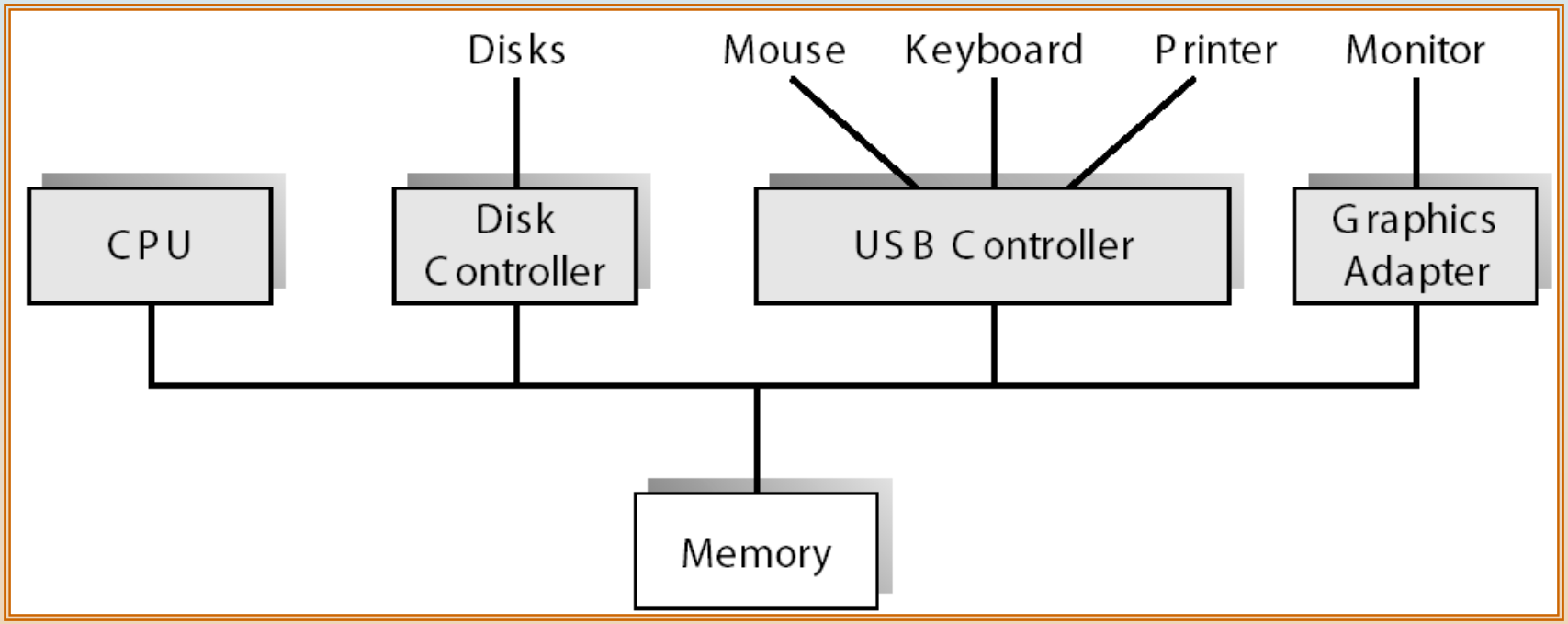
# Chapter 2: Computer-System Structures

- Computer System Operation
- I/O Structure
- Storage Structure
- Storage Hierarchy
- Hardware Protection
- Network Structure

# A Modern Computer System




# Computer-System Operation

- I/O devices and the CPU can execute concurrently
- Each device controller is in charge of a particular device type
- Each device controller has a local buffer
- CPU moves data from/to main memory to/from local buffers
- I/O is from the device to local buffer of controller
- Device controller informs CPU that it has finished its operation by causing an *interrupt*

