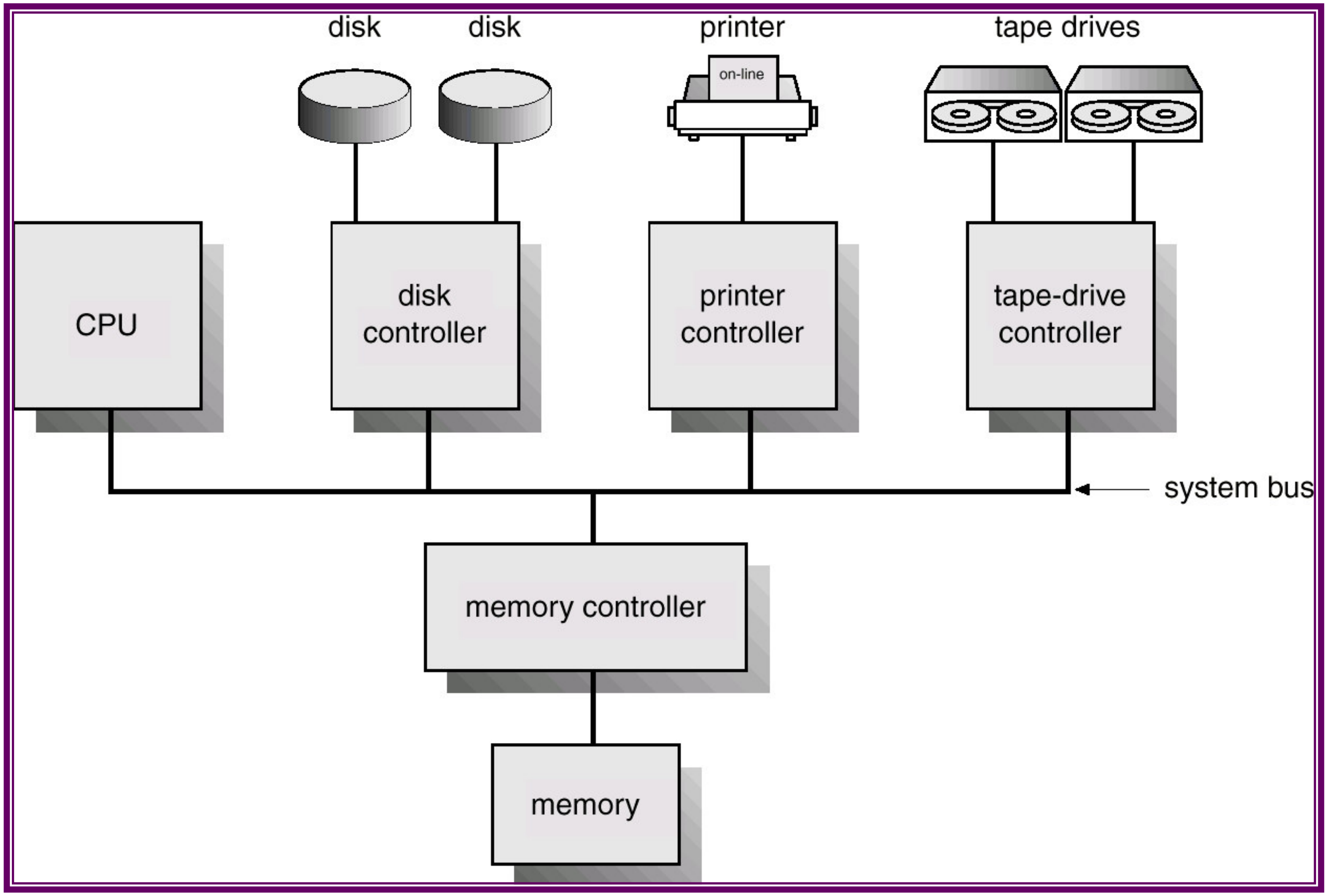
Chapter 2: Computer-System Structures

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

Computer-System Architecture



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*.

