COP 4225 Advanced Unix Programming

Operating System Review

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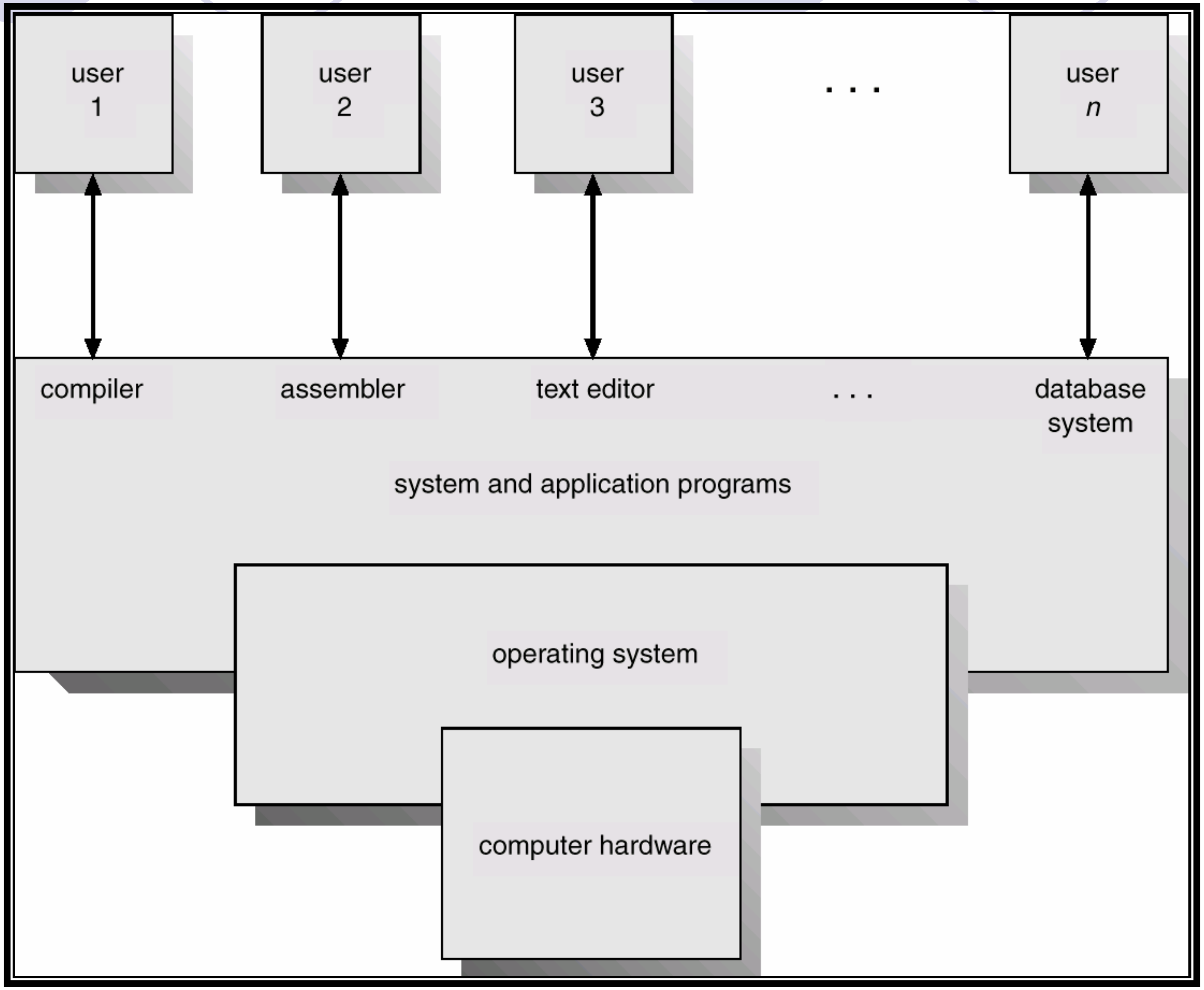
About the Course

- Prerequisite: COP 4610
- Concepts and Principles
- Programming
  - System Calls
- Advanced Topics
  - Internals, Structures, Details
  - Unix / Linux

What is an Operating System?

- A general purpose software that acts as an intermediary between users of a computer and the computer hardware.
  - Encapsulates hardware details.
  - Controls and coordinates the use of the hardware among the various application programs for the various users.
- Use the computer hardware in an efficient manner.

Abstract View of O.S.