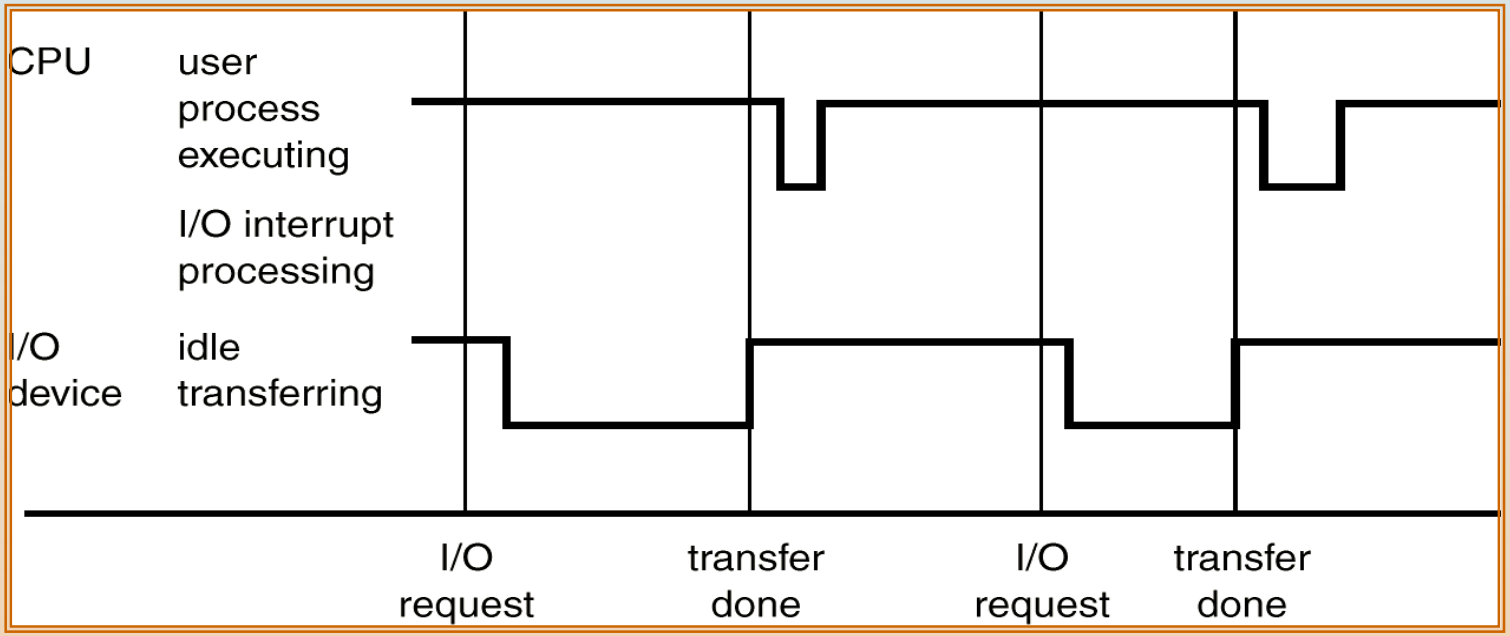
# Common Functions of Interrupts

- Interrupt transfers control to the interrupt service routine generally, through the *interrupt vector*, which contains the addresses of all the service routines
- Interrupt architecture must save the address of the interrupted instruction
- 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
- An operating system is *interrupt* driven

# Interrupt Handling

- The operating system preserves the state of the CPU by storing registers and the program counter
- Determines which type of interrupt has occurred:
  - *polling*
  - *vectored* interrupt system
- Separate kernel routines determine what action should be taken for each type of interrupt

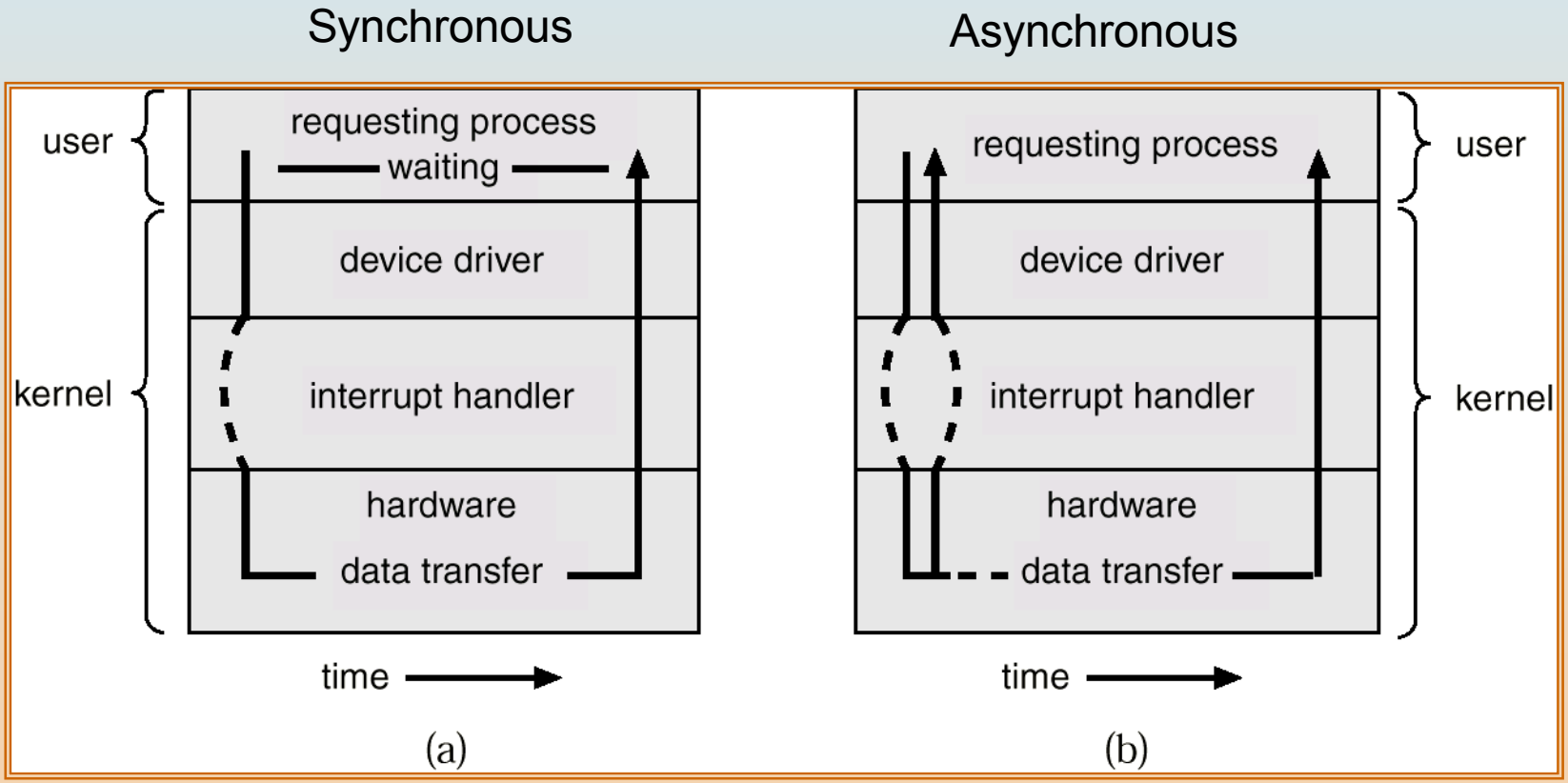
# Interrupt Time Line For a Single Process Doing Output



