OS Components, System Calls, Interrupt

ECE469, Jan 12

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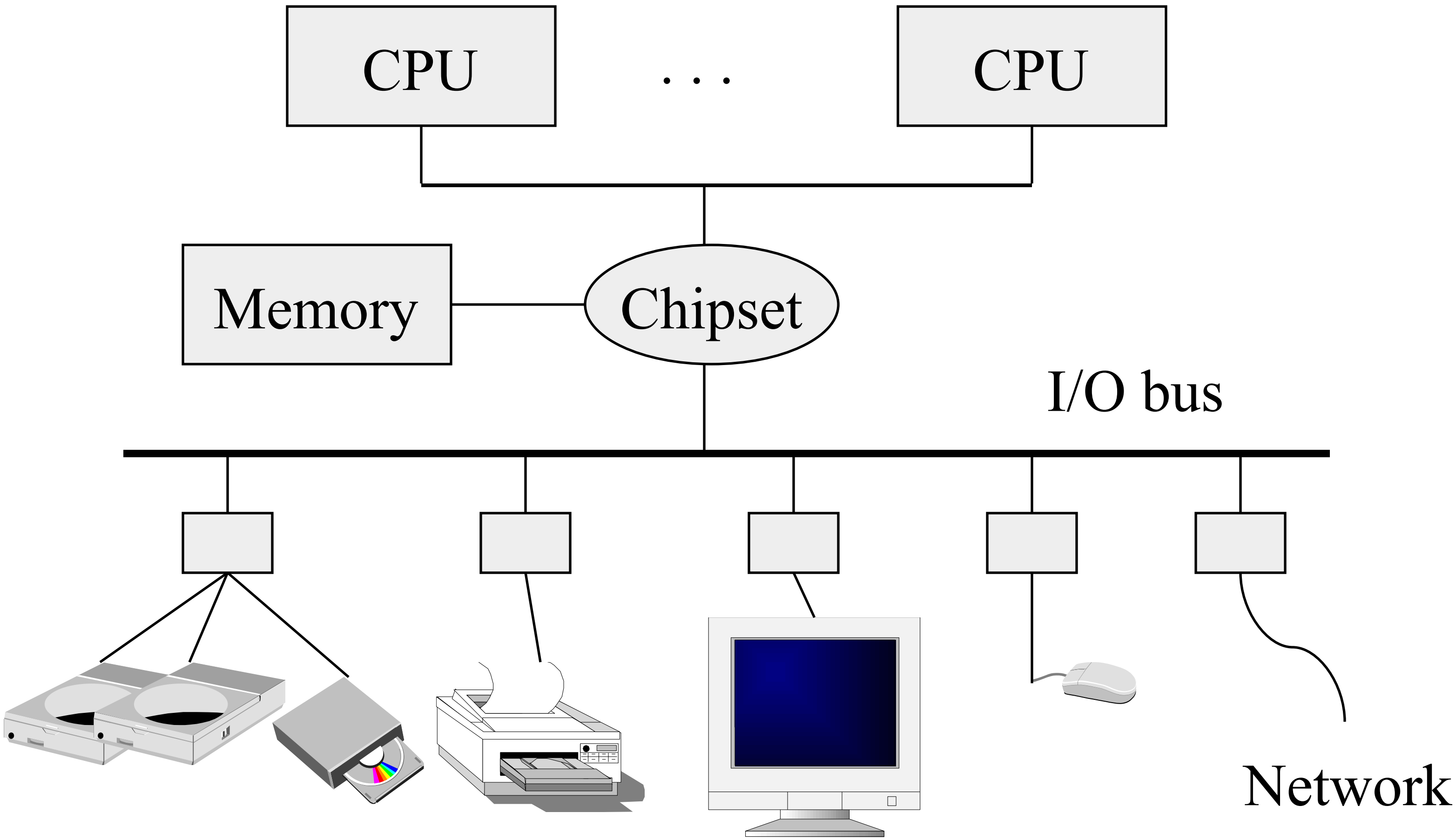
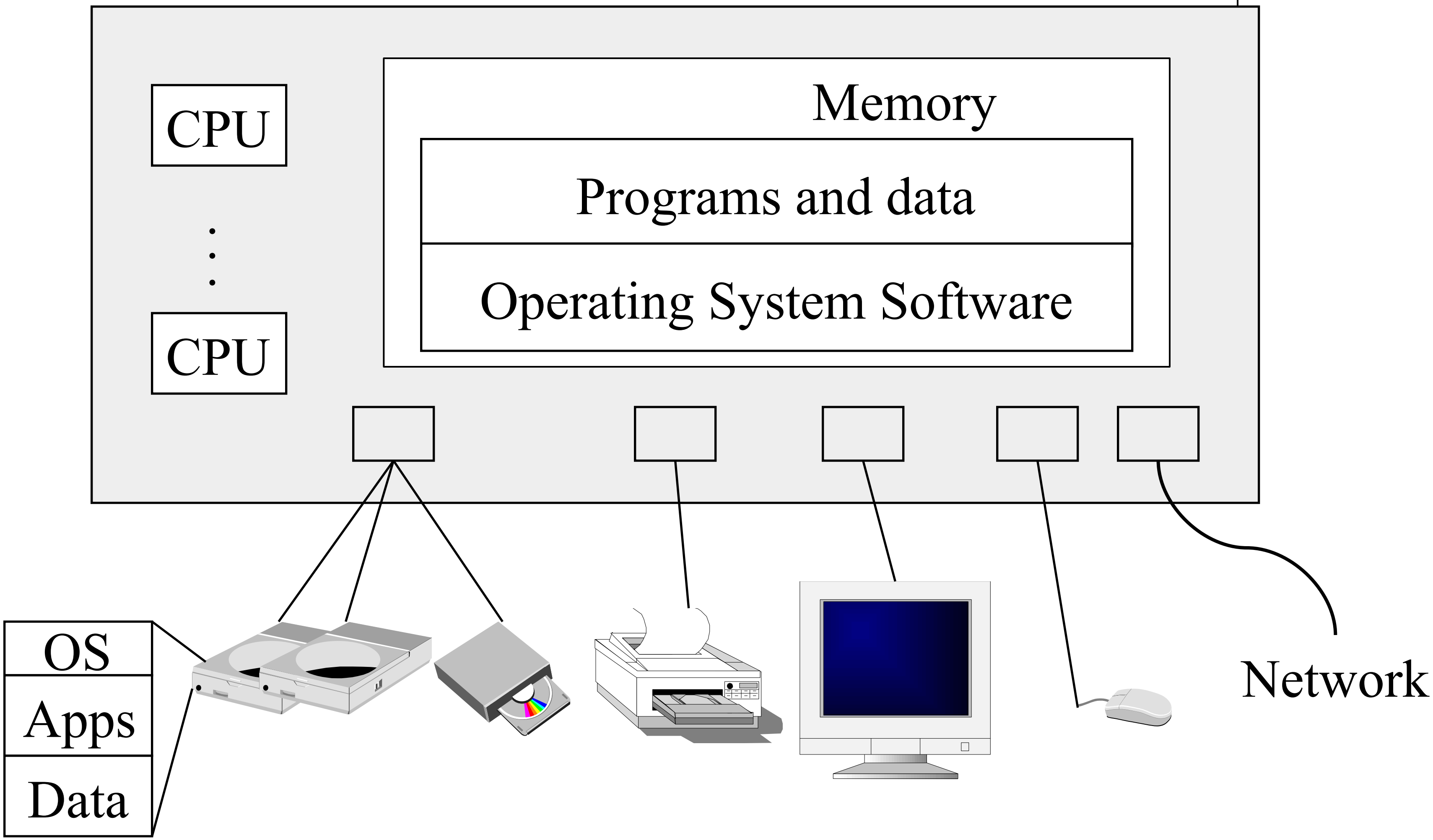
Announcement

