Chapter 11 - Lecture

Stallings - 9ed

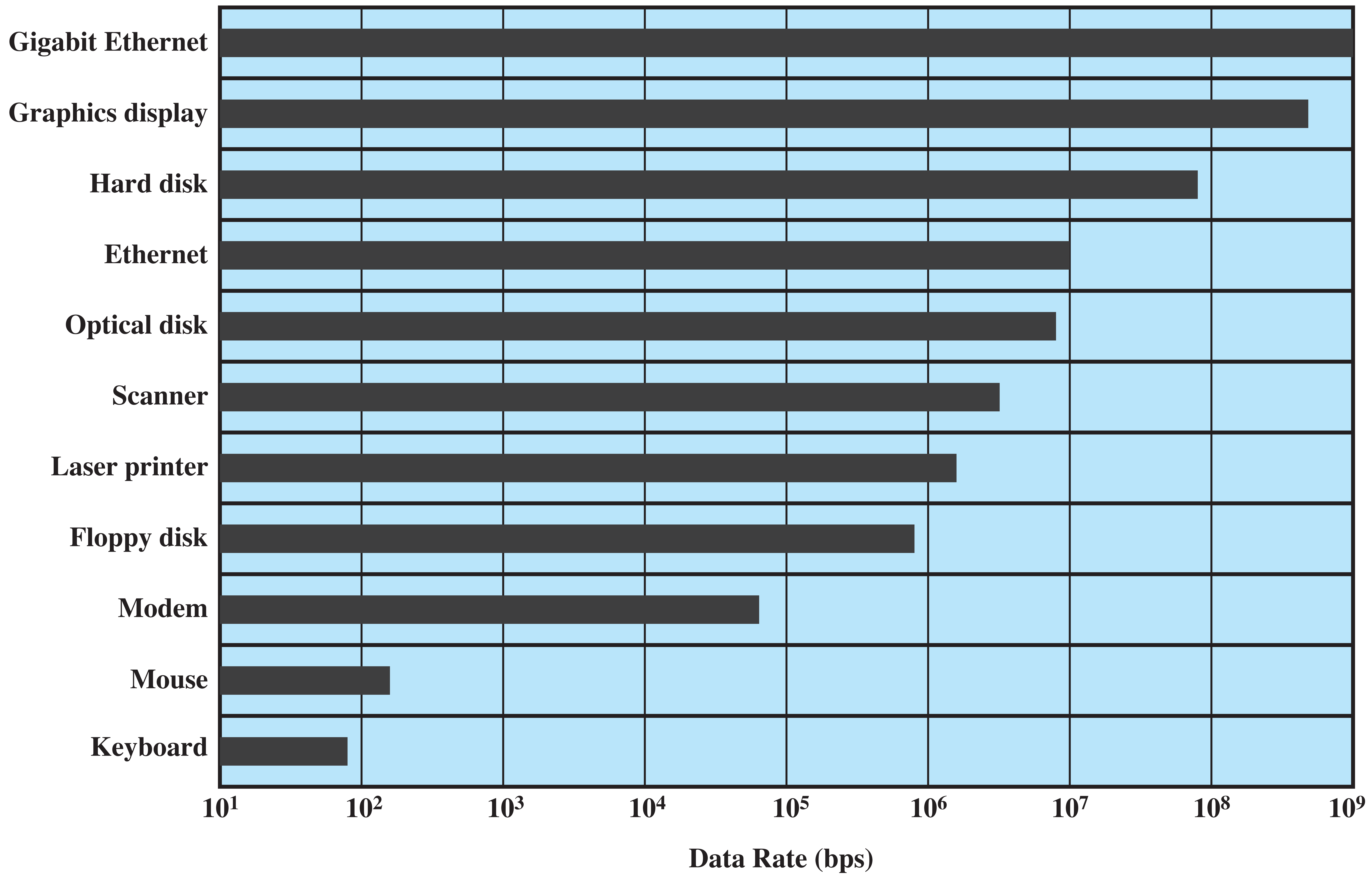


Figure 11.1 Typical I/O Device Data Rates

Differences in I/O Devices

- Data rate
  - May be differences of several orders of magnitude between the data transfer rates
- Complexity of control
- Unit of transfer
  - Data may be transferred as a stream of bytes for a terminal or in larger blocks for a disk
- Data representation
  - Encoding schemes
- Error conditions
  - Devices respond to errors differently