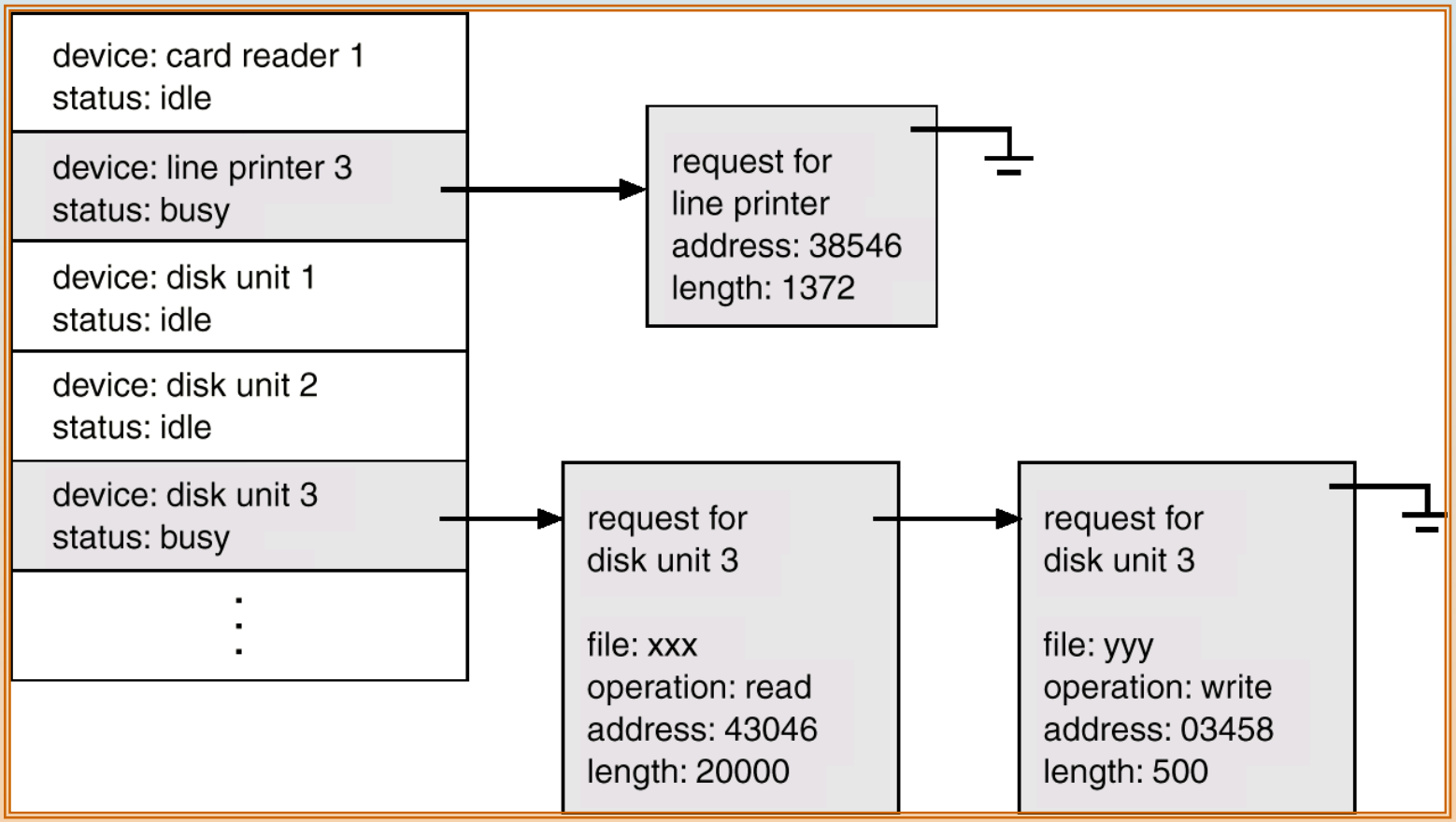

# I/O Structure

- *Synchronous I/O* - After I/O starts, control returns to user program only upon I/O completion
  - Wait instruction idles the CPU until the next interrupt
  - Wait loop (contention for memory access)
  - At most one I/O request is outstanding at a time, no simultaneous I/O processing
- *Asynchronous I/O* - After I/O starts, control returns to user program without waiting for I/O completion
  - *System call* – request to the operating system to allow user to wait for I/O completion
  - *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