- Find a lab partner and email TAs by Jan 24

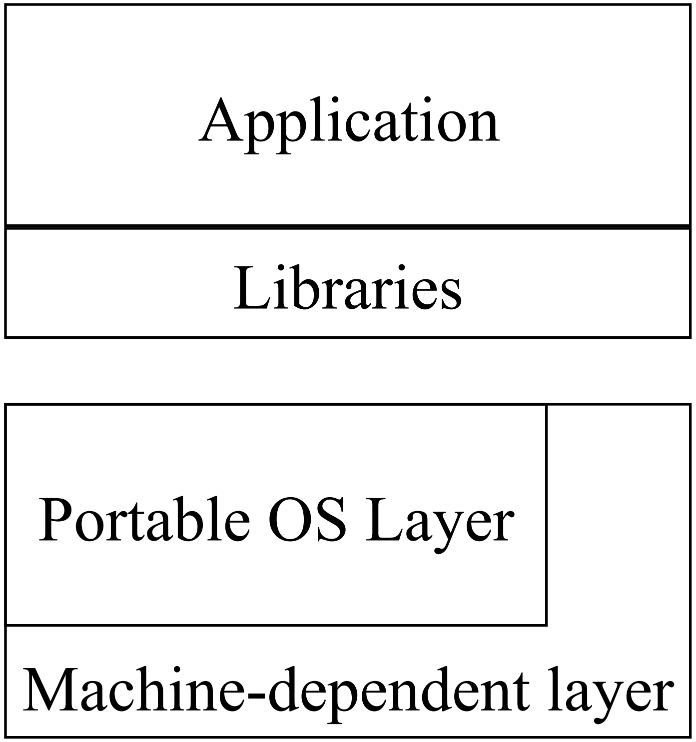
A Typical Computer from a Hardware Point of View



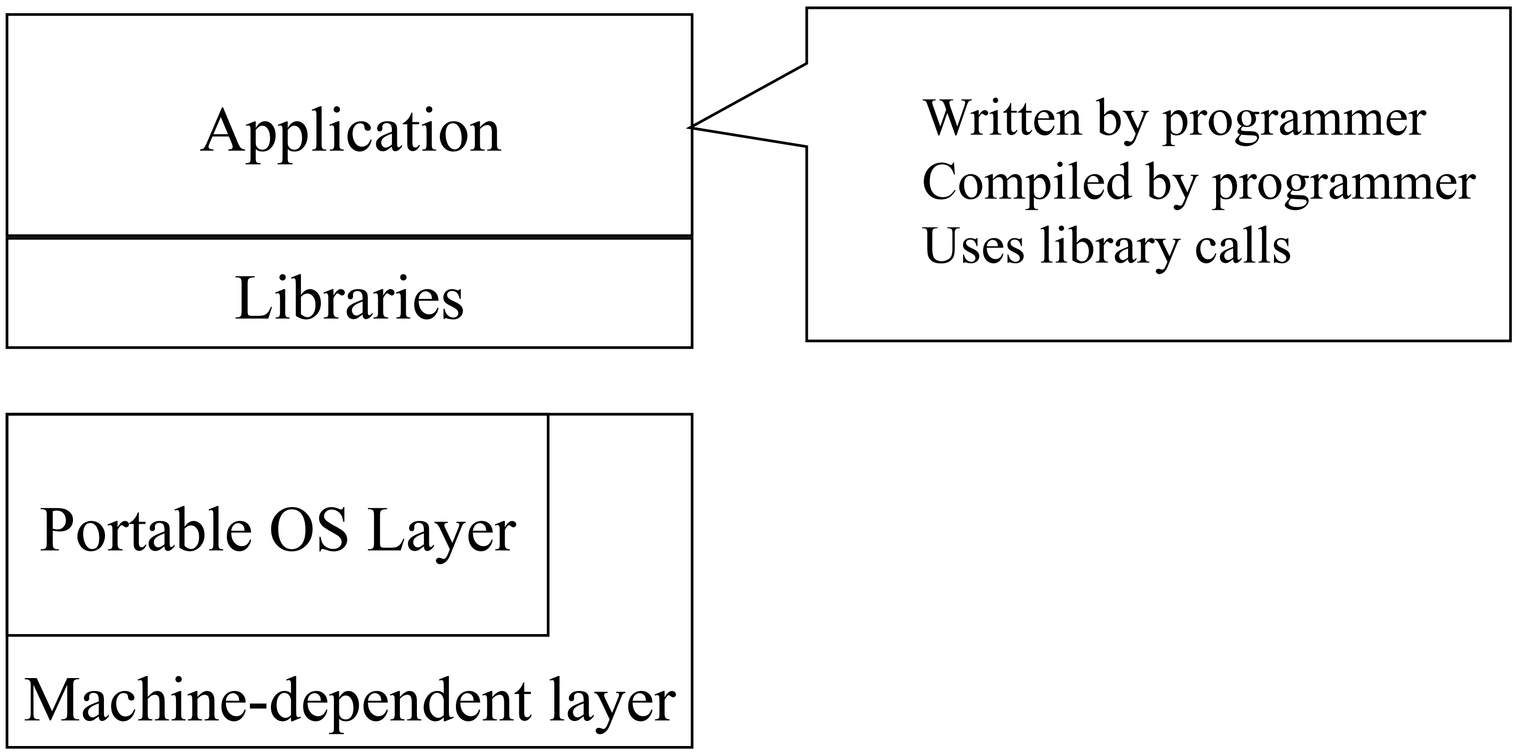
A Typical Computer System: adding software