Performing I/O

- Programmed I/O
  - Process is busy-waiting for the operation to complete
- Interrupt-driven I/O
  - I/O command is issued
  - Processor continues executing instructions
  - I/O module sends an interrupt when done

Performing I/O

- Direct Memory Access (DMA)
  - DMA module controls exchange of data between main memory and the I/O device
  - Processor interrupted only after entire block has been transferred

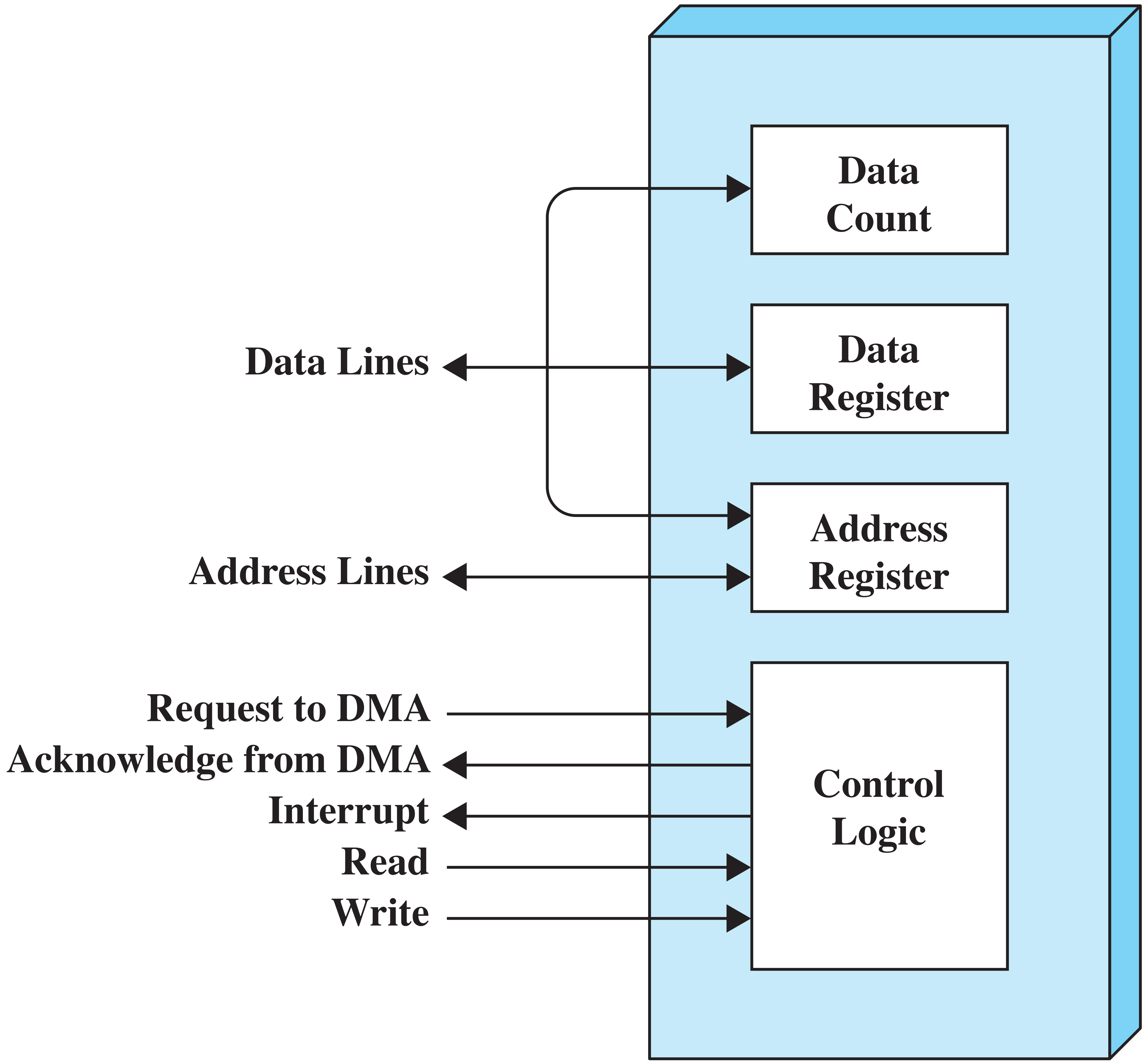


Figure 11.2 Typical DMA Block Diagram

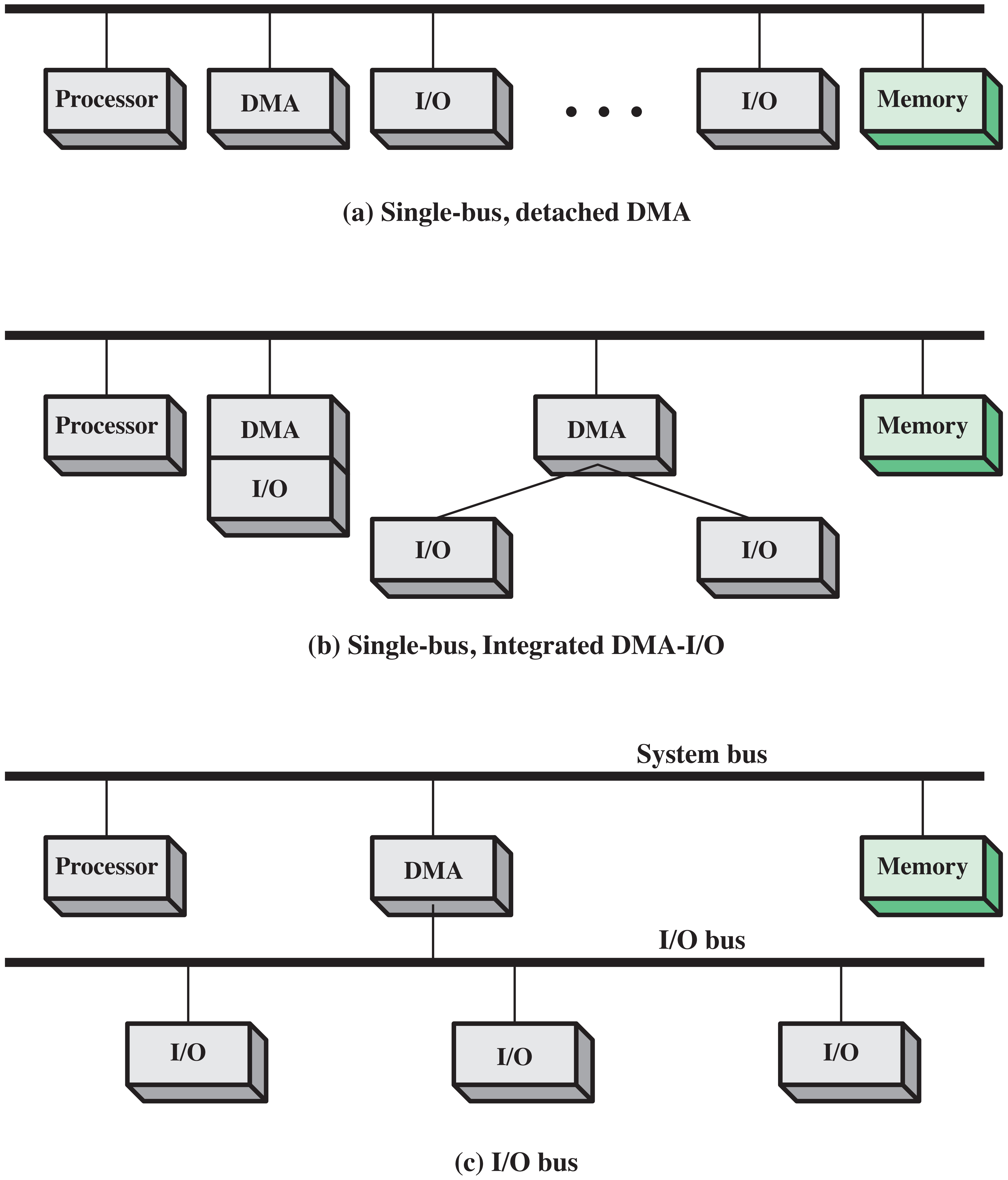


Figure 11.3 Alternative DMA Configurations

Relationship Among Techniques

Table 11.1 I/O Techniques

	No Interrupts	**Use of Interrupts**
I/O-to-memory transfer through processor	Programmed I/O	Interrupt-driven I/O
Direct I/O-to-memory transfer		Direct memory access (DMA)

Operating System Design Issues

- Efficiency
  - Most I/O devices extremely slow compared to main memory
  - Use of multiprogramming allows for some processes to be waiting on I/O while another process executes
  - I/O cannot keep up with processor speed
  - Swapping is used to bring in additional *Ready Processes,* which is an I/O operation

Operating System Design Issues

- Generality
  - Desirable to handle all I/O devices in a uniform manner
  - Hide most of the details of device I/O in lower-level routines so that processes and upper levels see devices in general terms such as read, write, open, close, lock, unlock