# Two I/O Methods




# Device-Status Table



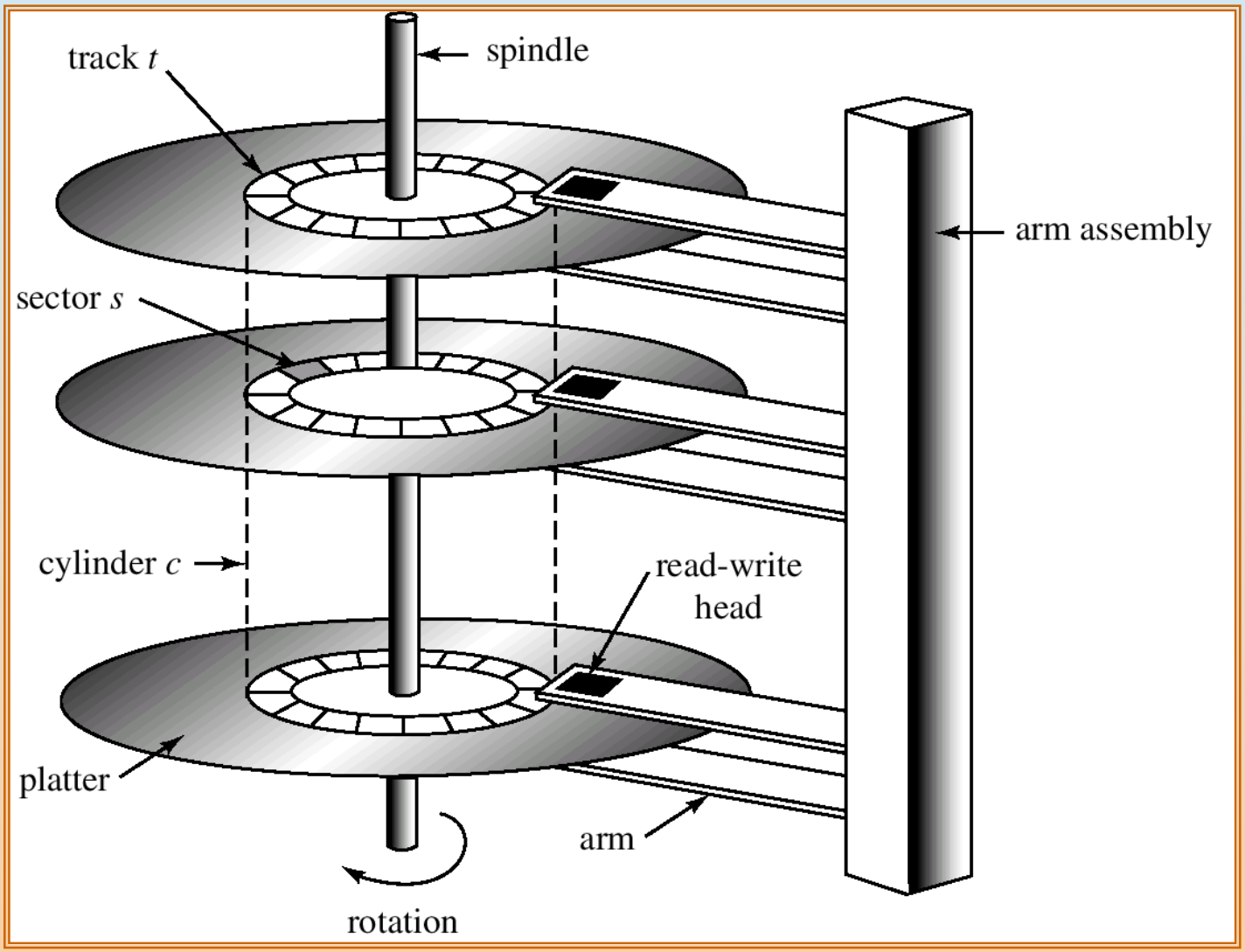

# Direct Memory Access Structure

- 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
- Only on interrupt is generated per block, rather than the one interrupt per byte

# Storage Structure

- *Main memory* – only large storage media that the CPU can access directly
- *Secondary storage* – extension of main memory that provides large nonvolatile storage capacity
- *Magnetic disks* – rigid metal or glass platters covered with magnetic recording material
  - 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