Typical OS Structure



Typical Unix OS Structure



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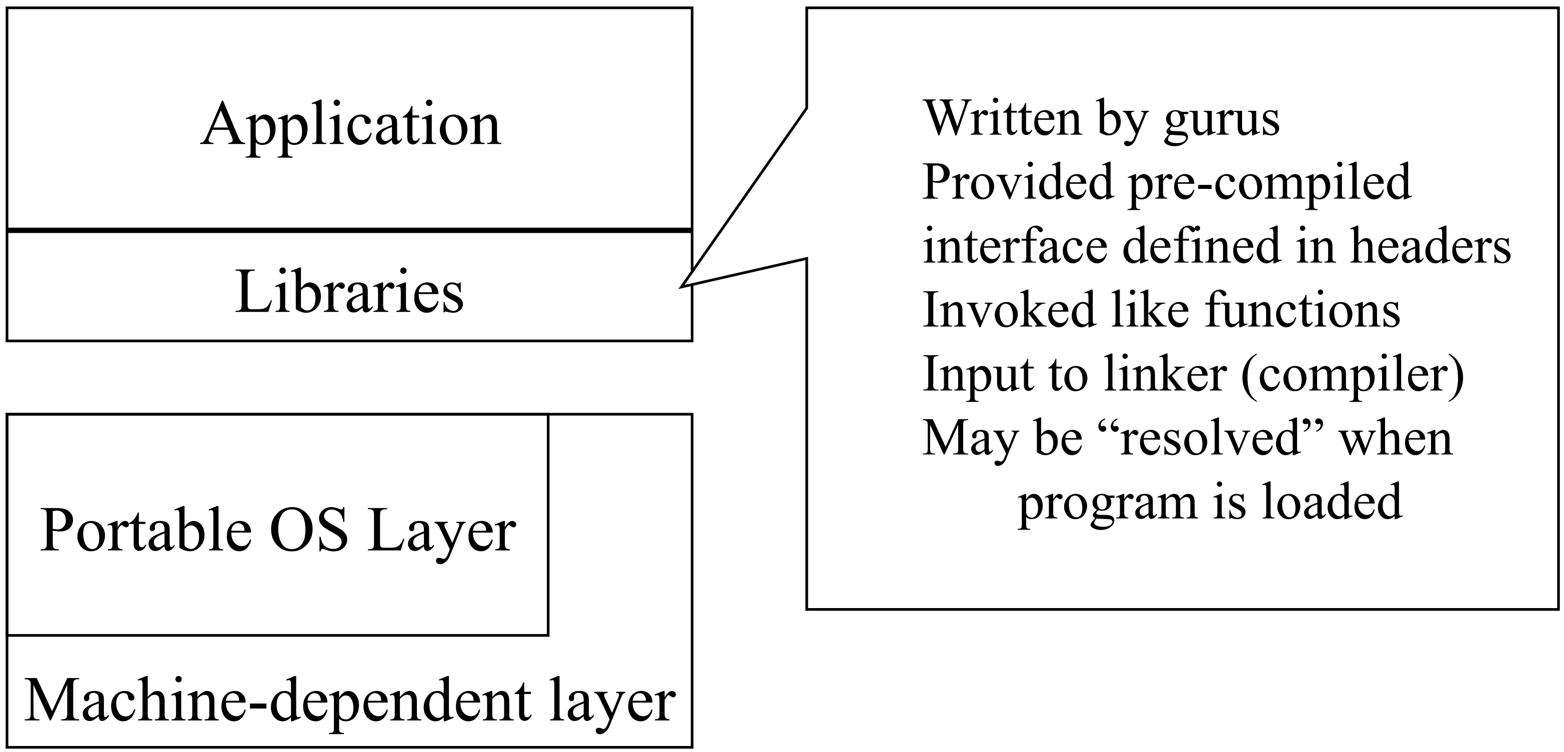
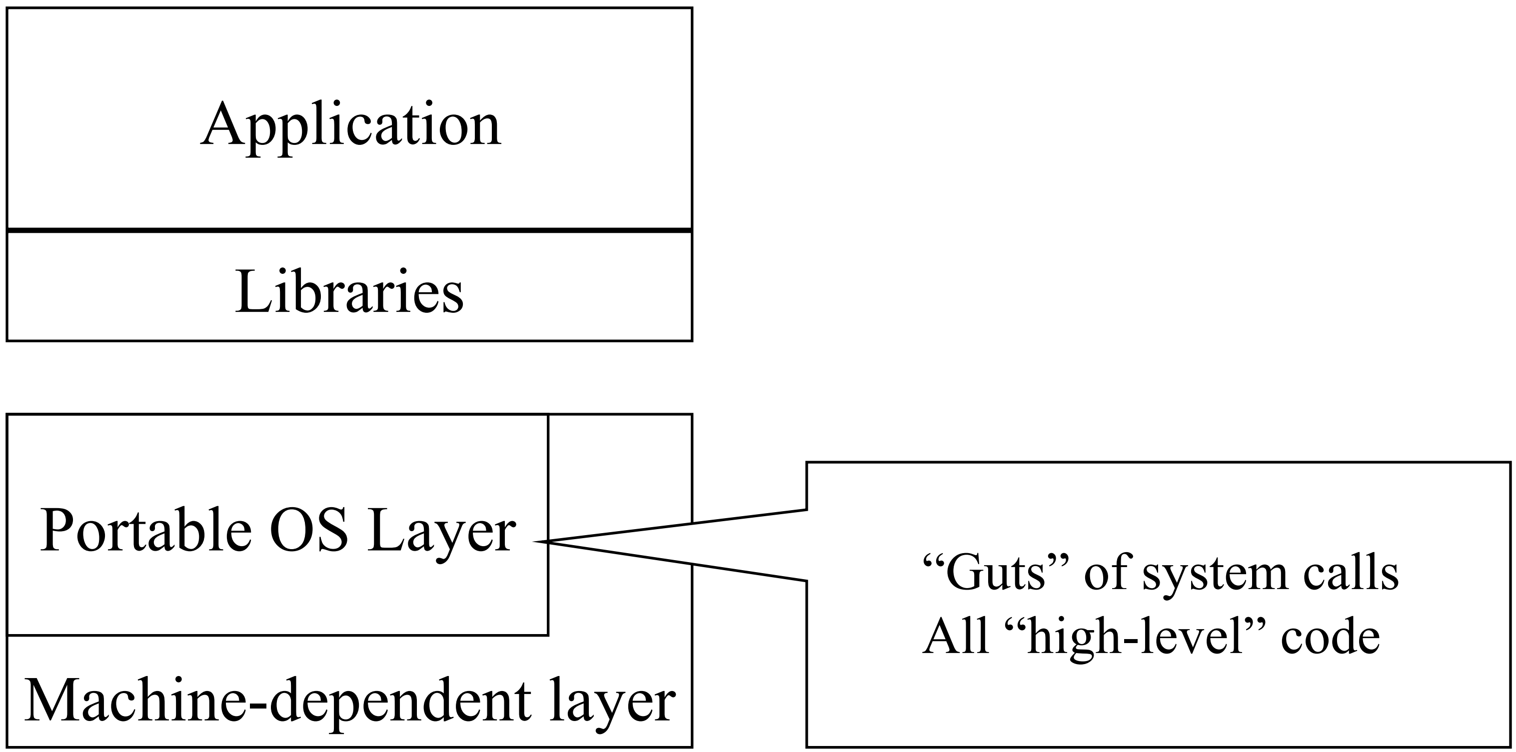