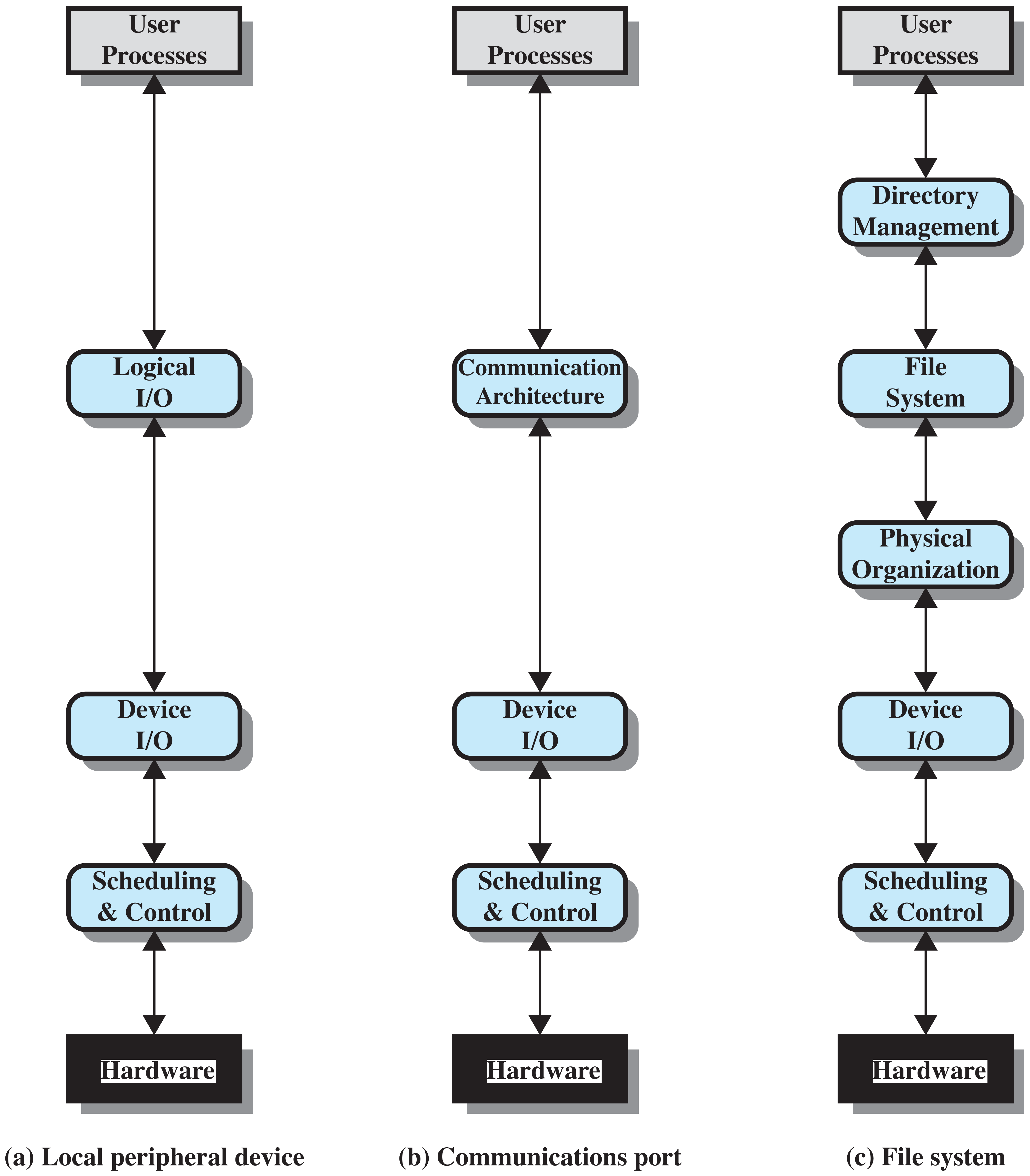


Figure 11.4   A Model of I/O Organization

I/O Buffering

- Reasons for buffering
  - Processes must wait for I/O to complete before proceeding
  - Certain pages must remain in main memory during I/O

I/O Buffering

- Block-oriented
  - Information is stored in fixed sized blocks
  - Transfers are made a block at a time
  - Used for disks and tapes
- Stream (character)-oriented
  - Transfer information as a stream of bytes
  - Used for terminals, printers, communication ports, mouse and other pointing devices, and most other devices that are not secondary storage