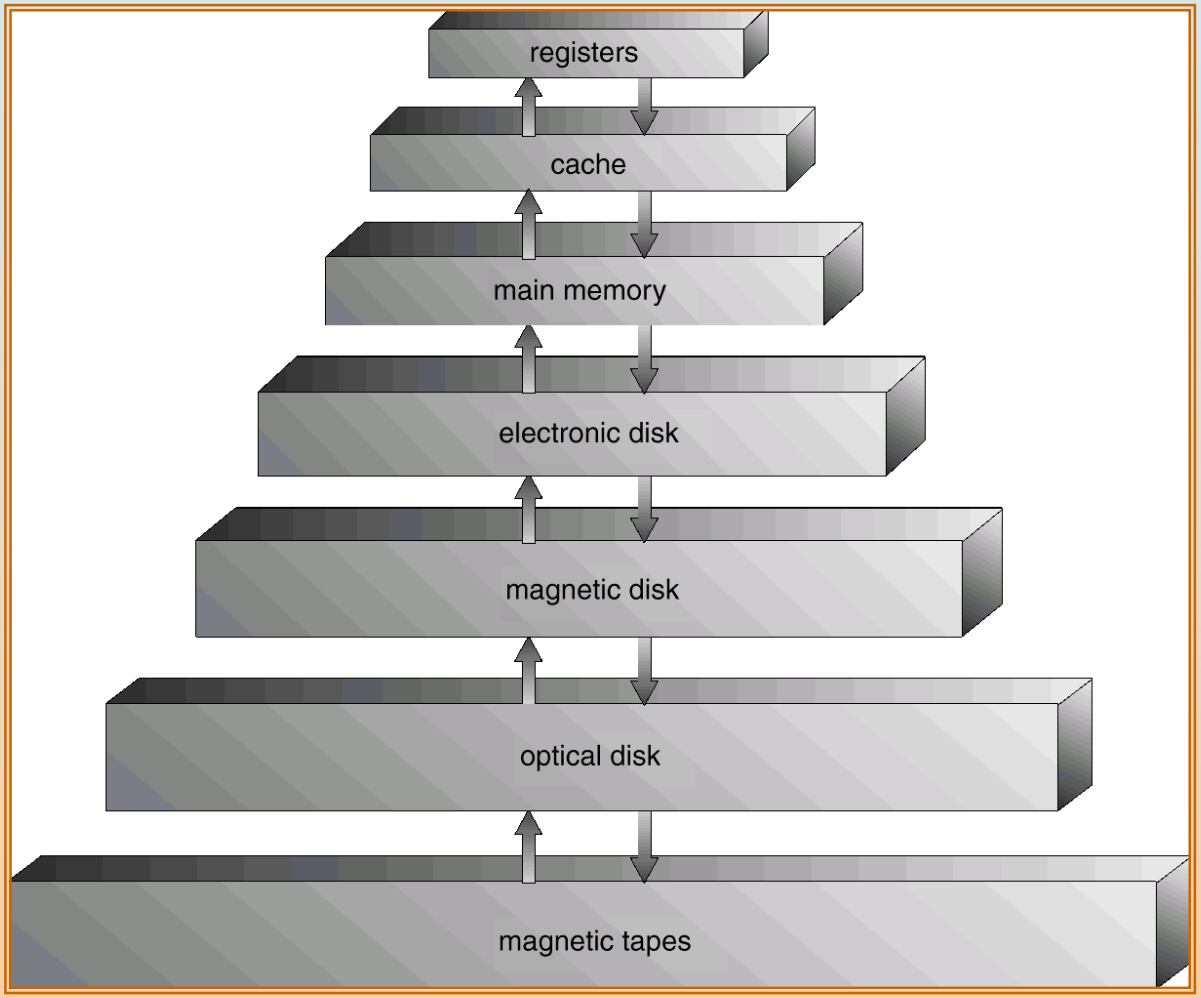
# Moving-Head Disk Mechanism



# Storage Hierarchy

- Storage systems organized in hierarchy
  - Speed
  - Cost
  - Volatility
- *Caching* – copying information into faster storage system; main memory can be viewed as a last *cache* for secondary storage

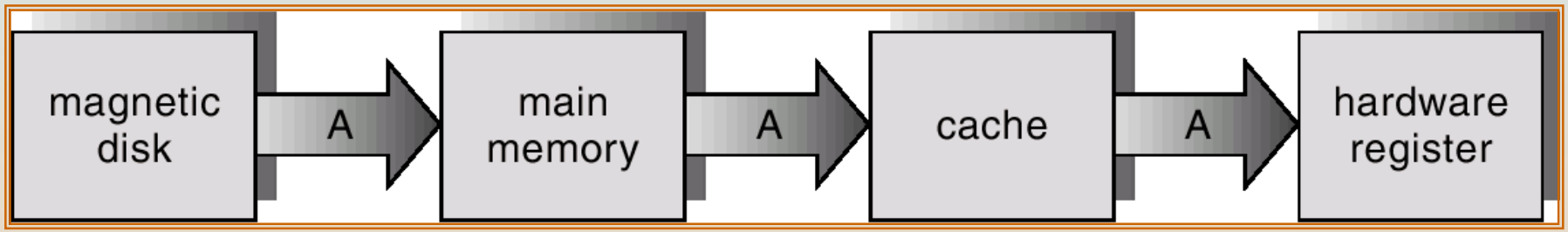
# Storage-Device Hierarchy




# Caching

- Use of high-speed memory to hold recently-accessed data
- Requires a *cache management* policy
- Caching introduces another level in storage hierarchy.
  - This requires data that is simultaneously stored in more than one level to be *consistent*