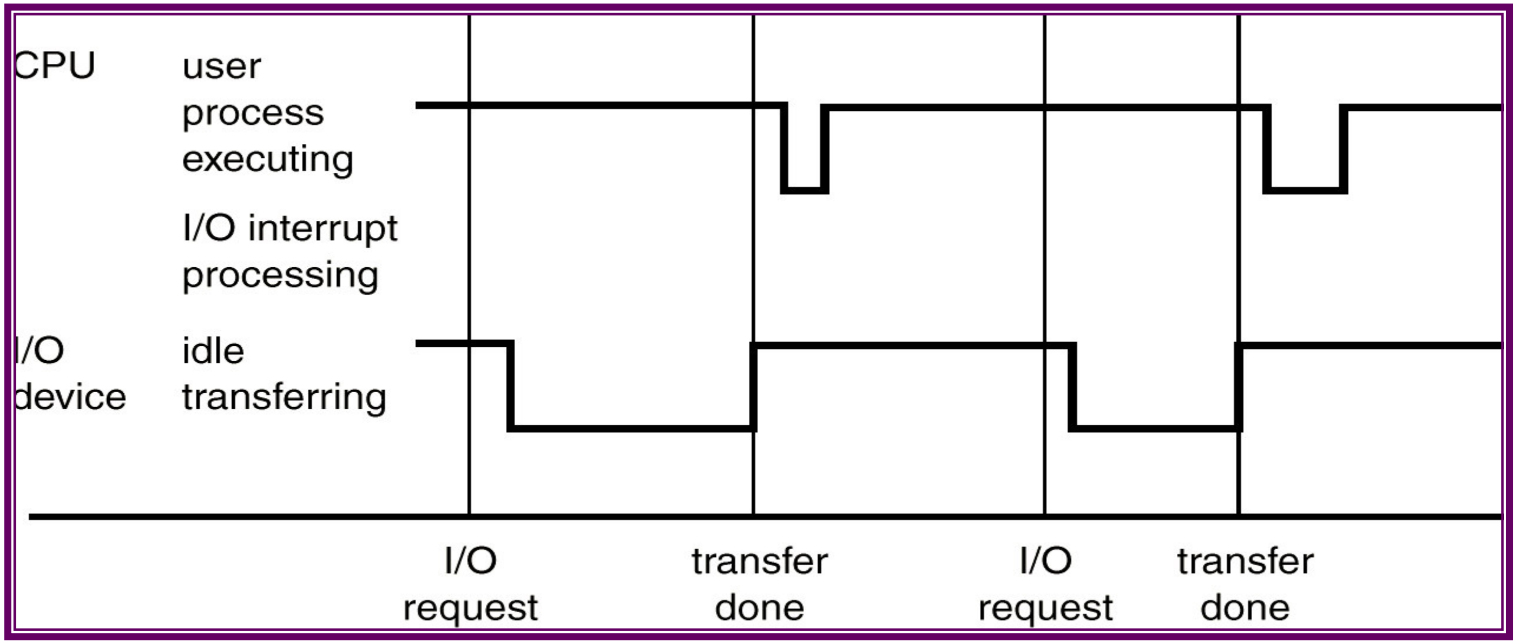
Common Functions of Interrupts

- An operating system is *interrupt* driven, i.e. its code is invoked only when interrupt occurs.
- Interrupt transfers control to the interrupt service routine (part of OS), 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 OS corruption; must be quick to prevent a *lost interrupt*.
- A *trap* is a software-generated interrupt caused either by an error or a user request.

Interrupt Handling

- The operating system preserves the state of the CPU by storing registers and the program counter in addition to address of the interrupted instruction.
- The OS determines which type of interrupt has occurred:
  - *polling*
  - *vectored* interrupt system
  - mixed
- Different service routine for each type of interrupt

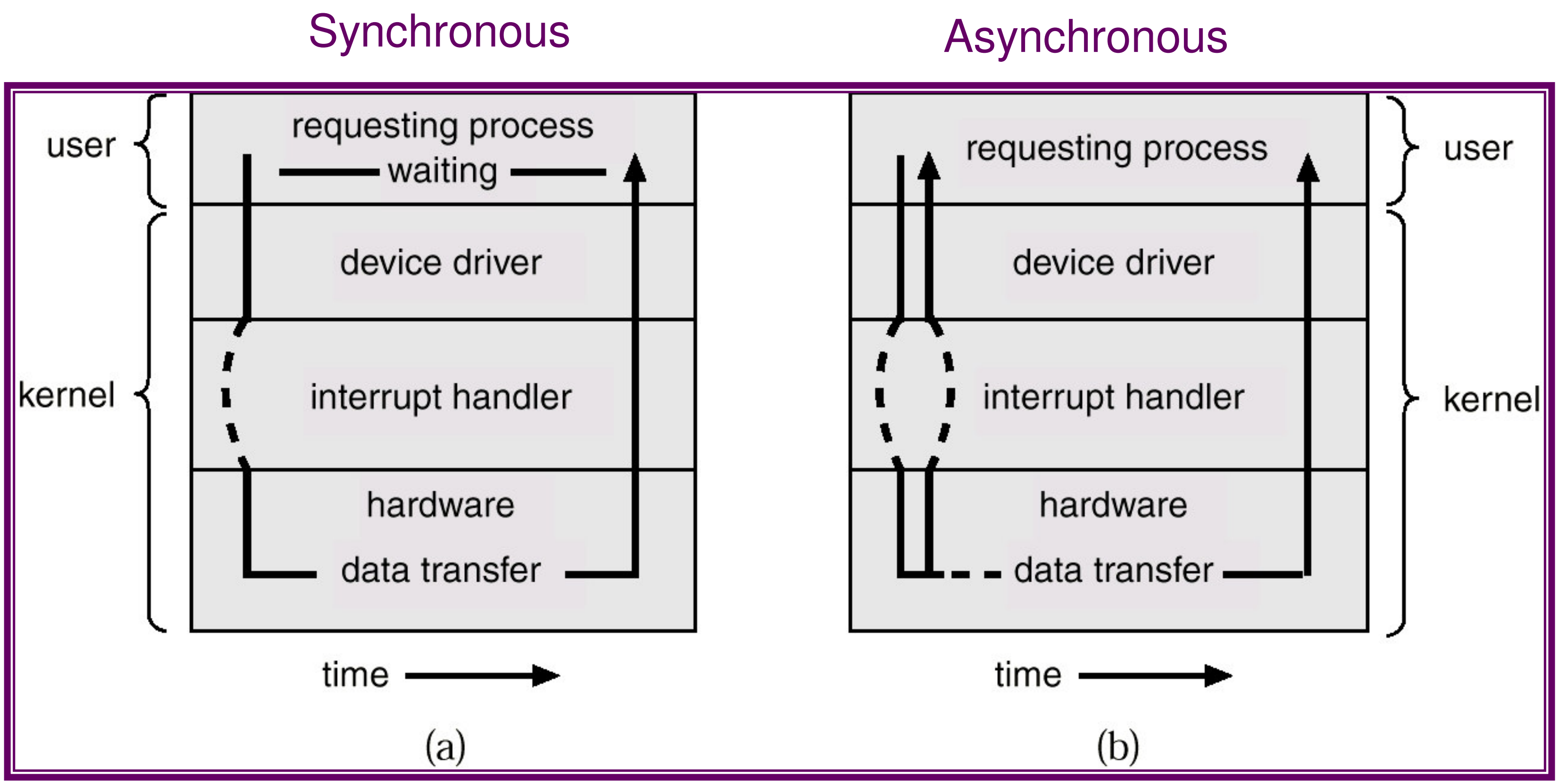
Interrupt Time Line For a Single Process Doing Output