Typical Unix OS Structure



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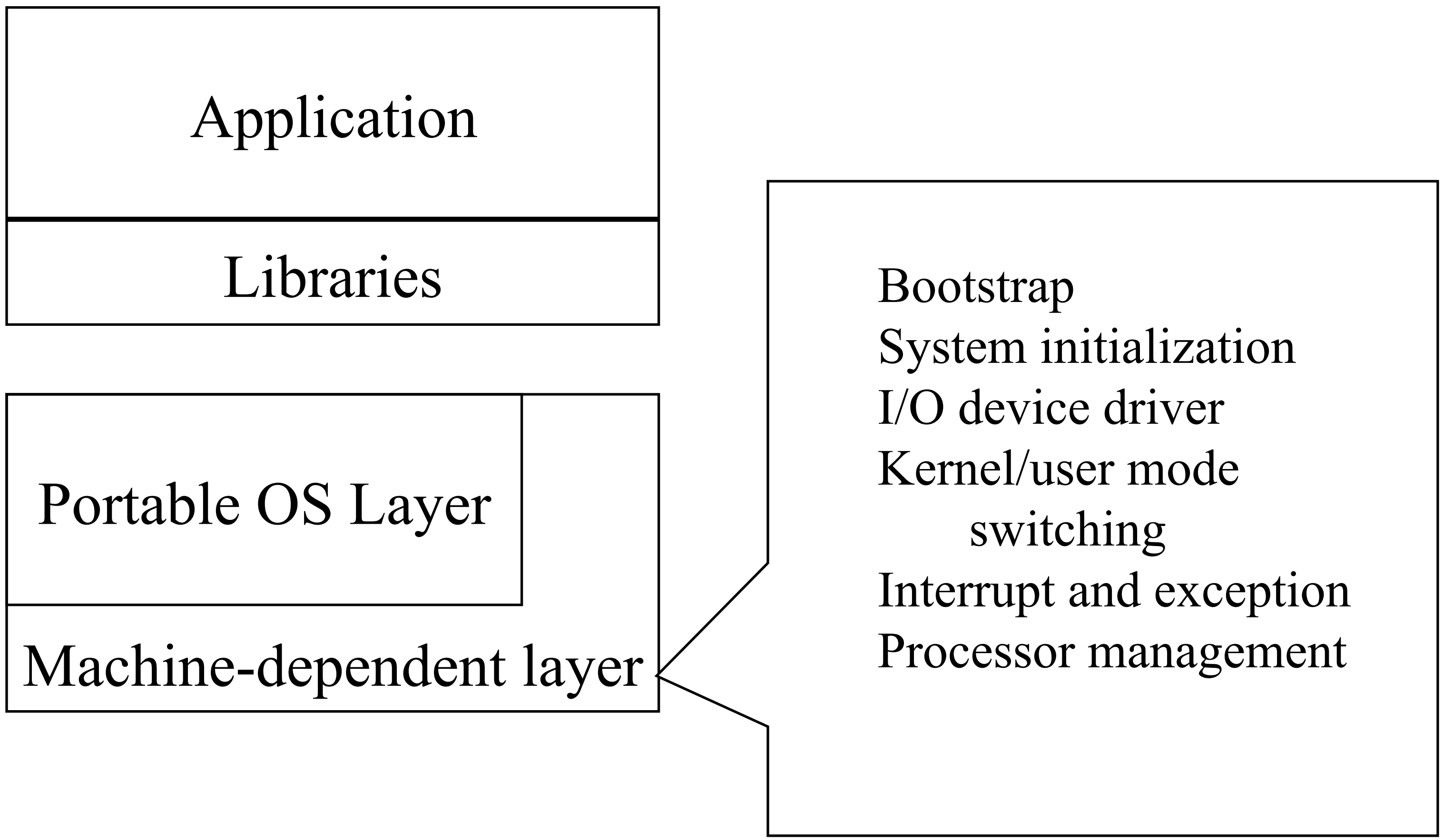
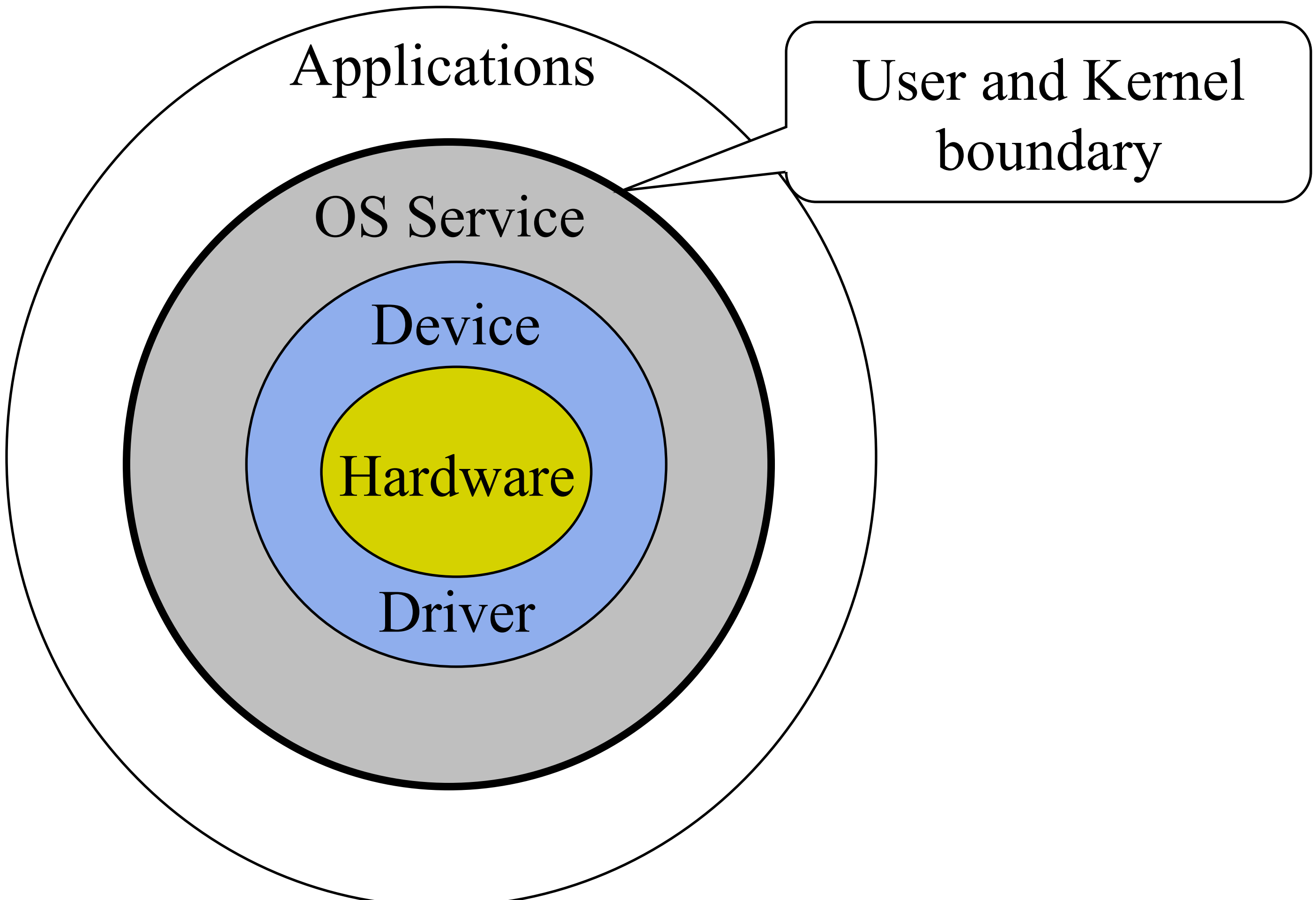


Another Look: UNIX "Onion"



Roadmap

- OS components
- System calls
- Interrupt (connecting back to ece437)

Operating system components

- Process management
- Main-memory management
- Secondary-storage management
- File management

- I/O system management
- Networking
- Command-interpreter system

Process management

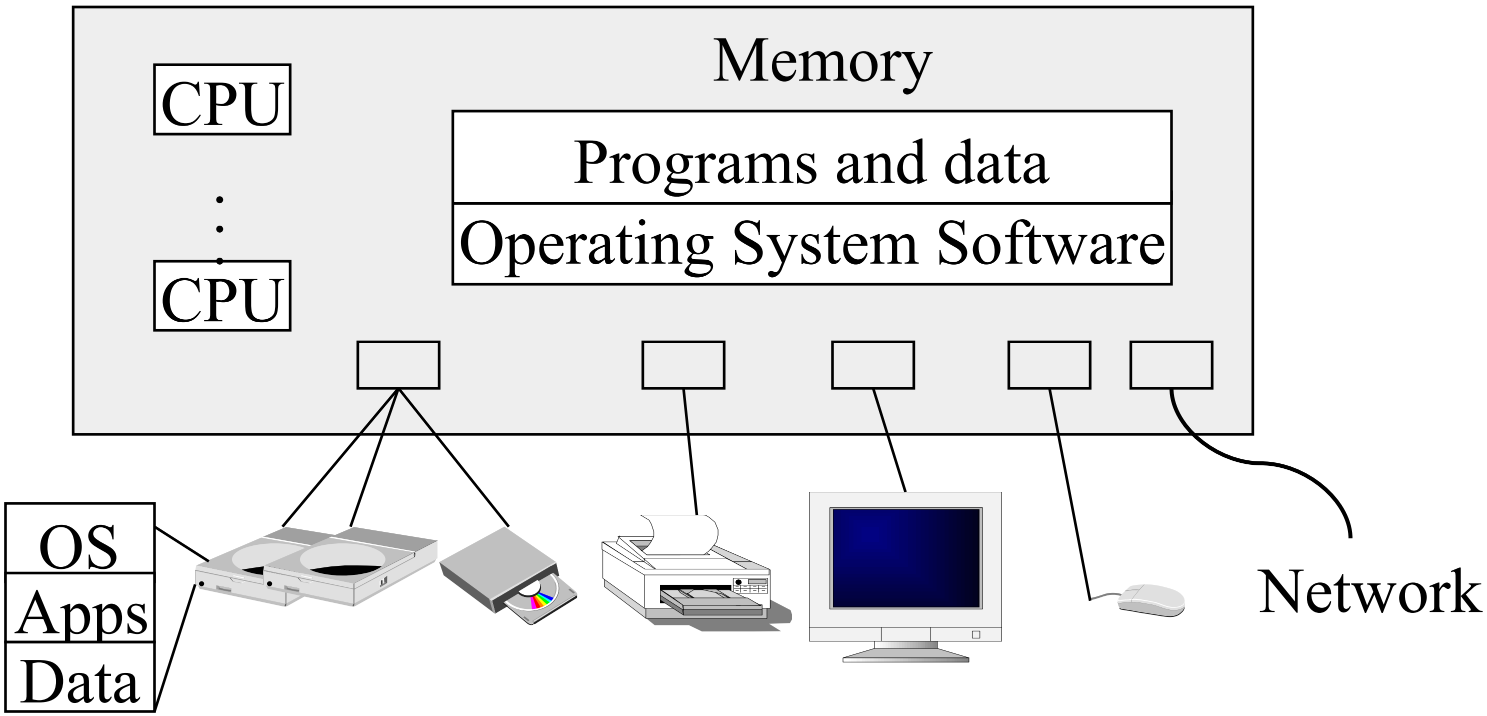
- A *process* is a program in execution
  - Process is *active*, program is *passive*
  - A process needs resources to accomplish its task:
    - CPU time
    - Memory
    - Files
    - I/O devices

Process management

- The OS is responsible for:
  - Process creation and deletion
  - Process suspension and resumption
  - Provision of mechanisms for:
    - Process communication
    - Process synchronization (e.g. parallel computing)
      - E.g.10 processes together adding up 10 billion numbers
      - Lab2
    - Deadlock detection and handling

Main-memory management

- Memory: a *volatile* storage device
  - shared by the CPU and I/O devices
  - shared by processes



Main-memory management

- The OS is responsible for:
  - Allocate and free memory space as needed
    - Keep track of which parts of memory are currently being used and by whom
  - Protection
    - How to do it fast?
  - Support larger address space than physical memory
    - malloc(2G) on a 1G machine?