# Migration of Integer "A" From Disk to Register




# Hardware Protection

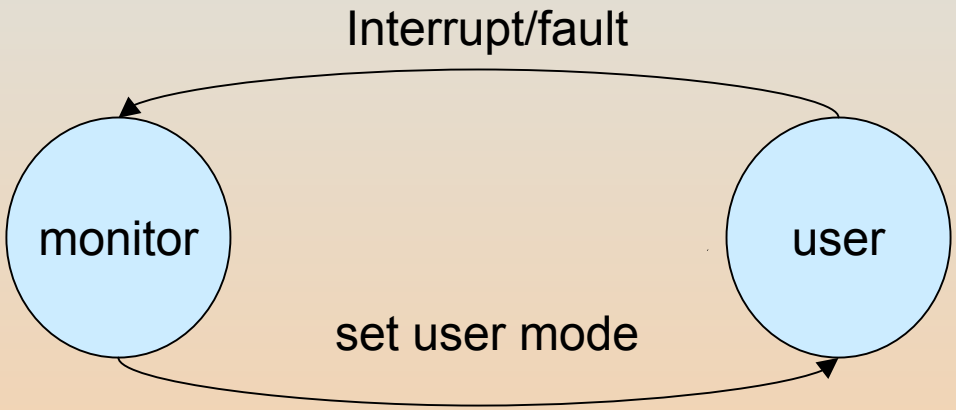
- Dual-Mode Operation
- I/O Protection
- Memory Protection
- CPU Protection

# Dual-Mode Operation

- Sharing system resources requires operating system to ensure that an incorrect program or poorly behaving human cannot cause other programs to execute incorrectly
- OS must provide hardware support to differentiate between at least 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

# Dual-Mode Operation (Cont.)

- *Mode bit* added to computer hardware to indicate the current mode: monitor (0) or user (1)
- When an interrupt or fault occurs hardware switches to monitor mode

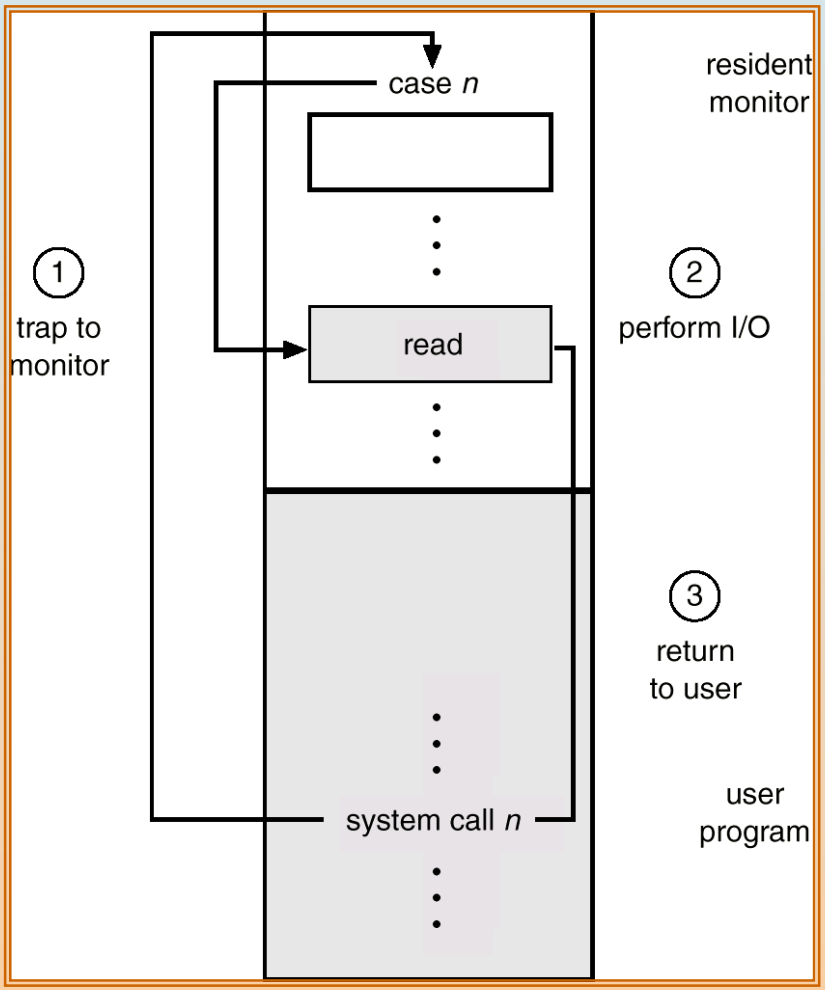



*Privileged instructions* can be issued only in monitor mode

# 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 (I.e., a user program that, as part of its execution, stores a new address in the interrupt vector)