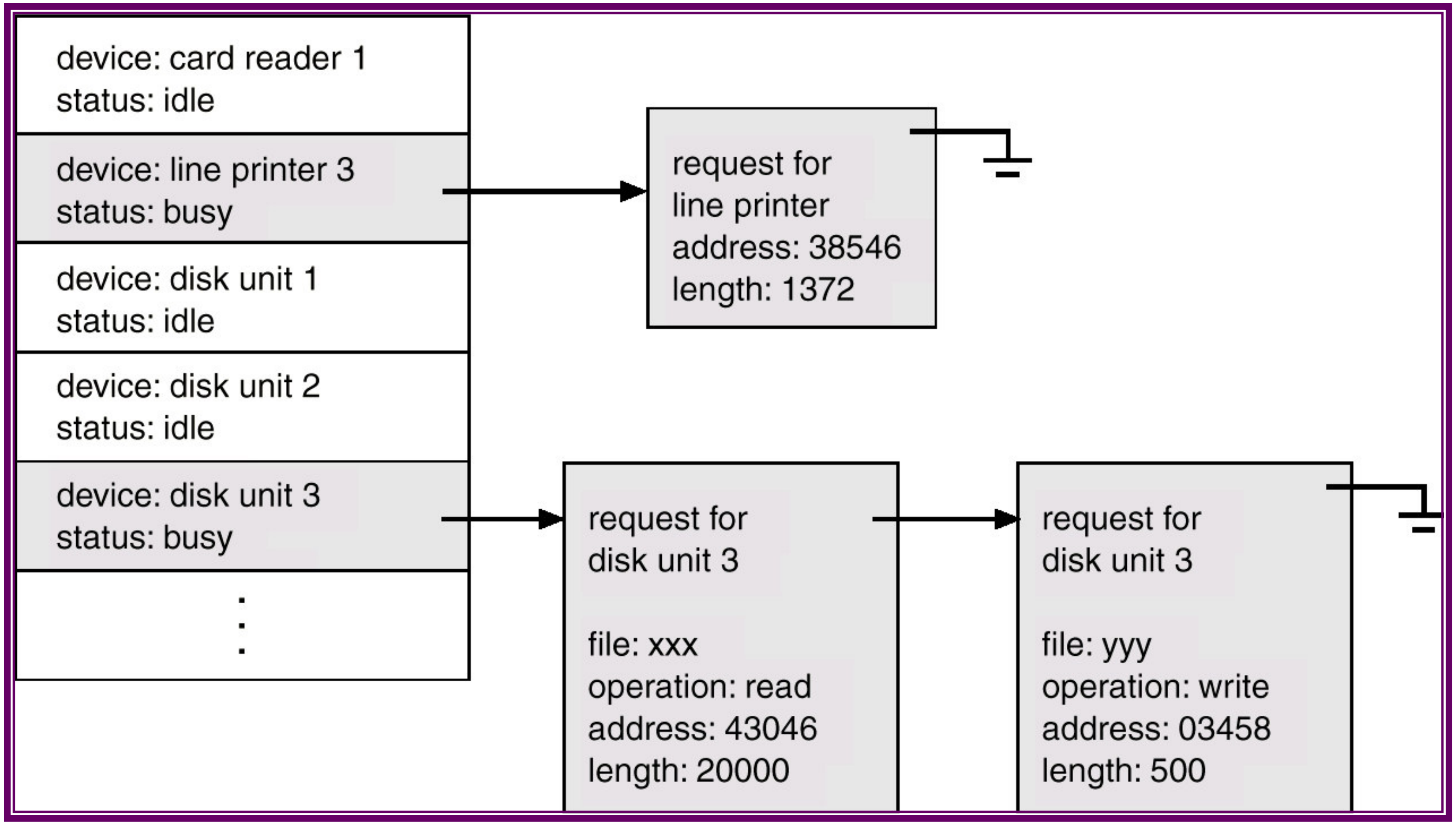
I/O Structure

- 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.
  - 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 (or other job if need block) without waiting for I/O completion.
  - *System call* – used if user program wants to wait for I/O completion: system call is “call” into OS code.
  - *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 (e.g. mark idle or start working on next request).

Two I/O Methods



Device-Status Table



