - Identified by a number that leads to address of the routine
  - Arguments provided in designated registers
  - Linux x86_64 table, code snippets

In LC3 Traps are system calls

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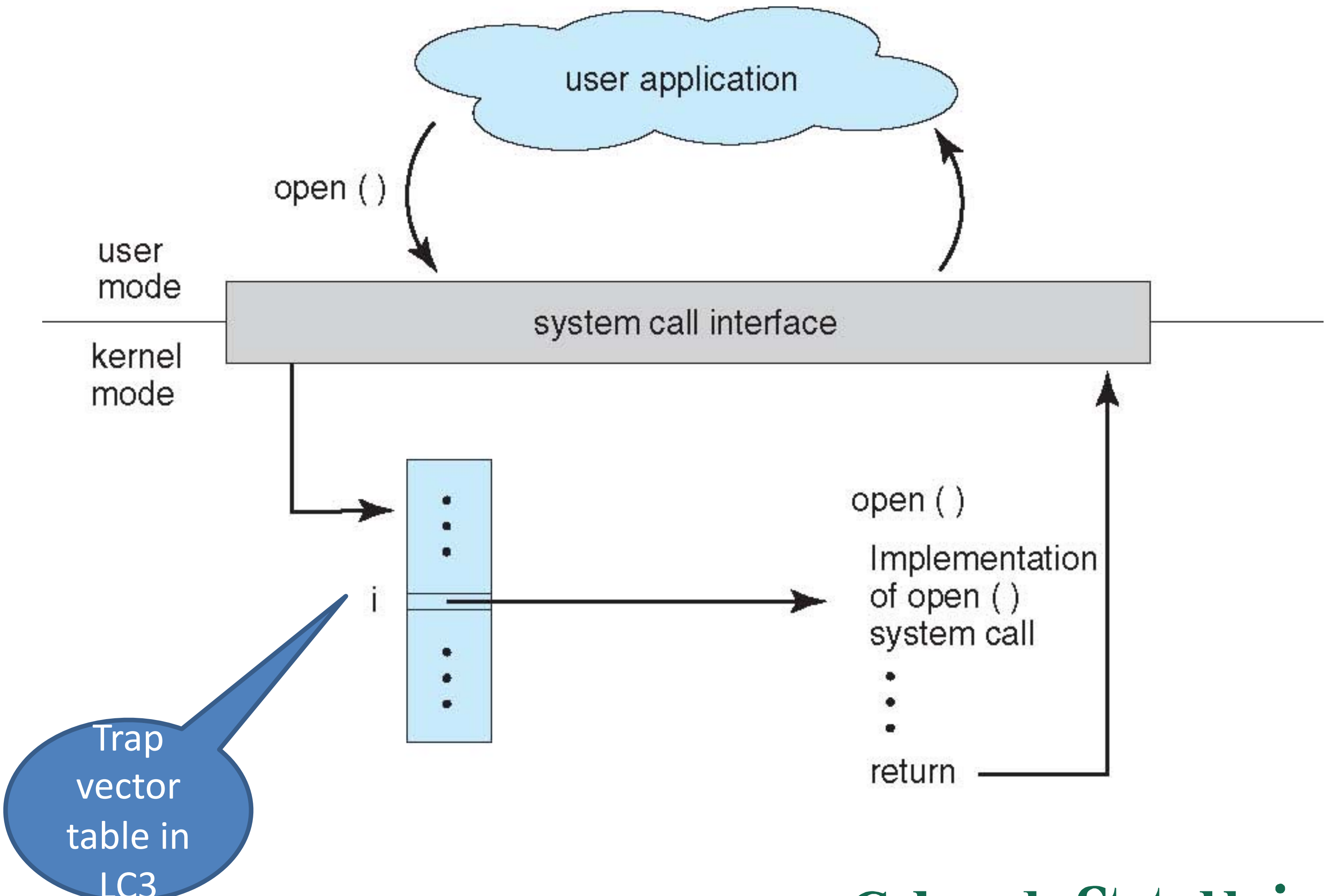
API – System Call – OS Relationship