OS Features Needed for Multiprogramming

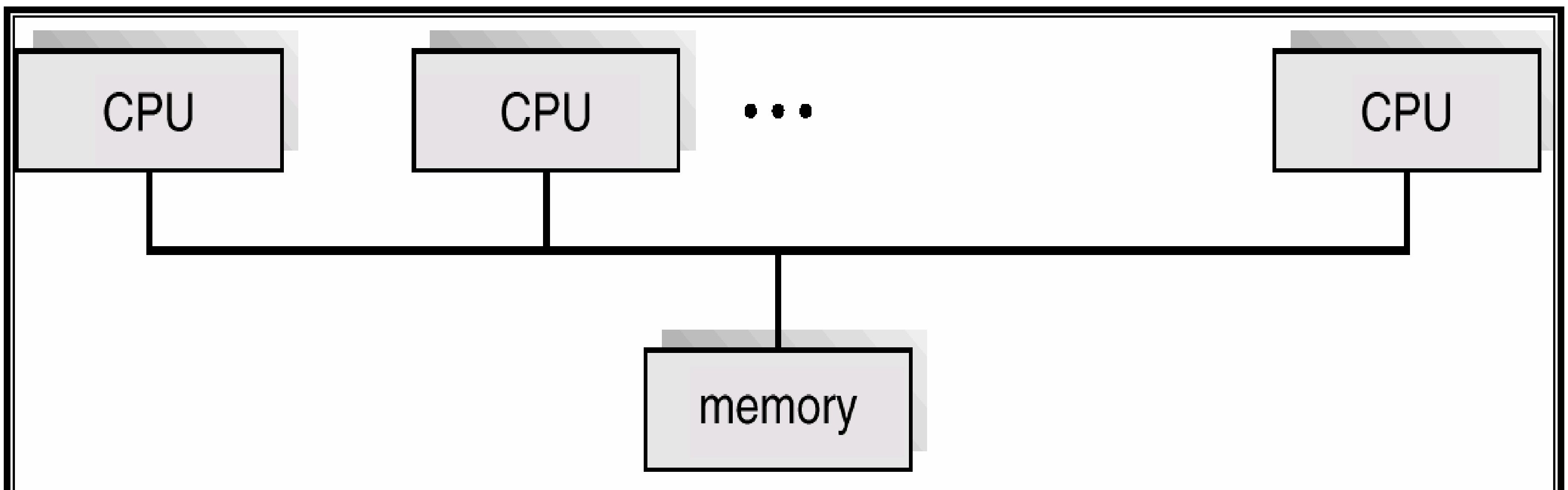
- CPU scheduling – the system must choose among several jobs ready to run.
- Memory management – the system must allocate the memory to several jobs.
- I/O routine supplied by the system.
- Allocation of devices (e.g. Disk usage).

Parallel Systems

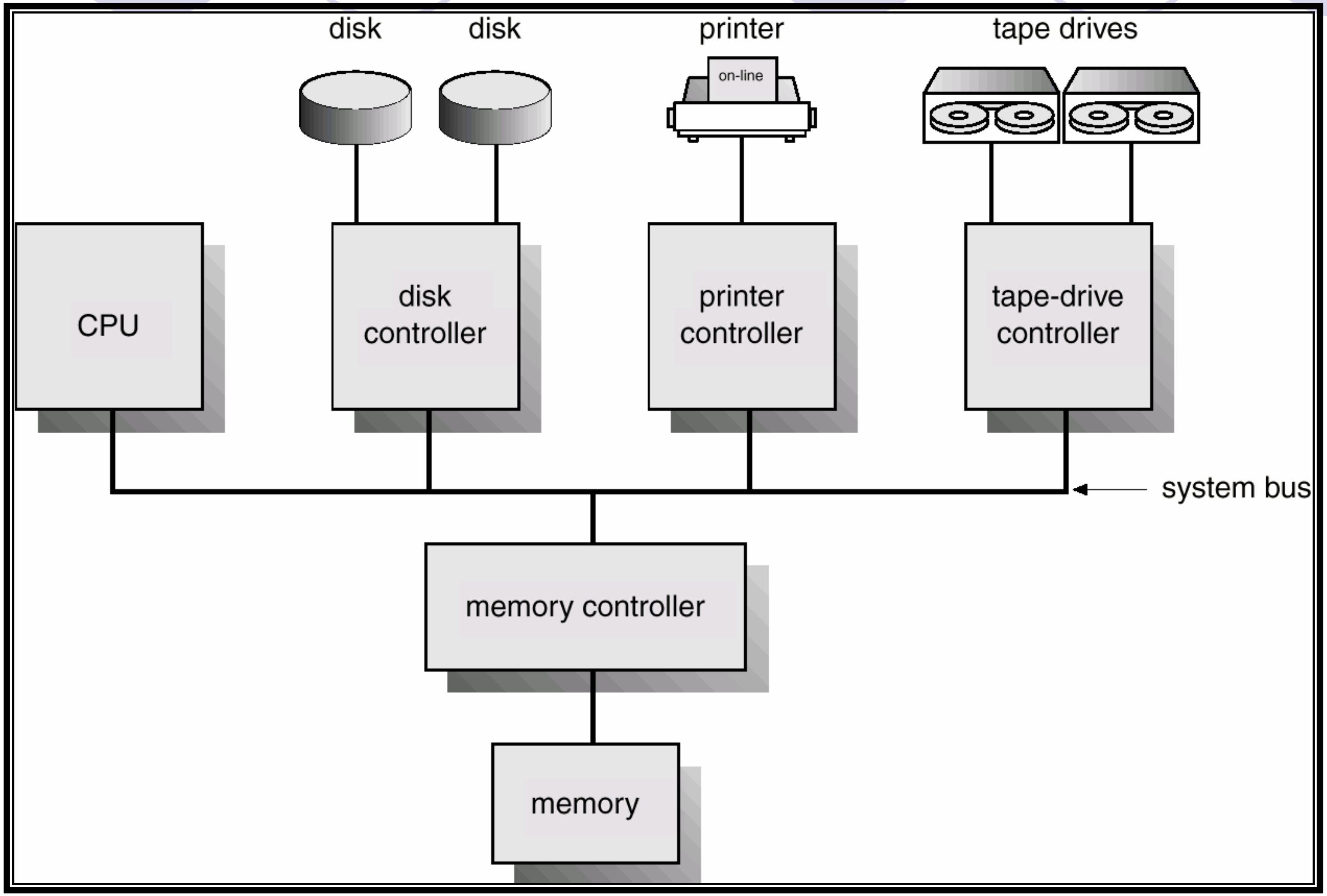
- Multiprocessor systems with more than one CPU in close communication.
- *Tightly coupled system* – processors share memory and a clock; communication usually takes place through the shared memory.
- Advantages of parallel system:
  - Increased *throughput*
  - Economical
  - Increased reliability