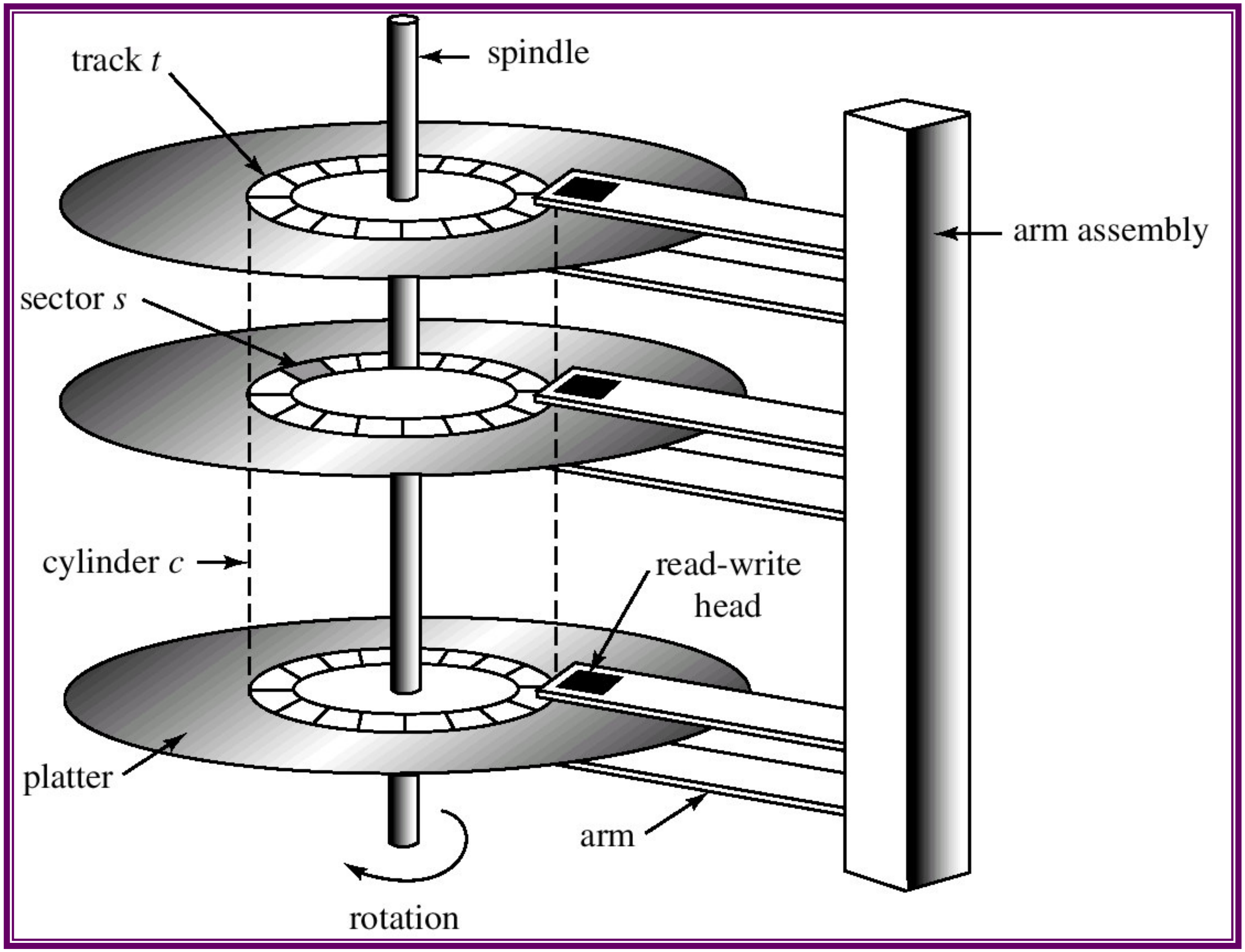
Direct Memory Access Structure

- Used for high-speed I/O devices able to transmit information at close to memory speeds (possibly because transfer is from a local buffer, or device is removable memory chip).
- Device controller transfers blocks of data from buffer storage directly to main memory without CPU intervention.
- Only one interrupt is generated per block, rather than the one interrupt per byte as for keyboards/mice.

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.