Secondary-storage management

- Main memory (*primary storage*) is volatile and small → OS needs a *secondary storage* to back up main memory
- Most modern systems use disks or SSDs as the principle on-line storage medium

- The OS is responsible for:
  - Allocating/freeing disk storage
  - Disk scheduling

File management

- *A file* is a logical entity
  - It is a collection of related information defined by its creator.
- The OS is responsible for:
  - File creation and deletion
  - Directory creation and deletion
  - Mapping files onto secondary storage
  - Support of primitives for manipulating files and directories (e.g. ls, ls -l)
  - Sharing and protection

Operating system components

- Process management
- Main-memory management
- Secondary-storage management
- File management

- I/O system management
- Networking
- Command-interpreter system

I/O subsystem management

- I/O devices of many flavors
  - Storage devices: drives, tapes
  - Transmission devices: NIC, modems
  - Human-interface devices: screen, keyboard, mouse

- I/O subsystem hides peculiarities of I/O devices

- I/O subsystem consists of:
  - A uniform device-driver interface (wrapper)
  - Drivers for specific hardware devices
  - Buffering / spooling / prefetching / caching (access locality)

Networking (distributed systems)

- A *distributed system*:
  - A collection of machines that do not share memory or a clock
  - Connected through a network to provide user access to various system resources
  - Examples: Internet, WWW, banking, peer-to-peer, cloud, …
  - Allows computation scalability, speed-up, increased data availability, enhanced reliability, …

- The OS is responsible for
  - Communication between processes
  - Reliability – reliable protocols on unreliable Internet

Command-interpreter system

- Interface between user and OS
- Many commands are given to the OS by control statements which deal with:
  - process creation and management (a.out, kill –9)
  - secondary-storage management (partition disk)
  - file system
    - access (ls, cat)
    - protection (chmod 700 *, umask 077)
  - networking (telnet, ssh)
  - monioring (ps, top, vmstat, netstat)

Command-interpreter system (cont.)

- The program that reads and interprets control statements is called the *command-line interpreter* (or the *shell* in UNIX)

- Two prevalent approaches to the interface
  - moused-based windows-and-menus (Mac, Windows)
  - command line (UNIX)

Roadmap for ECE469 lectures (labs)

Introduction to OS components

Individual components

- Process management
- Memory management
- File system

- (Device management)
- (shell)
- (Networking)

Hardware support for OS interspersed (before relevant topics)

Common Themes in our journey

- Functionality, performance, tradeoff if applicable
- Software vs. hardware vs. hybrid solutions

Roadmap

- OS components
- System calls
- Interrupt

[lec1] What is an OS?

- Resource manager
  - Manage shared resources (CPU, mem, I/O, networking)
- Extended (abstract) machine

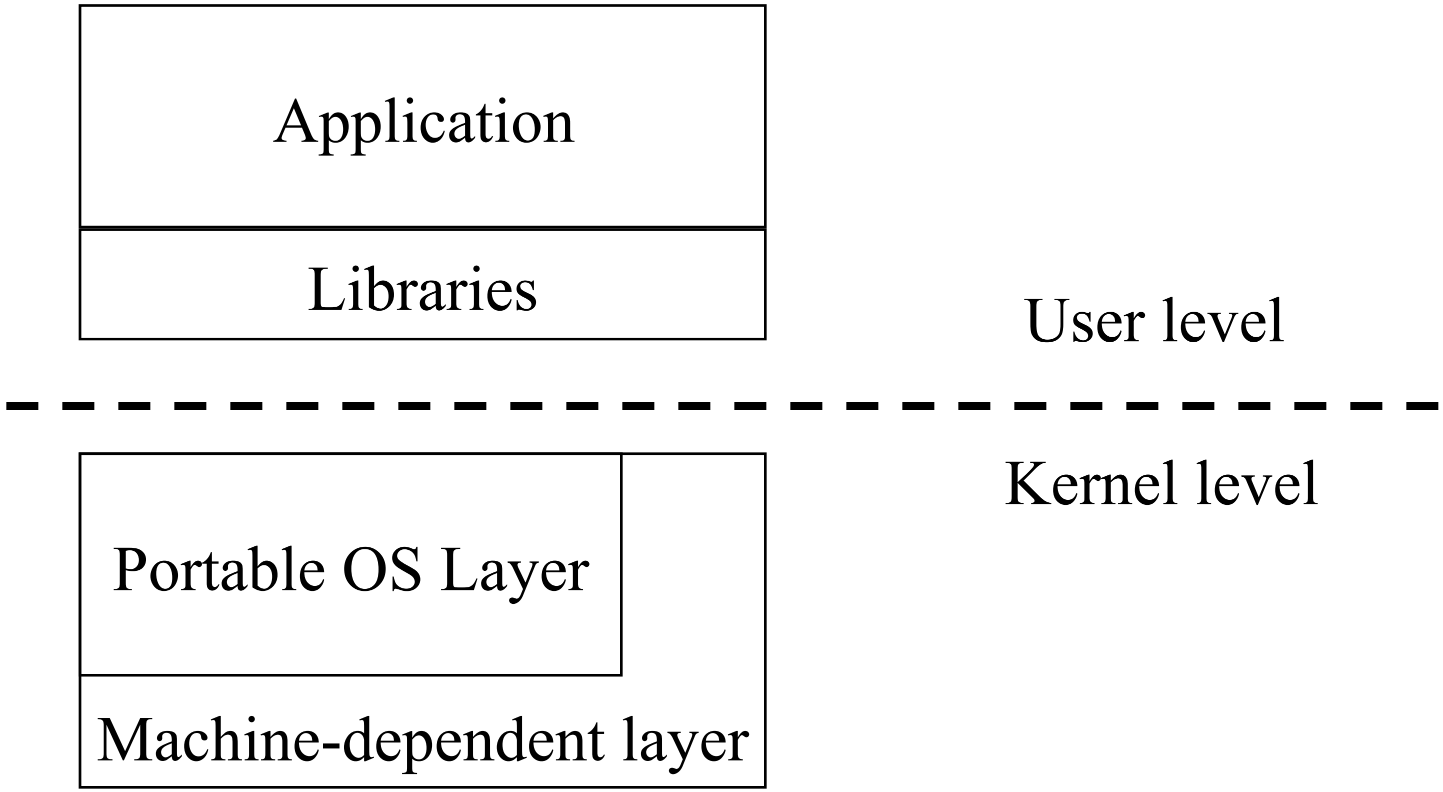
Dual-Mode Operation (ECE437)

- OS manages shared resources
- OS protects programs from other programs

➔ OS needs to be “privileged”

- Dual-mode operation of hardware
  - Kernel mode – can run *privileged* instructions
  - User mode – can only run *non-privileged* instructions