Parallel Systems (Cont.)

- *Symmetric multiprocessing (SMP)*
  - Each processor runs an identical copy of the operating system.
  - Many processes can run at once without performance deterioration.
  - Most modern operating systems support SMP



Computer-System Architecture



Computer-System Operation

- I/O devices and the CPU can execute concurrently, competing for memory accesses.
  - Memory controller synchronizes accesses.
- Each device controller has a local buffer.
- CPU moves data between main memory and local buffers of controllers.
- I/O is from the device to local buffer of controller.
  - The buffer size varies
- Device controller informs CPU that it has finished its operation by causing an *interrupt*.

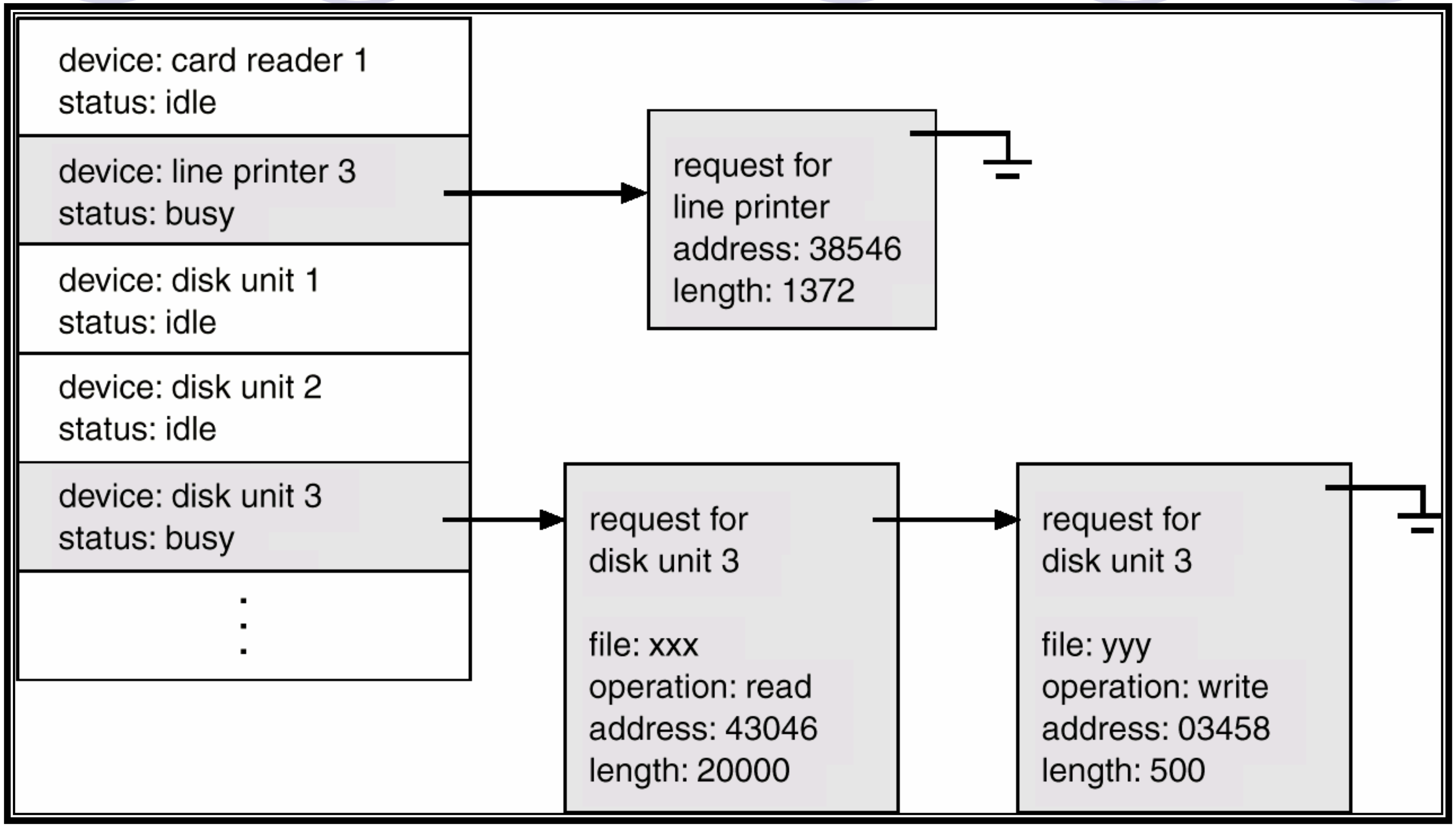
Common Functions of Interrupts

- Interrupt transfers control to the interrupt service routine generally, through the *interrupt vector*, which contains the addresses of all the service routines.
- The operating system preserves the state of the CPU before the interrupt by storing registers and the program counter.
- Incoming interrupts are *disabled* while another interrupt is being processed to prevent a *lost interrupt*.
- A *trap* is a software-generated interrupt caused either by an error or a user request.