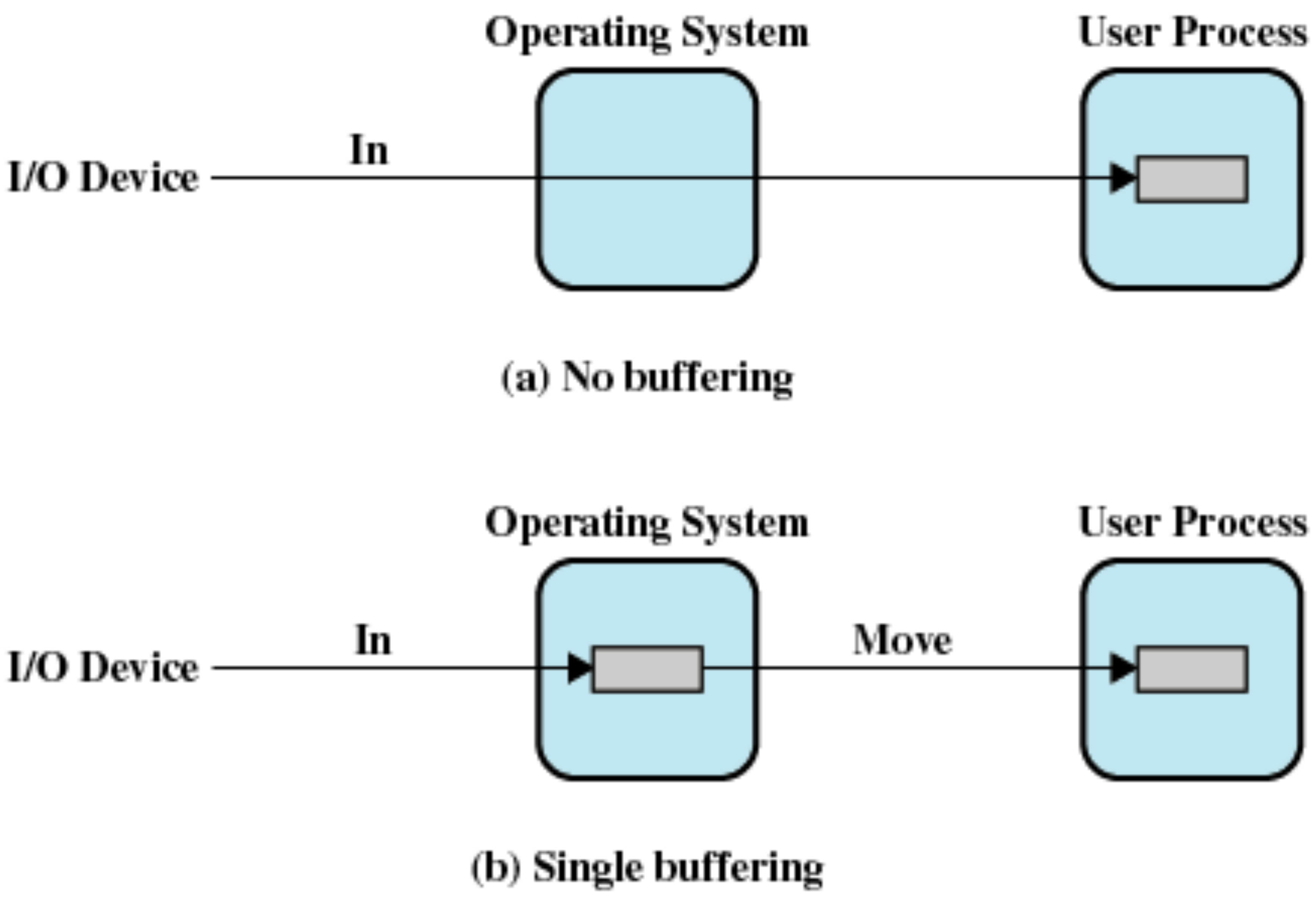
Single Buffer

- Operating system assigns a buffer in main memory for an I/O request
- Block-oriented
  - Input transfers made to buffer
  - Block moved to user space when needed
  - Another block is moved into the buffer
    - "Read ahead"
  - Swapping can occur since input is taking place in system memory, not user memory