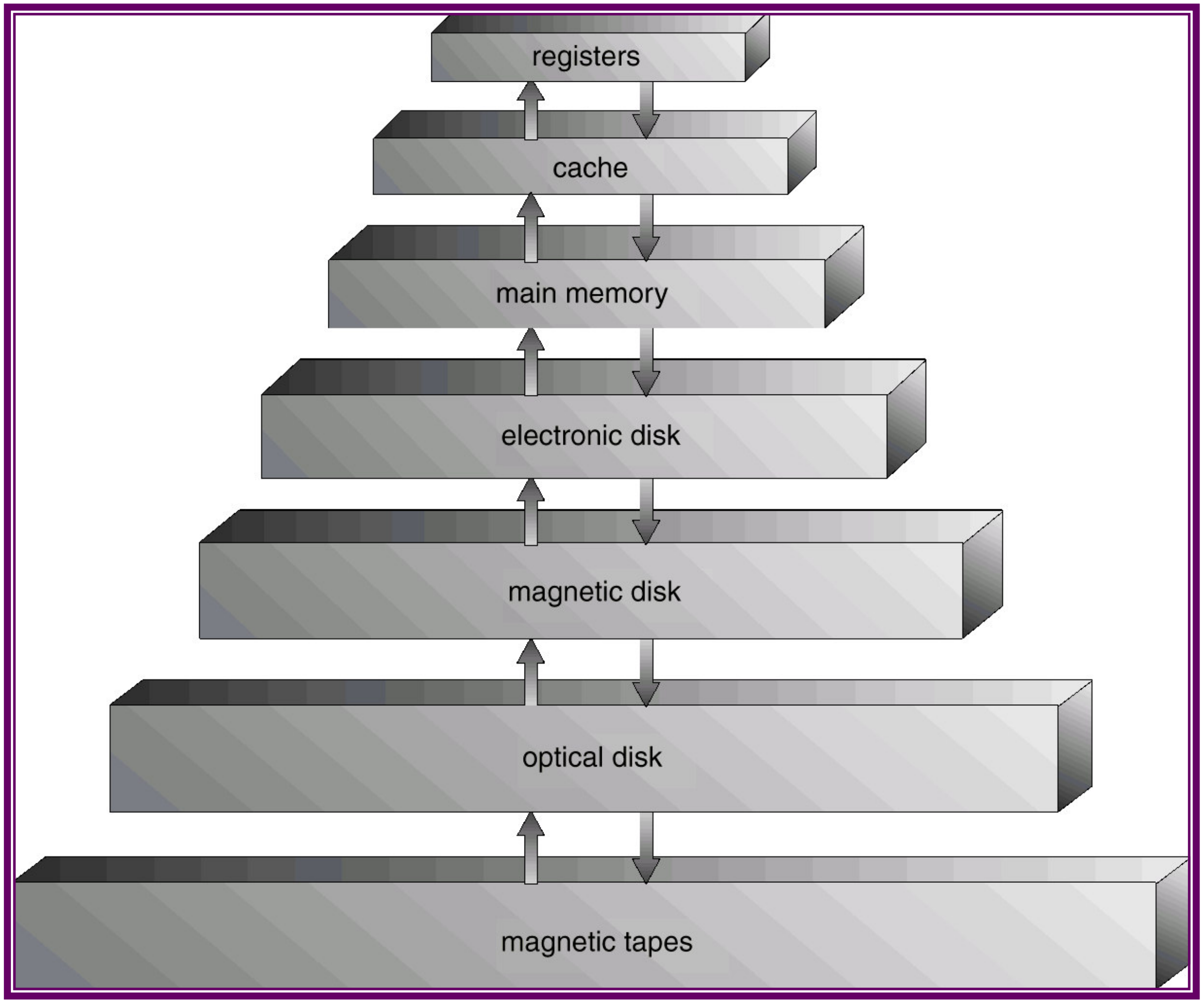
Moving-Head Disk Mechanism



Storage Hierarchy

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

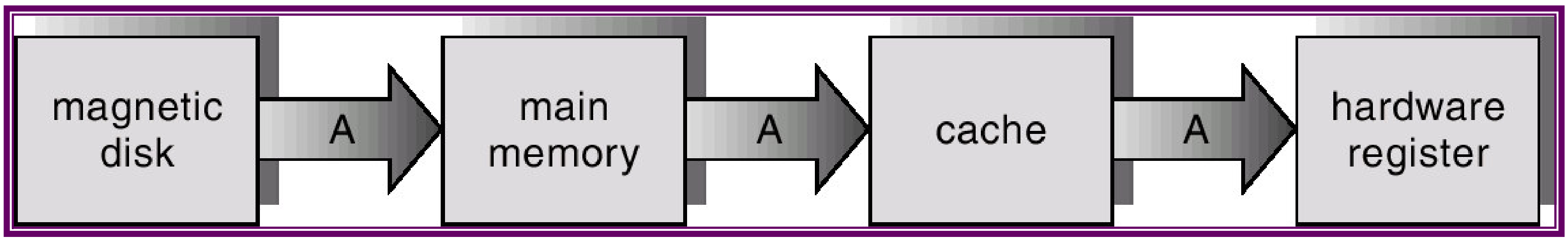
Storage-Device Hierarchy



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 A From Disk to Register



Hardware Protection

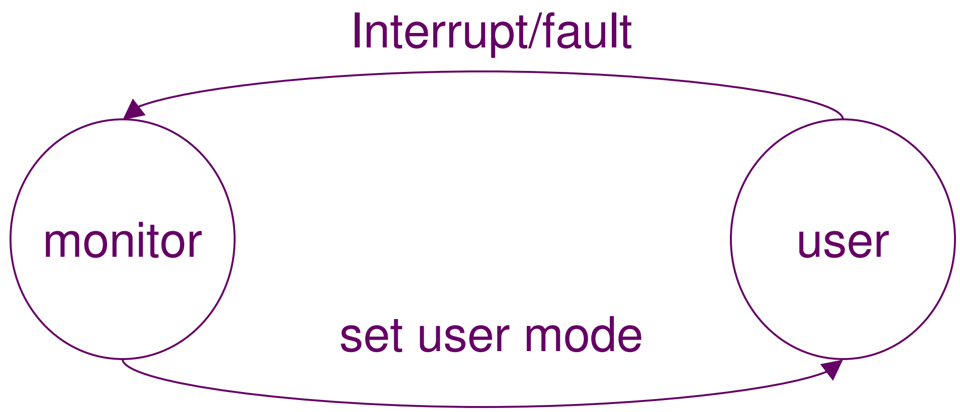
- Dual-Mode Operation
- I/O Protection
- Memory Protection