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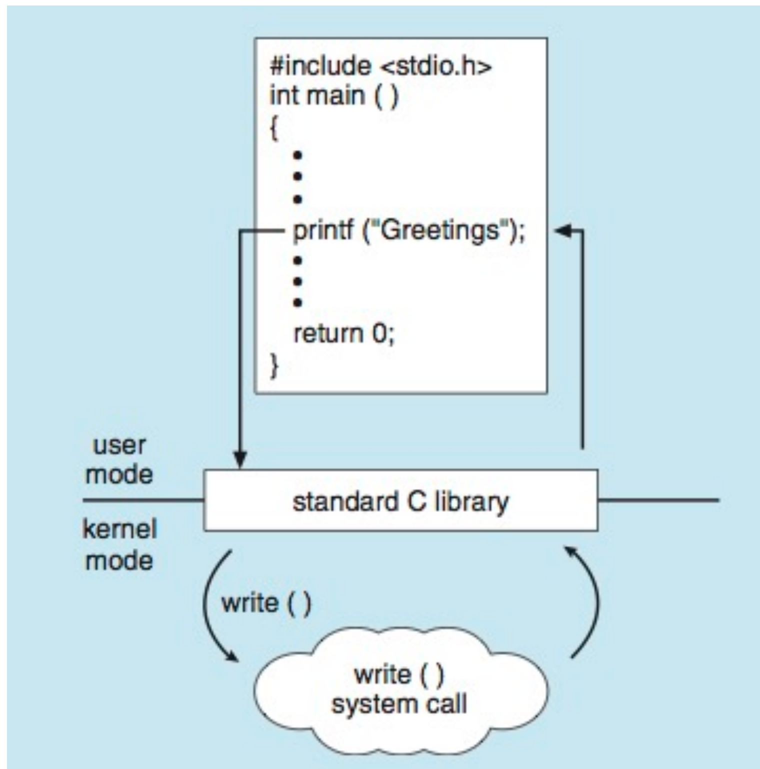
Examples of Windows and Unix System Calls

	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() shmget() mmap()
Protection	SetFileSecurity() InitlializeSecurityDescriptor() SetSecurityDescriptorGroup()	chmod() umask() chown()

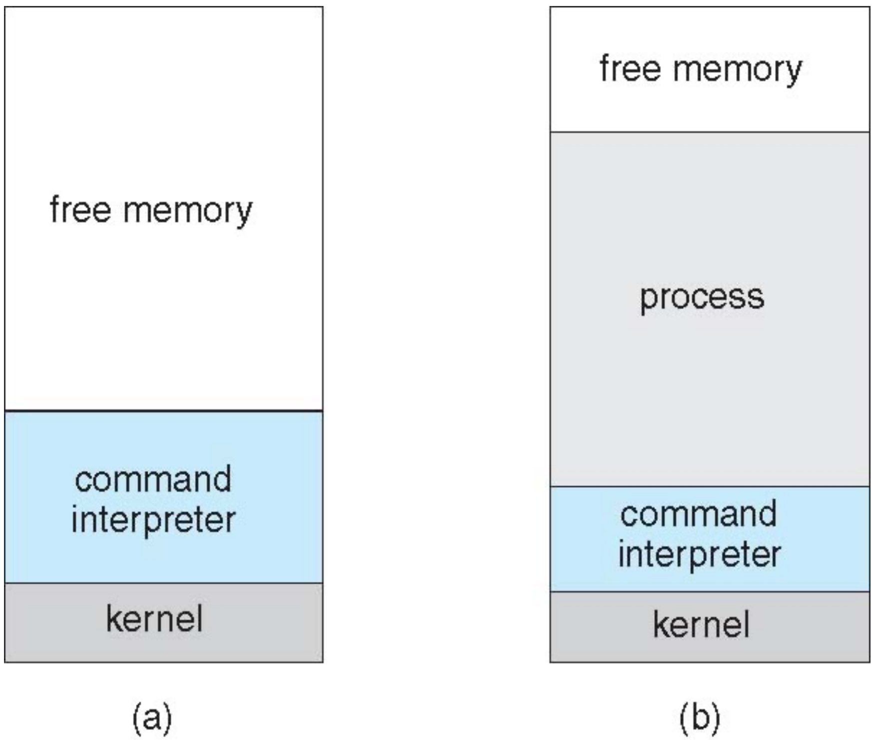
Standard C Library Example

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



Example OS: MS-DOS '81..