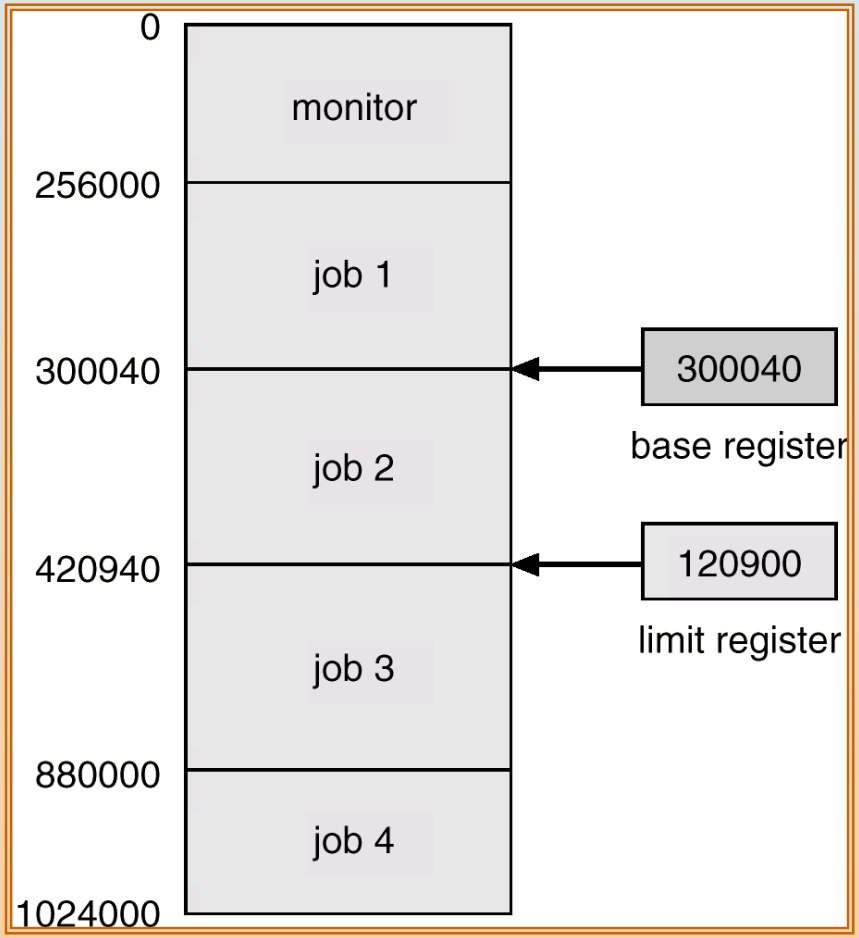
# Use of A System Call to Perform I/O



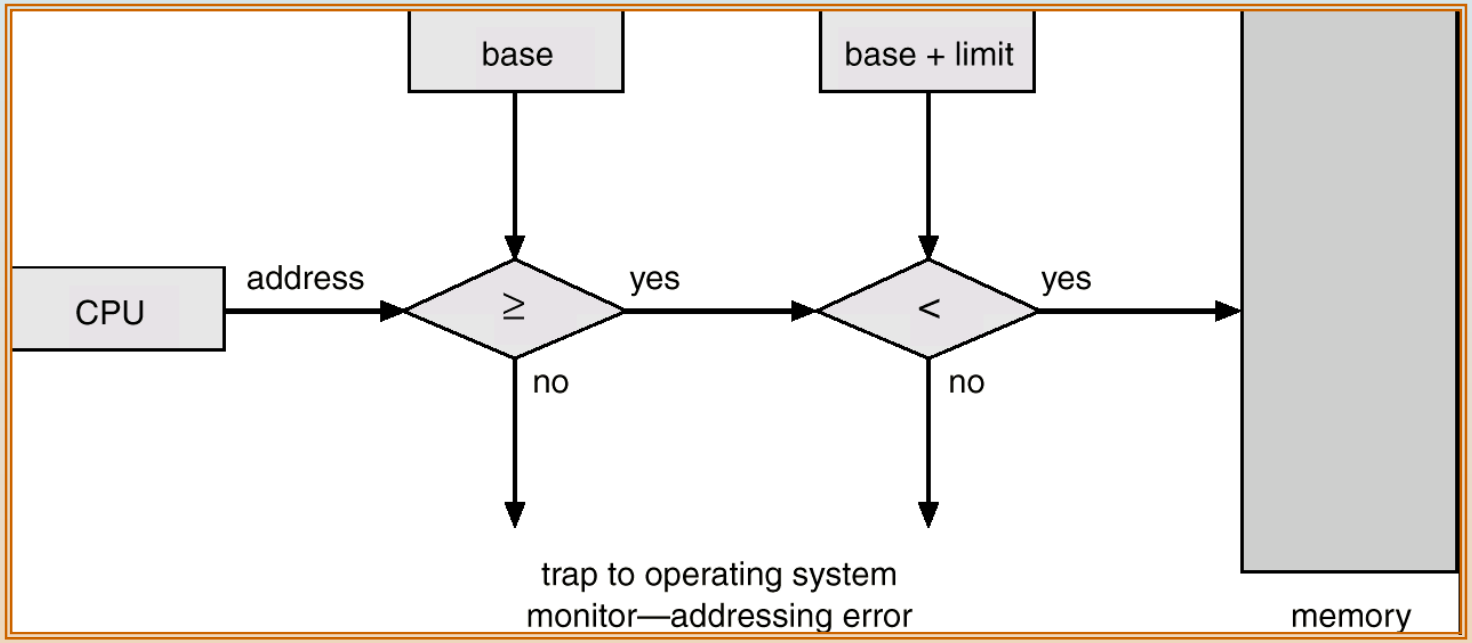

# Memory Protection

- Must provide memory protection at least for the interrupt vector and the interrupt service routines
- In order to have memory protection, at a minimum 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
- Memory outside the defined range is protected