  - Operating system keeps track of assignment of system buffers to user processes

Single Buffer

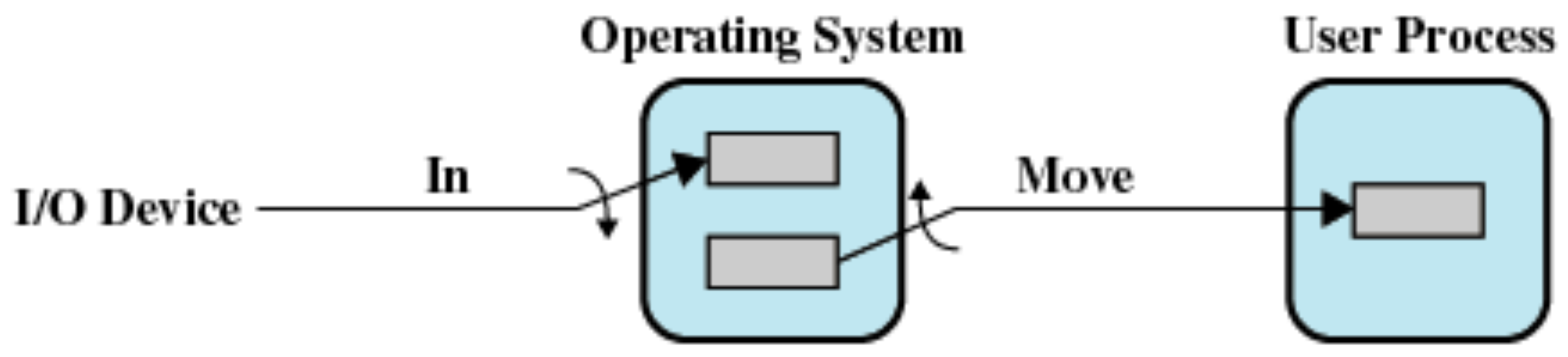
- Stream-oriented
  - e.g. terminal
    - Used a line at time
    - User input from a terminal is one line at a time with carriage return signaling the end of the line
    - Output to the terminal is one line at a time
  - e.g. network I/O
    - NIC (**n**etwork **i**nterface **c**ard)
    - protocol stack