Typical Unix OS Structure



Dual-Mode Operation

- OS manages shared resources
- OS protects programs from other programs

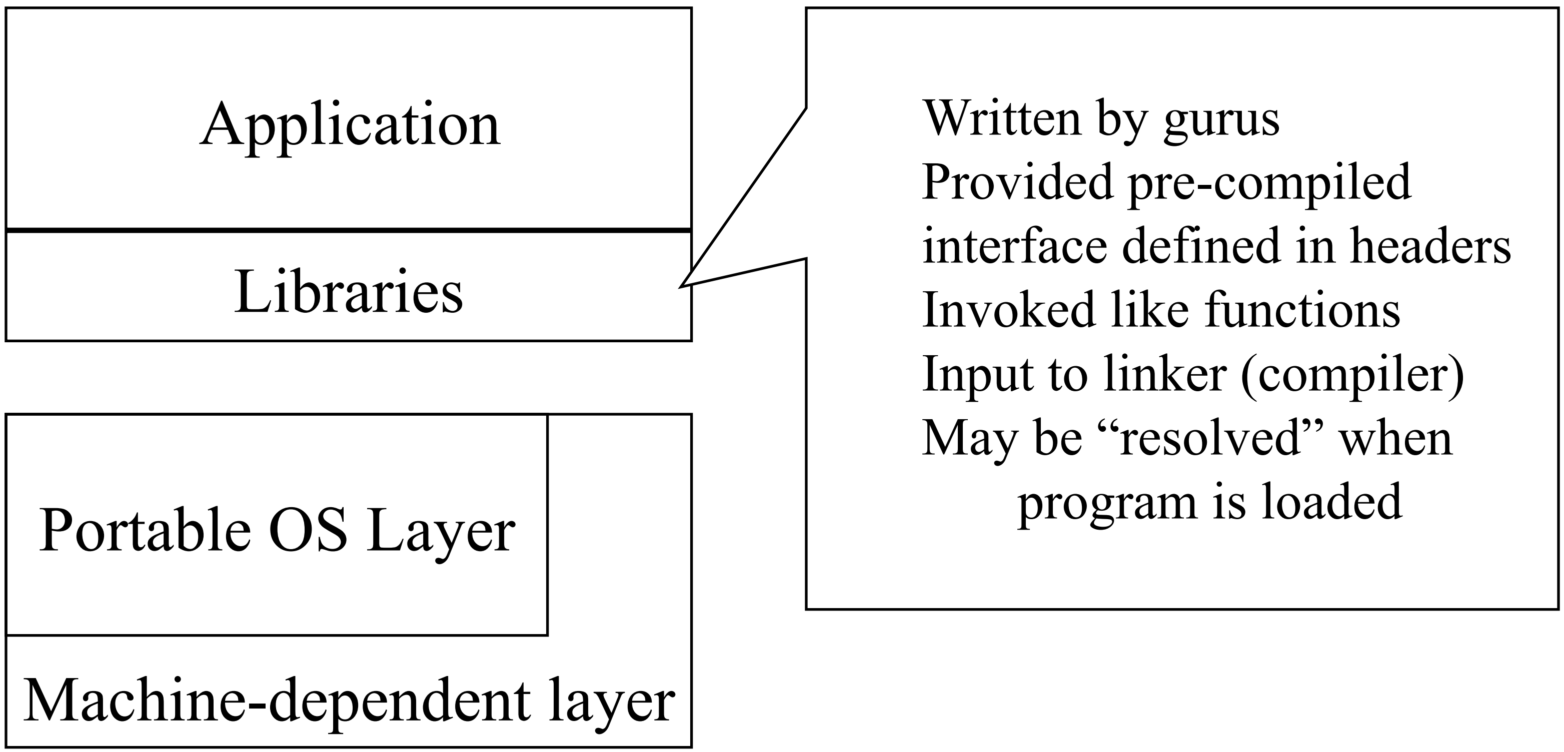
➔ OS needs to be privileged

- If OS manages shared resources, how does a user program request for accessing shared resources (e.g. hard drive)?

System calls

- Interface between a *process* and the operating system kernel
  - Kernel manages shared resources & exports interface
  - Process requests for access to shared resources
- Generally available as assembly-language instructions
- Directly invoked in many languages (C, C++, Perl)
  - Who is helping out here?

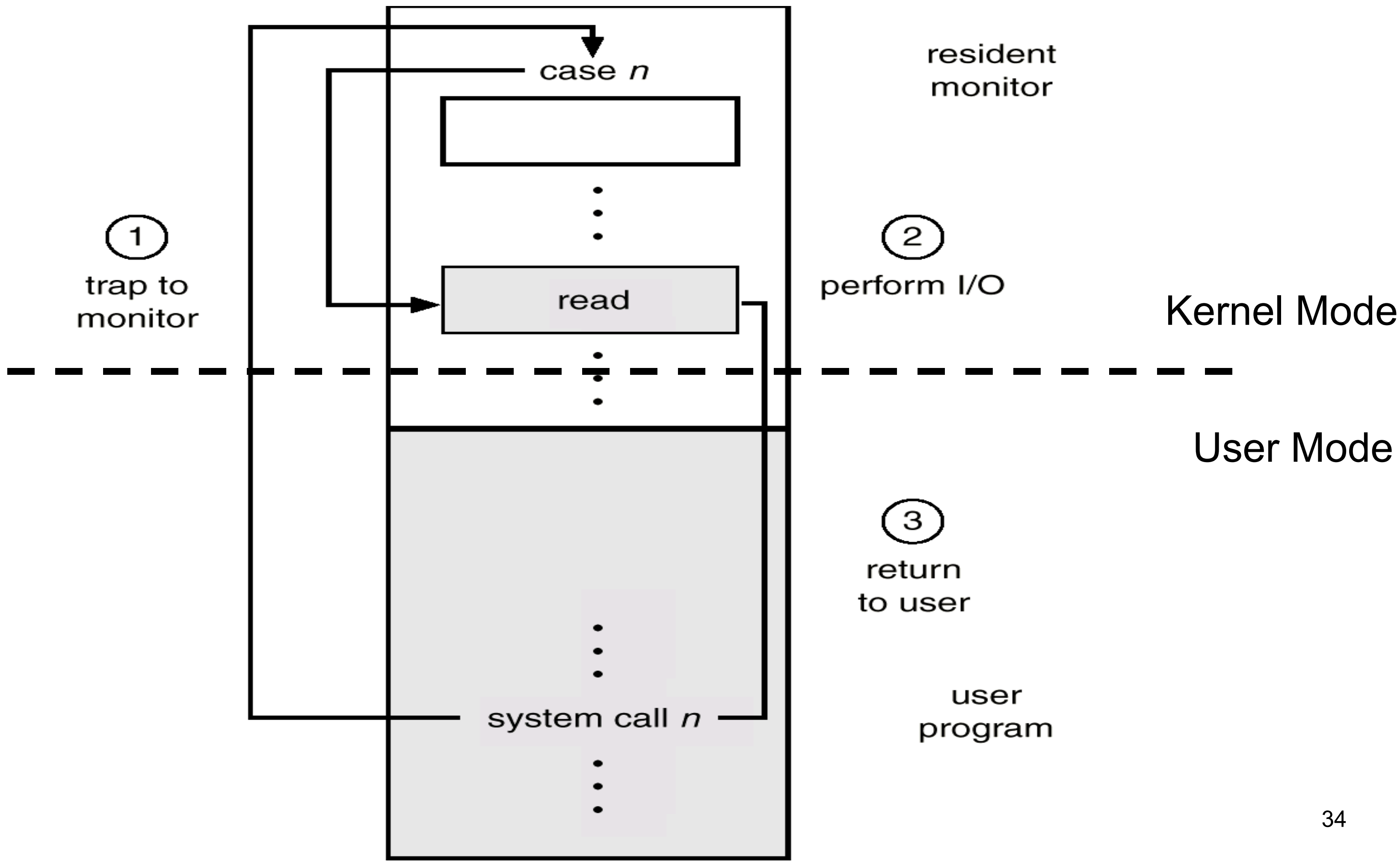
Typical Unix OS Structure



Example

- Given the I/O instructions are privileged, how does the user program perform I/O?
  - open()
  - read()
  - write()
  - close()

Use of a system call to perform I/O



System calls

- Categories
  - Process management
  - Memory management
  - File management
  - Device management
  - Networking

System calls in Linux (man syscalls)

- SYSCALLS(2) Linux Programmer's Manual SYSCALLS(2)

- NAME
- none - list of all system calls

- SYNOPSIS
- Linux 2.4 system calls.