# Use of A Base and Limit Register




# Hardware Address Protection




# Hardware Protection

- When executing in monitor mode, the operating system has unrestricted access to both monitor and user's memory
- 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
- Timer commonly used to implement time sharing
- Time also used to compute the current time
- Load-timer is a privileged instruction

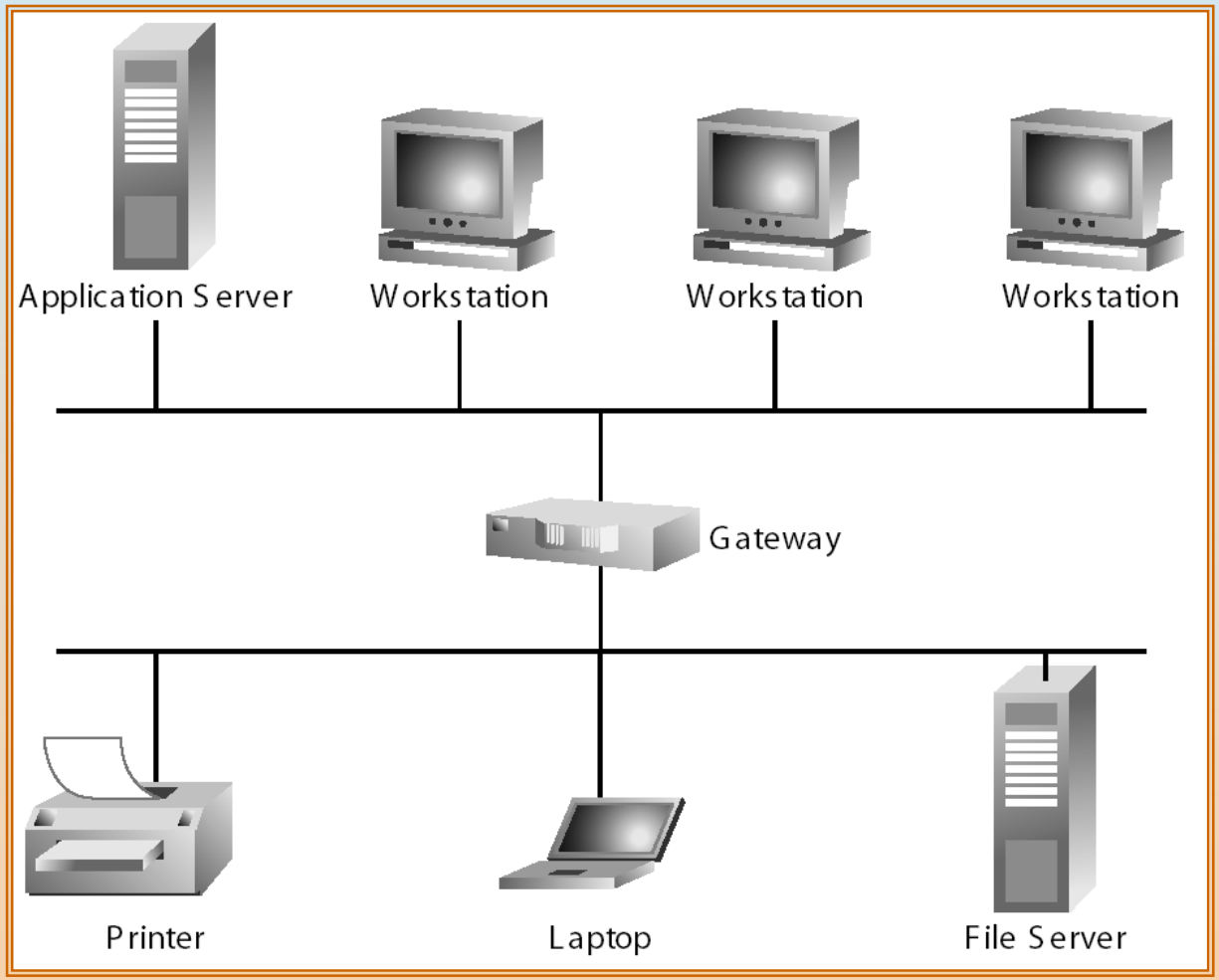
# General-System Architecture

- Given the I/O instructions are privileged, how does the user program perform I/O?
- System call – the method used by a process to request action by the operating system
  - Usually takes the form of a trap to a specific location in the interrupt vector
  - Control passes through the interrupt vector to a service routine in the OS, and the mode bit is set to monitor mode
  - The monitor verifies that the parameters are correct and legal, executes the request, and returns control to the instruction following the system call

# Network Structure

- Local Area Networks (LAN)
- Wide Area Networks (WAN)

# Local Area Network Structure




# Wide Area Network Structure