I/O Buffering



Double Buffer

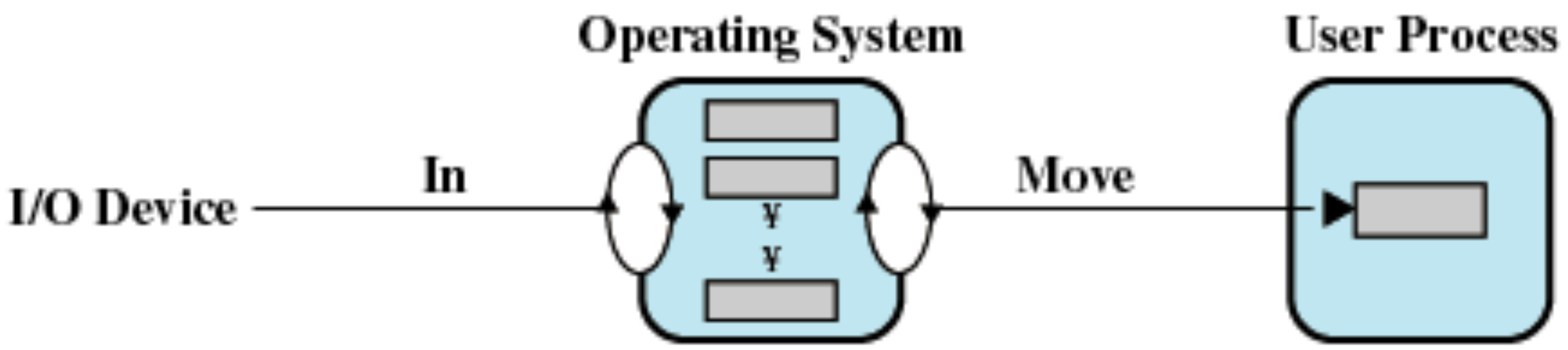
- Use two system buffers instead of one
- A process can transfer data to or from one buffer while the operating system empties or fills the other buffer