- CPU Protection

Dual-Mode Operation

- Sharing system resources requires operating system to ensure that an incorrect program cannot cause other programs to execute incorrectly.
- 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.

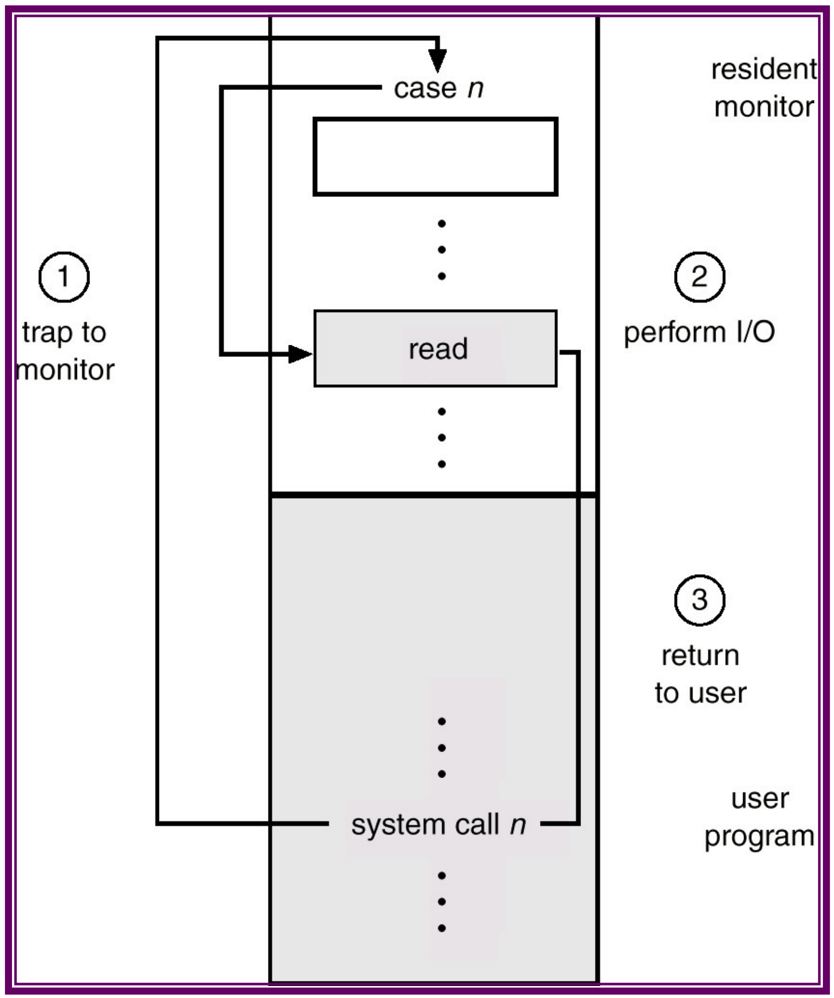


Privileged instructions can be issued only in monitor mode.

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).