- 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



At system startup running a program

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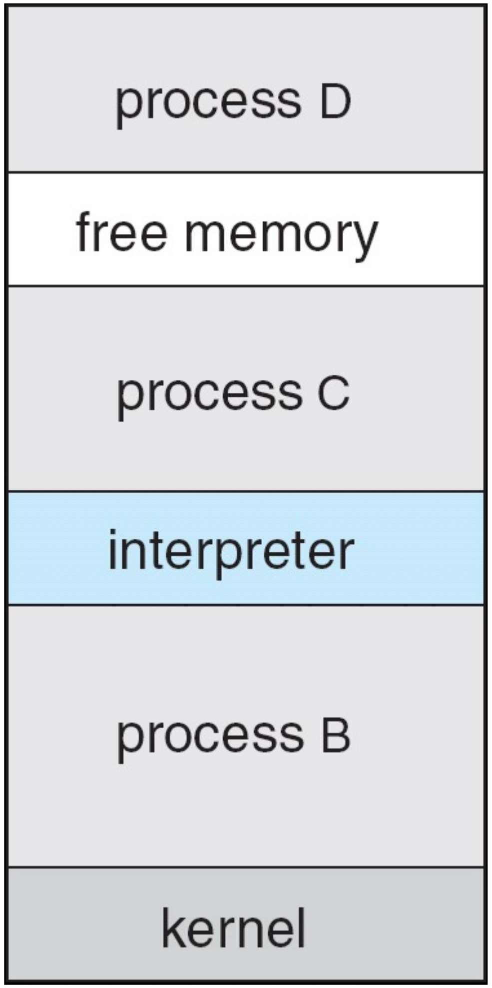
Example: xBSD '93 Berkely

- Unix '73 variant, inherited by several later OSs
- 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 = 0 – no error
  - code > 0 – error code



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POSIX

- POSIX: Portable Operating Systems Interface for UNIX   Pronounced *pahz-icks*
- **POSIX.1** published in 1988
- Final POSIX standard: Joint document
  - Approved by IEEE & Open Group End of 2001
  - ISO/IEC approved it in November 2002
  - Most recent *IEEE Std 1003.1-2008, 2016 Edition*
- Most OSs are *mostly POSIX-compliant*

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Back from ICQ

System Programs 1/4

- System programs provide a convenient environment for program development and execution. They can be divided into:
  - File manipulation
  - Status information sometimes stored in a File modification
  - Programming language support
  - Program loading and execution
  - Communications
  - Background services
  - Application programs
- Most users' view of the operation system is defined by system programs, not the actual system calls

System Programs 2/4

- Provide a convenient environment for program development and execution
  - Some of them are simply user interfaces to system calls; others are considerably more complex
- **File management** - Create, delete, copy, rename, print, dump, list, and generally manipulate files and directories
- **Status information**
  - Some ask the system for info - date, time, amount of available memory, disk space, number of users
  - Others provide detailed performance, logging, and debugging information
  - Typically, these programs format and print the output to the terminal or other output devices
  - Some systems implement a **registry** - used to store and retrieve configuration information

System Programs 3/4

- **File modification**
  - Text editors to create and modify files
  - Special commands to search contents of files or perform transformations of the text
- **Programming-language support** - Compilers, assemblers, debuggers and interpreters sometimes provided
- **Program loading and execution**- Absolute loaders, relocatable loaders, linkage editors, and overlay-loaders, debugging systems for higher-level and machine language
- **Communications** - Provide the mechanism for creating virtual connections among processes, users, and computer systems
  - Allow users to send messages to one another's screens, browse web pages, send electronic-mail messages, log in remotely, transfer files from one machine to another

System Programs 4/4

- **Background Services**
  - Launch at boot time
    - Some for system startup, then terminate
    - Some from system boot to shutdown
  - Provide facilities like disk checking, process scheduling, error logging, printing
  - Run in user context not kernel context
  - Known as **services**, **subsystems**, **daemons**
- **Application programs**
  - Don’t pertain to system
  - Run by users
  - Not typically considered part of OS
  - Launched by command line, mouse click, finger poke

Operating System Design

- General-purpose OS is very large program
- Various ways to structure ones
  - Simple structure – MS-DOS. not modular
  - More complex – UNIX.
    - Kernel+systems programs
  - Layered – an abstracation
  - Microkernel –Mach: kernel is minimal
  - hybrid

Tanenbaum–Torvalds debate: (January 29, 1992). "LINUX is obsolete".

CS370 OS Ch3 Processes

- Process Concept: a program in execution
- Process Scheduling
- Processes creation and termination
- Interprocess Communication using shared memory and message passing

Process Concept

- An operating system executes a variety of programs:
  - Batch system – **jobs**
  - Time-shared systems – **user programs** or **tasks**
- Textbook uses the terms ***job*** and ***process*** almost interchangeably
- **Process** – a program in execution; process execution must progress in sequential fashion. Includes
  - The program code, also called "**text section**"
  - Current activity including **program counter**, processor registers
  - **Stack** containing temporary data
    - Function parameters, return addresses, local variables
  - **Data section** containing global variables
  - **Heap** containing memory dynamically allocated during run time

Process Concept (Cont.)

- Program is ***passive*** entity stored on disk (**executable file**), process is ***active***
  - Program becomes process when executable file loaded into memory
- Execution of program started via GUI mouse clicks, command line entry of its name, etc
- One program can be several processes
  - Consider multiple users executing the same program

Process in Memory