I/O Structure

- *Device-status table* contains entry for each I/O device indicating its type, address, and state.
- Operating system indexes into I/O device table to determine device status and to modify table entry to include interrupt.
- After I/O starts, control returns to user program only upon I/O completion (Synchronous I/O).
  - *System call* – request to the operating system to allow user to wait for I/O completion.
  - Wait instruction idles the CPU (could be used by other processes) until the next **interrupt**
  - **Wait loop** (contention for memory access and CPU).
    - Poll the device status if it does not support interrupt
  - At most one I/O request is outstanding at a time, no simultaneous I/O processing.
- After I/O starts, control returns to user program without waiting for I/O completion (Asynchronous I/O).

Device-Status Table

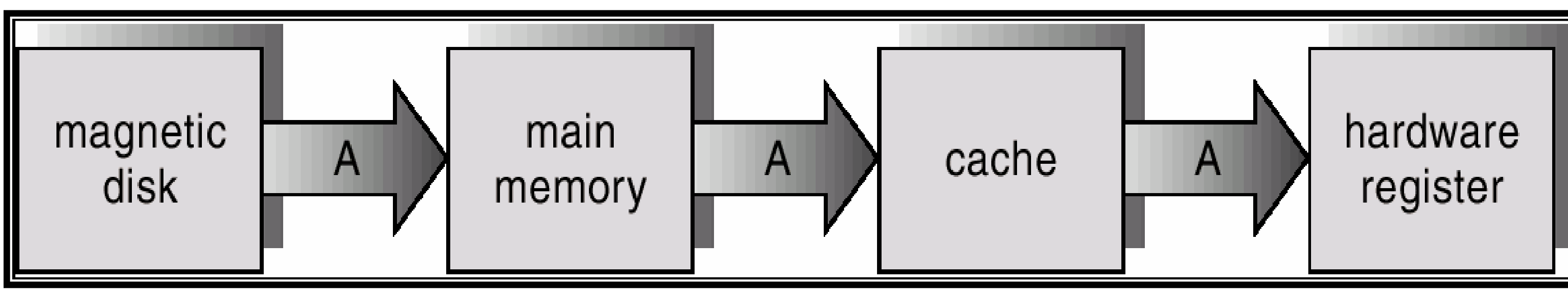


Direct Memory Access Structure

- Used for high-speed I/O devices able to transmit information at close to memory speeds.
- Device controller transfers blocks of data from buffer storage directly to main memory without CPU intervention.
  - Direct I/O: Device ↔ CPU Register ↔ Mem
- Only one interrupt is generated per block, rather than the one interrupt per byte.

Storage Hierarchy

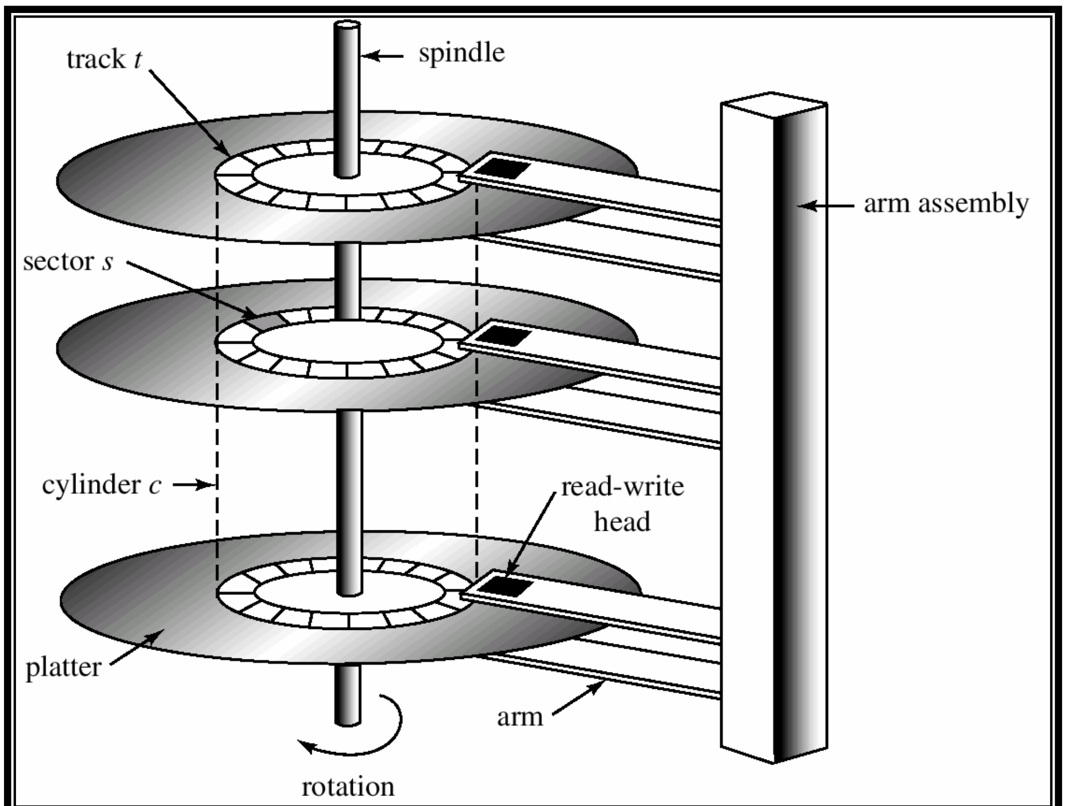
- Storage systems organized in hierarchy.
  - Speed / Cost / Volatility
- *Caching* – copying information into faster storage system
  - Consistency and Coherency (Multiple CPUs): guaranteed by the hardware.
  - main memory can be viewed as a last *cache* for secondary storage (e.g. Hard disk).