- DESCRIPTION
- The system call is the fundamental interface between an application and
- the Linux kernel. As of Linux 2.4.17, there are 1100 system calls
- listed in /usr/src/linux/include/asm-*/unistd.h. This man page lists
- those that are common to most platforms (providing hyperlinks if you
- read this with a browser).

- _llseek(2), _newselect(2), _sysctl(2), accept(2), access(2), acct(2),
- adjtimex(2), afs_syscall, alarm(2), bdflush(2), bind(2), break, brk(2),
- cacheflush(2), capget(2), capset(2), chdir(2), chmod(2), chown(2),
- chown32, chroot(2), clone(2), close(2), connect(2), creat(2), cre-
- ate_module(2), delete_module(2), dup(2), dup2(2), execve(2), exit(2),
- fchdir(2), fchmod(2), fchown(2), fchown32, fcntl(2), fcntl64, fdata-
- …….

- NAME
- syscall - indirect system call

- SYNOPSIS
- #define _GNU_SOURCE /* See feature_test_macros(7) */
- #include <unistd.h>
- #include <sys/syscall.h> /* For SYS_xxx definitions */
- int syscall(int number, ...);

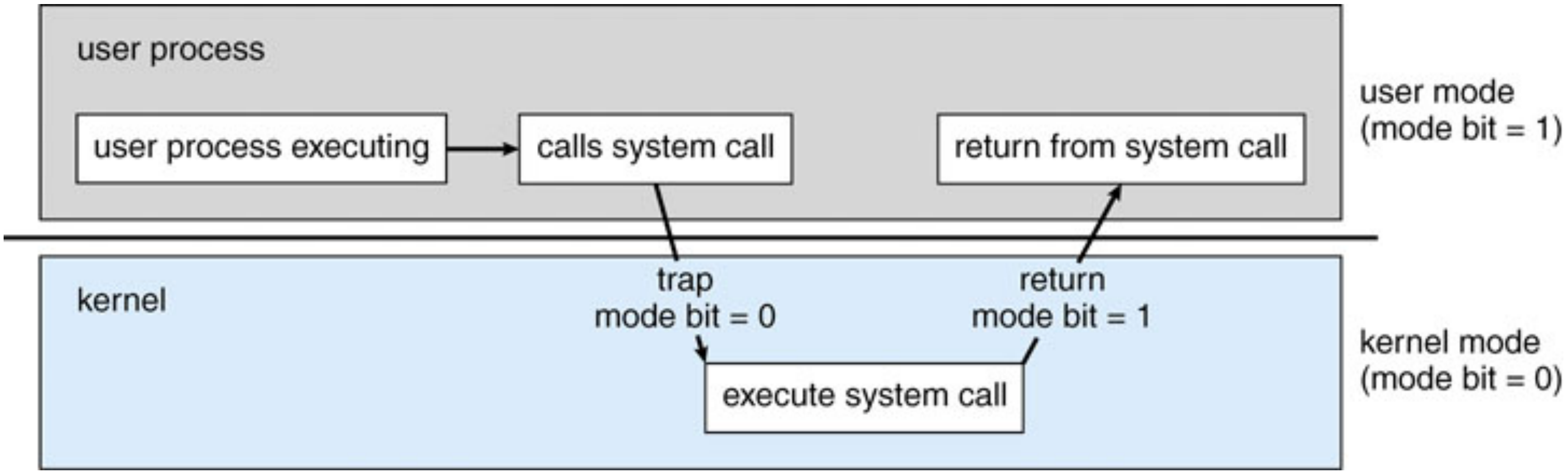
- DESCRIPTION
- syscall() is a small library function that invokes the system call whose assembly language interface has the specified number with the specified arguments. Employing syscall() is useful, for example, when invoking a system call that has no wrapper function in the C library.
- syscall() saves CPU registers before making the system call, restores the registers upon return from the system call, and stores any error code returned by the system call in errno(3) if an error occurs.
- Symbolic constants for system call numbers can be found in the header file <sys/syscall.h>.

- RETURN VALUE
- The return value is defined by the system call being invoked. In general, a 0 return value indicates success. A -1 return value indicates an error, and an error code is stored in errno.

- EXAMPLE
- #define _GNU_SOURCE
- #include <unistd.h>
- #include <sys/syscall.h>
- #include <sys/types.h>

- int main(int argc, char *argv[]) {
- pid_t tid;
- tid = syscall(SYS_gettid);
- tid = syscall(SYS_tgkill, getpid(), tid);
- }

Transition from user to kernel mode



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Lab 1 (week 1)

- DLXOS setup
- Trap (drop into the kernel) implementation
  - Used in later projects
  - Adding a new system call (getpid)

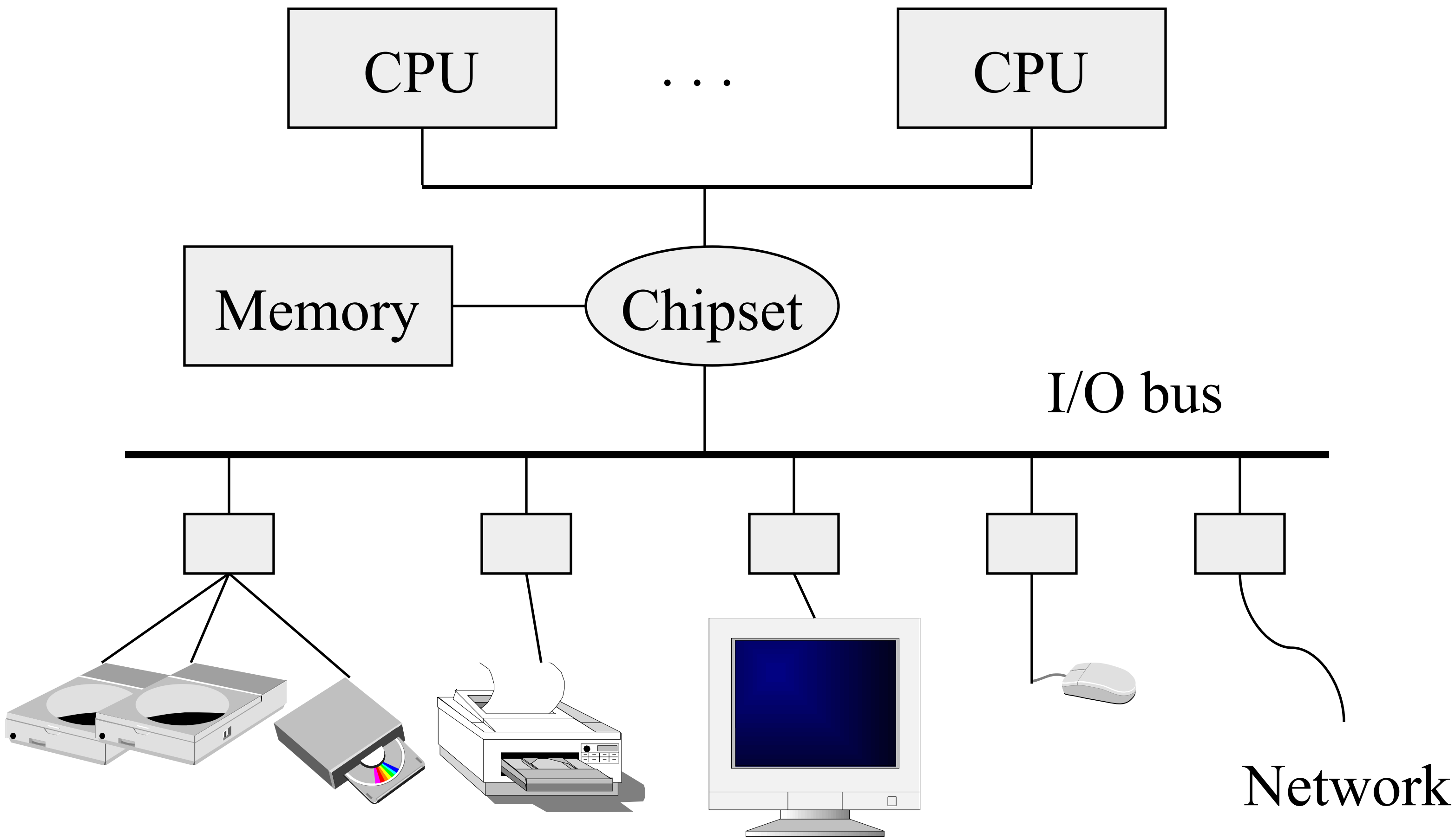
Break - brain teaser

- There are 25 horses and you need to figure out the three fastest horses by placing them into races. Assume there is no tie in the speed. There are five tracks so for each race, you can place five horses and figure out the relative rank among those five horses but you don't have the exact finishing time, i.e. there is no direct comparison between results from two different races. What's the minimum number of races you need to arrange in order to figure out the three fastest horses?