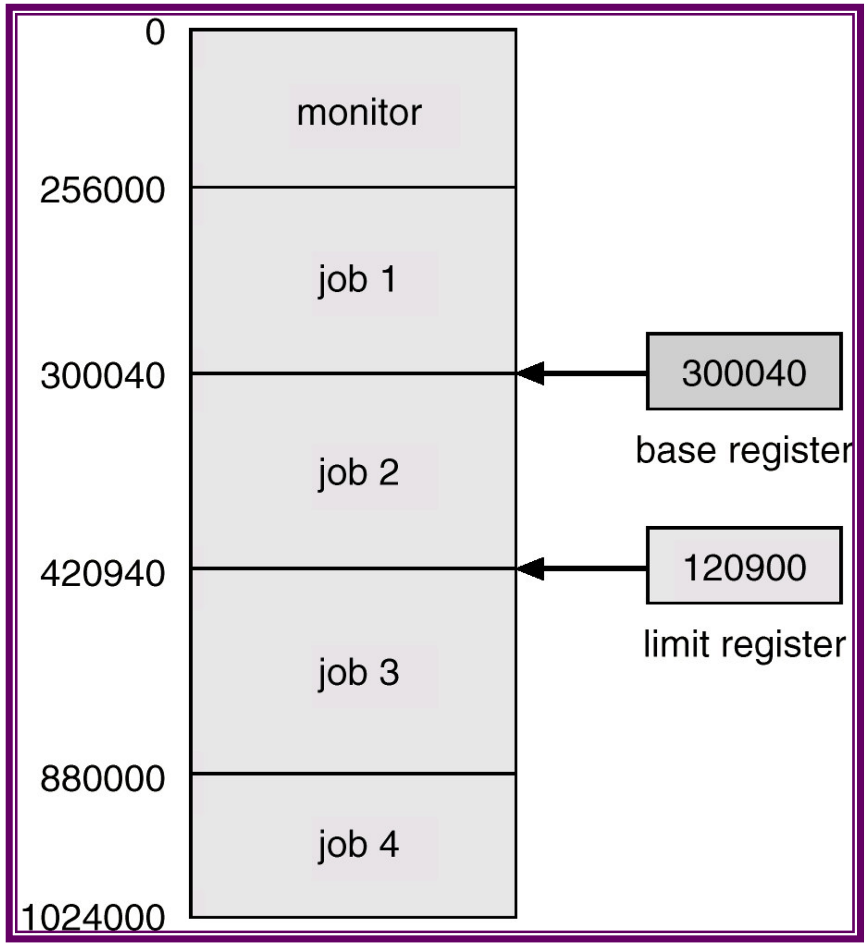
Use of A System Call to Perform I/O



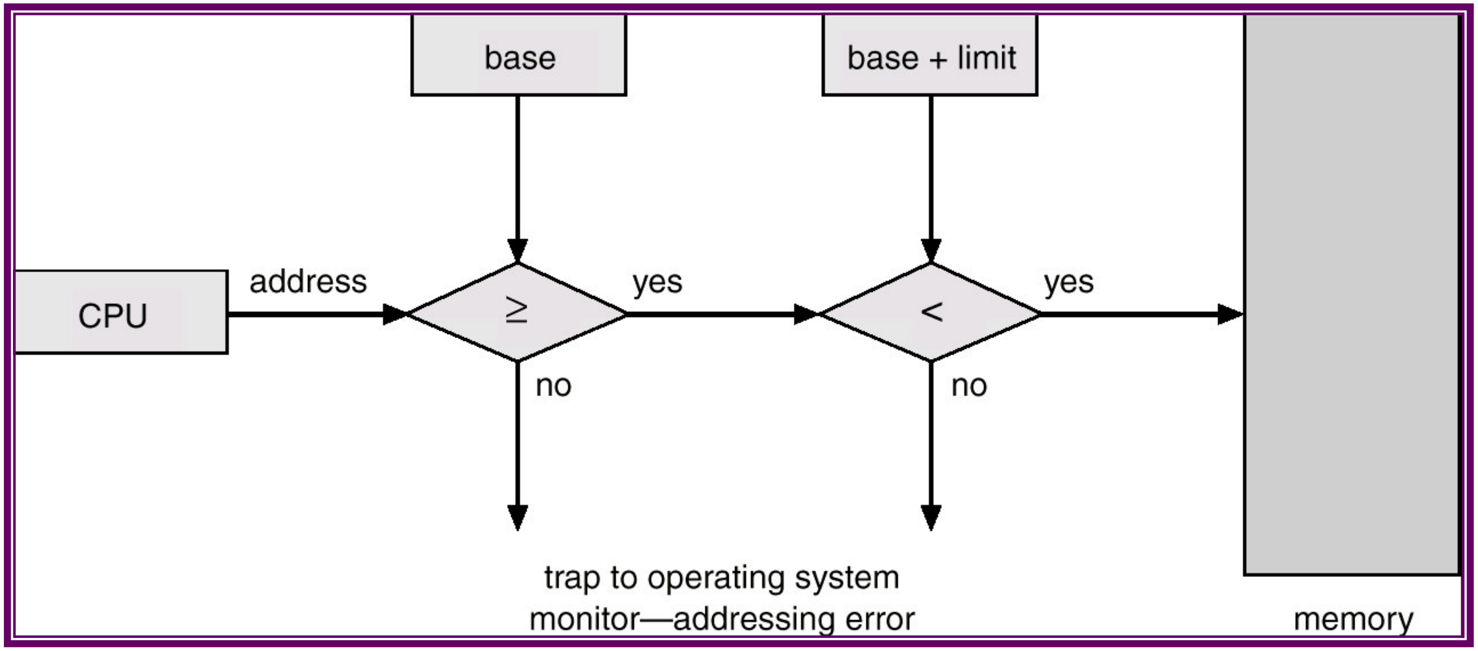
Memory Protection

- Must provide memory protection at least for the interrupt vector and the interrupt service routines.
- In order to have memory protection, 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.