Moving-Head Disk Mechanism

Disk surface is logically divided into *tracks*, which are subdivided into *sectors*.

The *disk controller* determines the logical interaction between the device and the computer.



Storage Structure

- Memory-mapped I/O
  - Physical memory is only part of the entire address space.
  - Each location on the screen is mapped to a memory location in the address space.
- Electronic Disk (Non-Volatile Memory)
  - DRAM array + battery-backed magnetic hard disk (small)
  - If external power is off, the data are copied from RAM to the disk
  - When the external power is restored, the data are copied back to the RAM.
- ROM

Hardware Protection

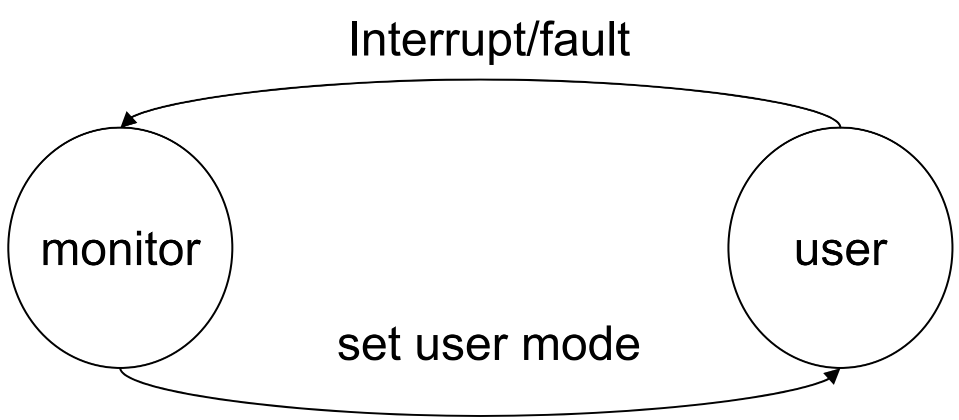
- Sharing system resources requires operating system to ensure that an incorrect program cannot cause other programs to execute incorrectly.
  - Dual-Mode Operation
  - I/O Protection
  - Memory Protection
  - CPU Protection (Time-Sharing)

Dual-Mode Operation

- Provide hardware support for two modes of operations.
  1. *User mode* – execution done on behalf of a user.
  2. *Monitor mode* (also *kernel mode* or *system mode*) – execution done on behalf of operating system.
     - *Privileged instructions* can be issued only in monitor mode.
- *Mode bit* added to computer hardware to indicate the current mode: monitor (0) or user (1).
  - associated with each memory segment

Dual-Mode Operation (Cont.)

- OS boots in monitor mode.
- OS starts user processes in user mode.
- When an interrupt or fault occurs hardware switches to monitor mode.
  - *trap* for system calls



Privileged instructions can be issued only in monitor mode.

I/O Protection

- All I/O instructions are privileged instructions.
- Must ensure that a user program could never gain control of the computer in monitor mode (loaded by OS).

Memory Protection

- In order to have memory protection, add two registers that determine the range of legal addresses a program may access:
  - **Base register** – holds the smallest legal physical memory address.
  - **Limit register** – contains the size of the range
- In user mode, memory outside the defined range is protected.
  - Attempts trap to error

Hardware Protection

- When executing in monitor mode, the operating system has unrestricted access to both monitor and user's memory.
  - The system call implementation can write back to buffers in user processes.
- The load instructions for the *base* and *limit* registers are privileged instructions.

CPU Protection

- *Timer* – interrupts computer after specified period to ensure operating system maintains control.
  - Timer is decremented every clock tick.
  - When timer reaches the value 0, an interrupt occurs and control transfers to OS
- OS performs various housekeeping tasks and switch context if necessary.
- Load-timer is a privileged instruction.