Roadmap

- OS components
- System calls
- Interrupt

A Typical Computer from a Hardware Point of View



Concurrency & Unexpected Events

- How do human handle unexpected events?
  - Assume
    - mail delivered to my mailbox continously
    - I have a secretary
  - Do I have mail now? (need to be processed quickly)
- Poll vs. interrupt
- Which one is more efficient?
    - Assume 1 interrupt more costly than 1 poll
    - If I have one mail per day?
    - If I have lots of mail per delivery?

Interrupt (ECE437)

- A mechanism for
  - coordination between concurrently operating units of a computer system (e.g. CPU and I/O devices)
  - for responding to specific conditions within a computer

- Results in transfer of flow of control (to interrupt handler in the OS), forced by hardware

Two types of Interrupts

- *Hardware interrupts*
  - timers
  - I/O devices: keyboards, NICs, etc.

- *Software interrupts* (aka. *trap, exception*)
  - an error (floating point exception)
  - a *system call* requesting OS for special services (e.g. I/O)

Handling interrupts (ECE437)

- Incoming interrupts are disabled (at this and lower priority levels) while the interrupt is being processed to prevent a lost interrupt
- Interrupt architecture must save the address of the interrupted instruction
- Interrupt transfers control to the interrupt service routine
  - generally, through the interrupt vector, which contains the addresses of all the service routines
- If interrupt routine modifies process state (register values)
  - save the current state of the CPU (registers and the program counter) on the system stack
  - restore the state before returning
- Interrupts are re-enabled affter servicing current interrupt
- Resume the interrupted instruction

X86 Interrupt and Exceptions (1)

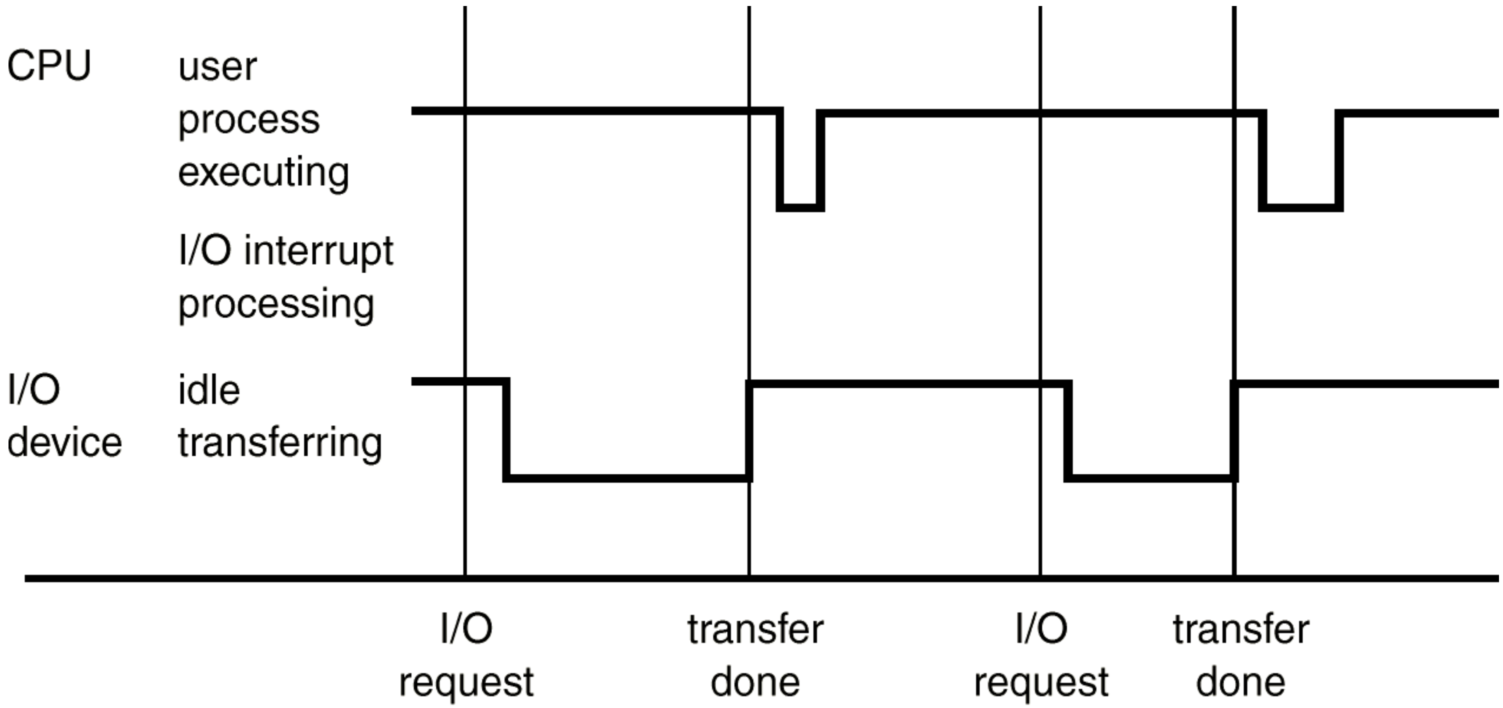
Vector #	Mnemonic	Description	Type
0	#DE	Divide error (by zero)	Fault
1	#DB	Debug	Fault/trap
2		Non-Maskable interrupt	Interrupt
3	#BP	Breakpoint	Trap
4	#OF	Overflow	Trap
5	#BR	BOUND range exceeded	Trap
6	#UD	Invalid opcode	Fault
7	#NM	Device not available	Fault
8	#DF	Double fault	Abort
9		Coprocessor segment overrun	Fault
10	#TS	Invalid TSS	

X86 Interrupt and Exceptions (2)

Vector #	Mnemonic	Description	Type
11	#NP	Segment not present	Fault
12	#SS	Stack-segment fault	Fault
13	#GP	General protection	Fault
14	#PF	Page fault	Fault
15		Reserved	Fault
16	#MF	Floating-point error (math fault)	Fault
17	#AC	Alignment check	Fault
18	#MC	Machine check	Abort
19-31		Reserved	
32-255		User defined	Interrupt

Vector 128 is for system calls

Interrupt time line for a single process doing I/O



What is an OS?

- Resource manager
  - Manage shared resources (I/O, CPU, mem, networking)
- Extended (abstract) machine

“Modern OSes are interrupt driven”

- “An OS is a giant interrupt handler!” (Def 3)
  - Timer interrupt → Context switches in multiprogramming
  - (unexpected) I/O interrupts
  - System calls (traps) to switch from user to supervisor mode
- At the lowest level an OS is just a bunch of interrupt service routings
  - Each routine simply returns to whatever was executing before it was interrupted
    - A user process
    - An OS process
    - Another interrupt routine
  - Else infinite wait loop

Questions?

- We will dive in process management next week
- Reading assignment
  - Dinosaur/Comet Chapters 1-2