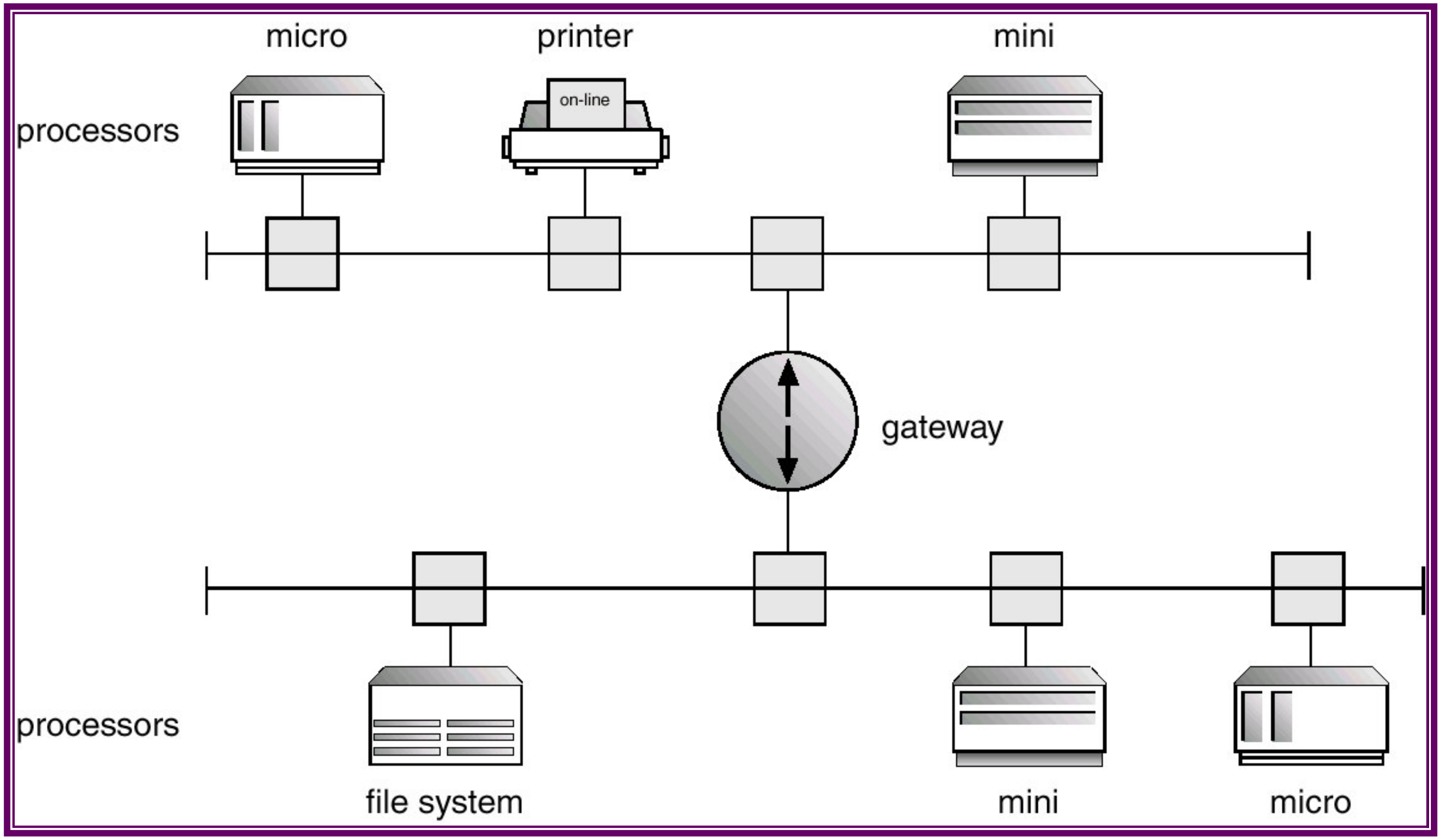
CPU Protection

- *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.

Network Structure

- Local Area Networks (LAN):
  - Wired (e.g. gigabit ethernet, 600Mbits/sec) or
  - Wireless (RF, up to 50Mbits/sec)
- Wide Area Networks (WAN):
  - Wired or
  - Wireless (satellite)
- LAN vs. WAN:
  - Faster
  - Single speed vs. low-speed-modem to fiber-optics
  - More expensive
  - Simpler components (cards, maybe gateway vs. Communication Processors, routers, etc.)

Local Area Network Structure



Wide Area Network Structure