Common System Components

- Process Management
- Main Memory Management
- File Management
- I/O System Management
- Secondary Management
- Networking
- Protection System
- Command-Interpreter System

Process Management

- A *process* is a program in execution. A process needs certain resources, including CPU time, memory, files, and I/O devices, to accomplish its task.
  - program counter: the next instruction to execute.
- OS is responsible for the following activities in connection with process management.
  - Process creation and deletion.
  - process suspension and resumption.

Main-Memory Management

- Memory is shared by the CPU and I/O devices.
- Main memory is a volatile storage device.
- The operating system is responsible for the following activities in connections with memory management:
  - Keep track of which parts of memory are currently being used and by whom.
  - Decide which processes to load when memory space becomes available.
  - Allocate and deallocate memory space as needed.

File Management

- The operating system is responsible for the following activities in file management:
  - File creation and deletion.
  - Directory creation and deletion.
  - Mapping files onto nonvolatile storage.
  - File backup on stable (nonvolatile) storage media.

Secondary-Storage Management

- The operating system is responsible for the following activities in disk management:
  - Free space management
  - Storage allocation
  - Disk scheduling

I/O System Management

- The I/O system consists of:
  - A buffer-caching system
  - A general device-driver interface
  - Drivers for specific hardware devices

Command-Interpreter System

- The program that reads and interprets control statements is called variously:
  - command-line interpreter
  - shell (in UNIX)
- Its function is to get and execute the next command statement.
  - process creation and management, I/O handling, secondary-storage management, main-memory management, file-system access, protection, networking

Additional Operating System Functions

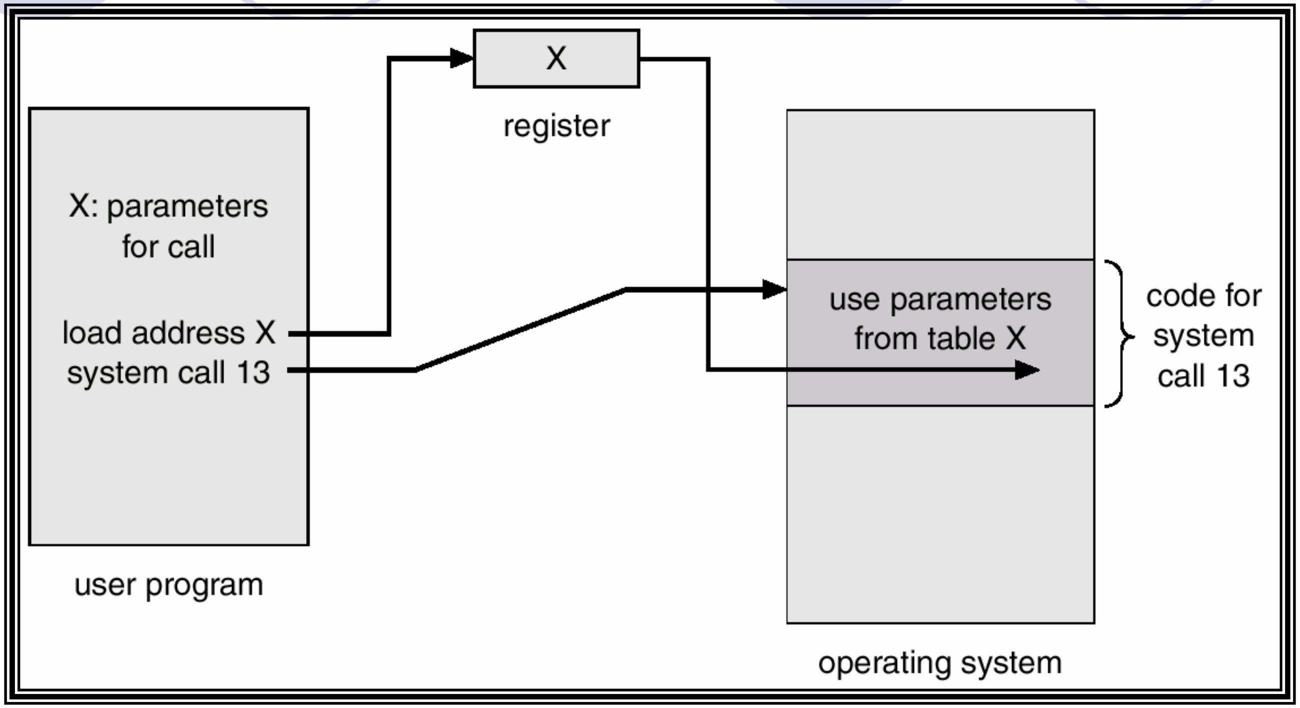
Additional functions exist for ensuring efficient system operations.

- Resource allocation – allocating resources to multiple users or multiple jobs running at the same time.
- Accounting – keep track of and record which users use how much and what kinds of computer resources for account billing or for accumulating usage statistics.
- Protection – ensuring that all access to system resources is controlled.

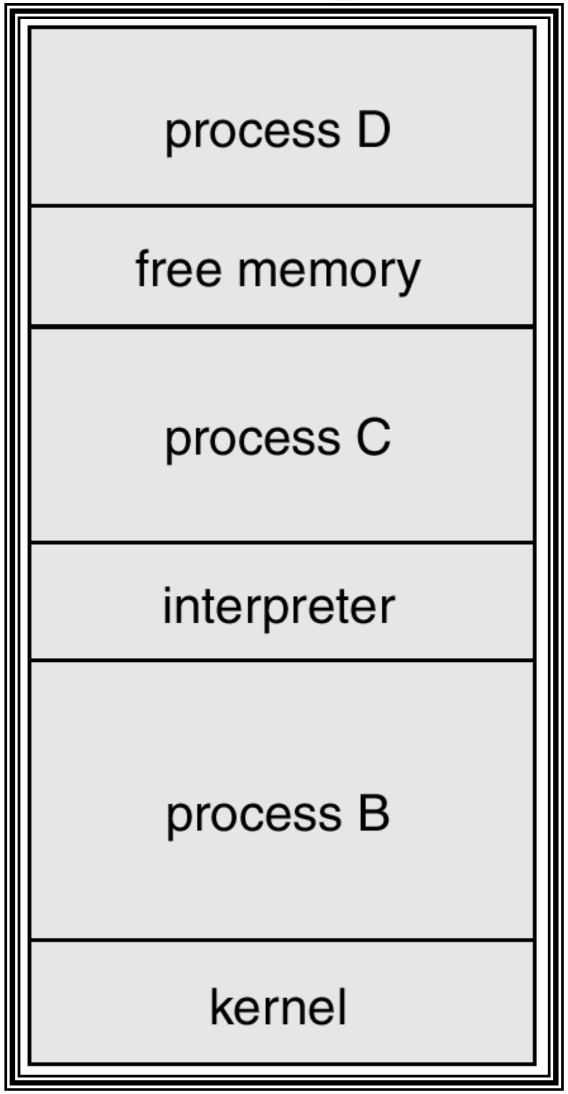
System Calls

- System calls provide the interface between a running program and the operating system.
- Three general methods are used to pass parameters between a running program and the operating system.
  - Pass parameters in *registers*.
  - Store the parameters in a table in memory, and the table address is passed as a parameter in a register (Linux).
  - *Push* (store) the parameters onto the *stack* by the program, and *pop* off the stack by operating system.

Passing of Parameters As A Table



UNIX Running Multiple Programs

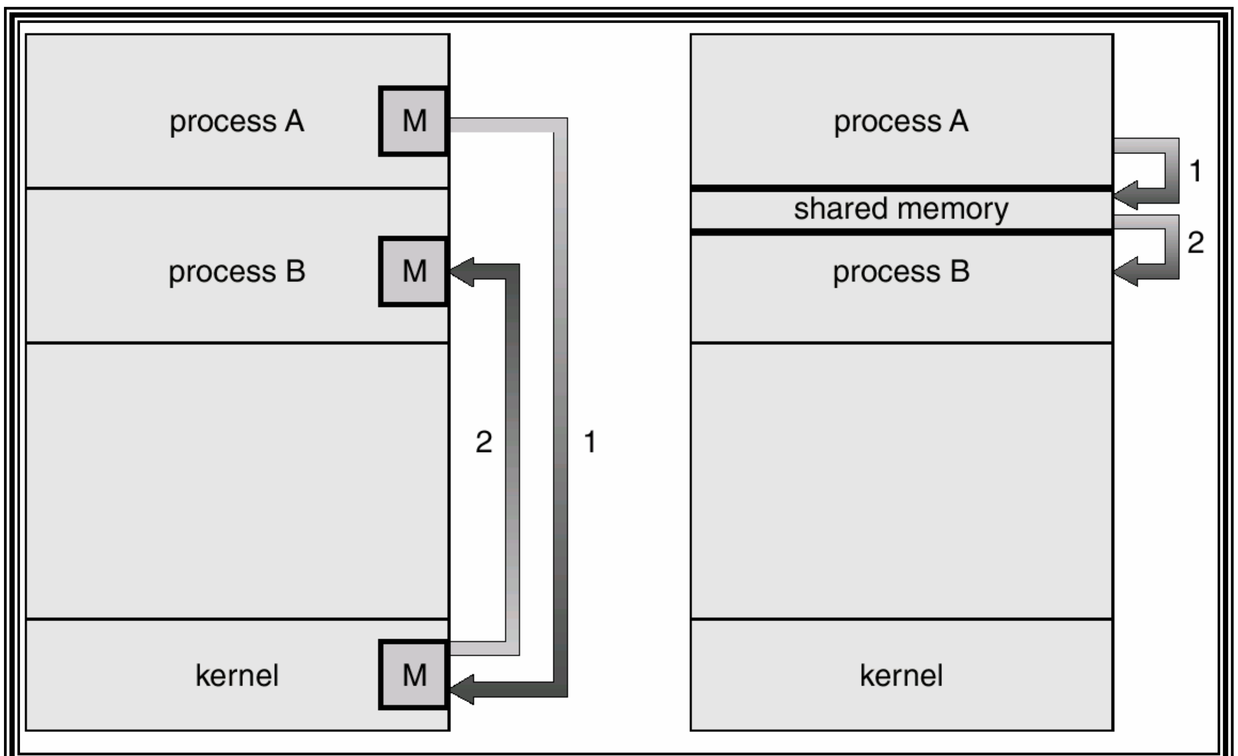


- *fork()*
- *exec()*
- *wait() / waitpid()*

- Foreground or Background execution.
- When a process is running in background, it cannot receive input directly from the keyboard.

Communication Models

- Communication may take place using either message passing (e.g. socket) or shared memory.



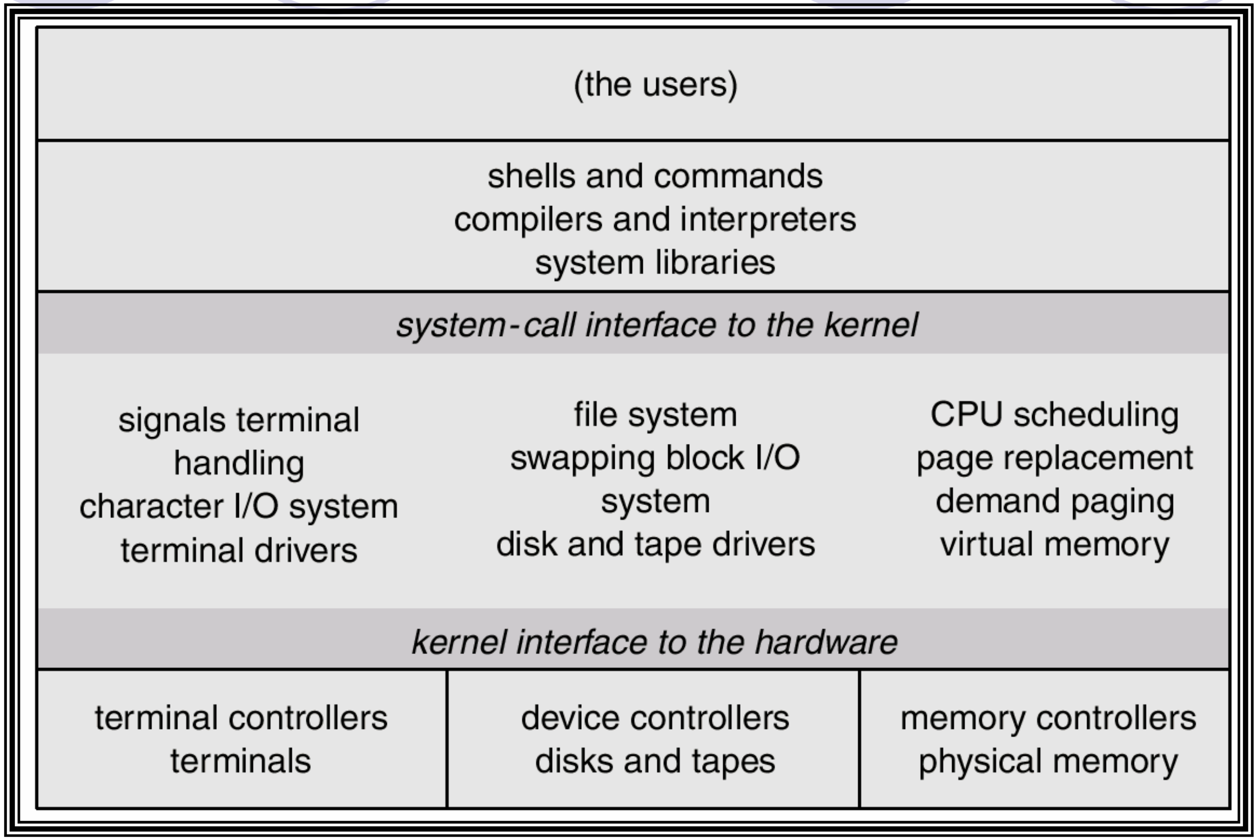
System Programs

- System programs provide a convenient environment for program development and execution. The can be divided into:
  - File manipulation
  - Status information
  - File modification
  - Programming language support
  - Program loading and execution
  - Communications
  - Application programs
- The view of O.S. seen by users is defined by the system programs, rather than by system calls.

UNIX System Structure

- The original UNIX operating system had limited structuring. The UNIX OS consists of two separable parts.
  - Systems programs
  - The kernel
    - everything below the system-call interface and above the physical hardware
    - Provides the file system, CPU scheduling, memory management, and other operating-system functions

UNIX System Structure



Mechanisms and Policies

- Mechanisms determine how to do something, policies decide what will be done.
- The separation of policy from mechanism allows maximum flexibility if policy decisions are to be changed later.
  - Timer is a mechanism for CPU protection, but deciding how long the timer is to be set for a particular user is a policy decision.

System Implementation

- Traditionally written in assembly language, operating systems can now be written in higher-level languages.
- Code written in a high-level language:
  - can be written faster.
  - is more compact.
  - is easier to understand and debug.
  - easier to *port* (move to some other hardware) if it is written in a high-level language.

System Generation (SYSGEN)

- Operating systems are designed to run on any of a class of machines; the system must be configured for each specific computer site.
- SYSGEN program obtains information concerning the specific configuration of the hardware system.
- *Bootstrap program* – code stored in ROM that is able to locate the kernel, load it into memory, and start its execution.