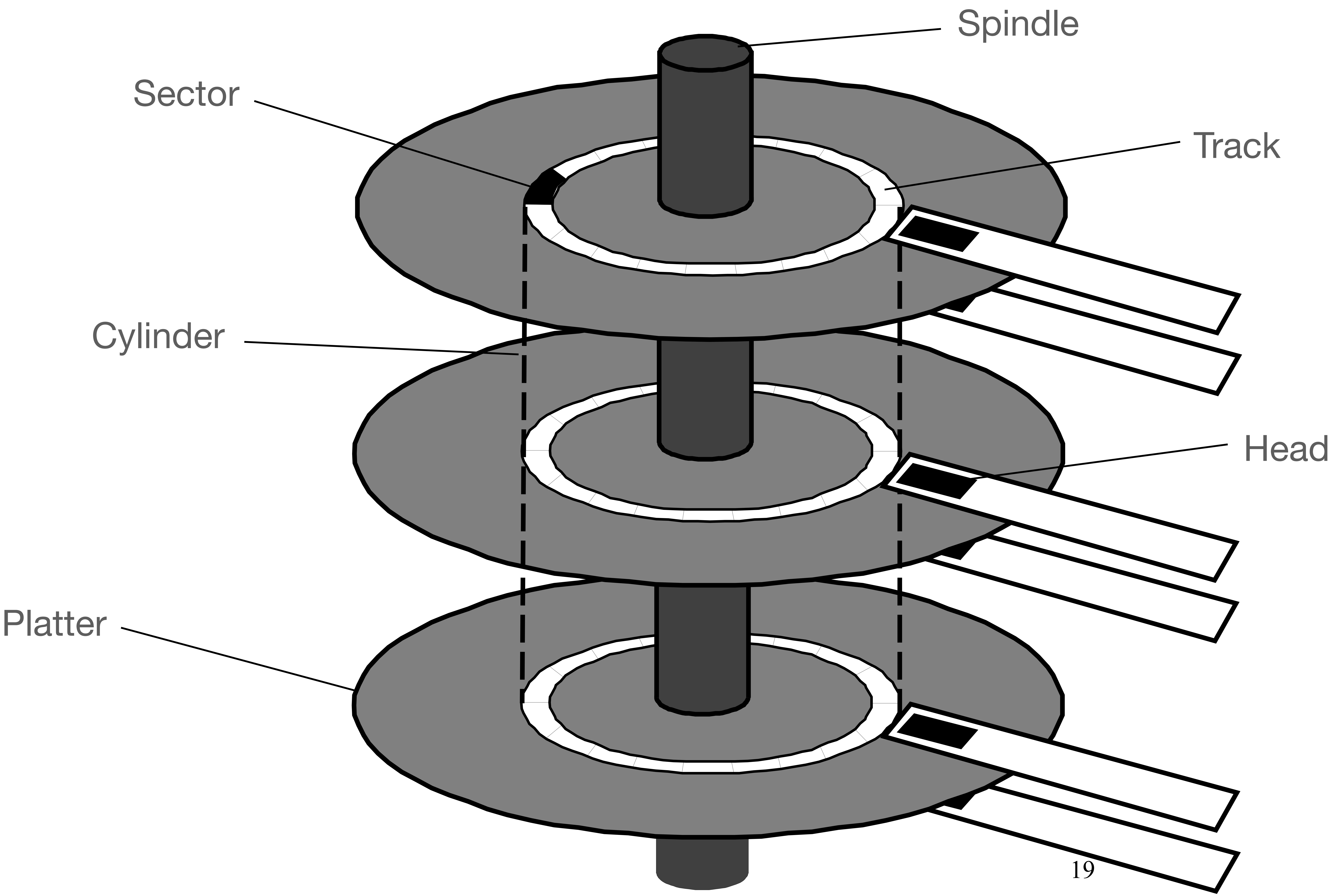
(c) Double buffering

Circular Buffer

- More than two buffers are used
- Each individual buffer is one unit in a circular buffer
- Used when I/O operation must keep up with process



(d) Circular buffering


Spindle
Sector
Track
Cylinder
Head
Platter

Disk Performance Parameters

- To read or write, the disk head must be positioned at the desired track and at the beginning of the desired sector
- Seek time
  - Time it takes to position the head at the desired track
- Rotational delay or rotational latency
  - Time it takes for the beginning of the sector to reach the head

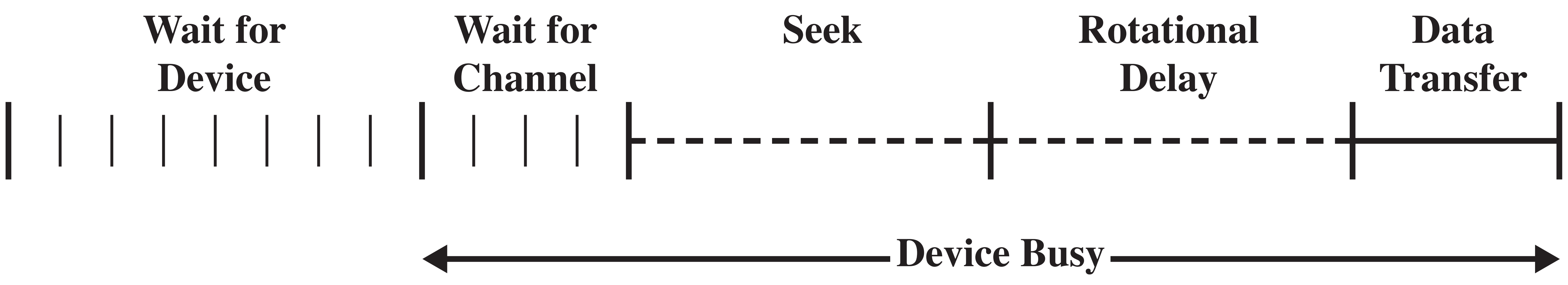


Figure 11.6 Timing of a Disk I/O Transfer

Seek Time - 2-30ms

Rotational Latency -

5400 rpm (90 rps) - 0-11ms (5.6ms avg)
10000 rpm (167 rps) - 0-6ms (3ms avg)
15000 rpm (250 rps) - 0-4ms (2ms avg)

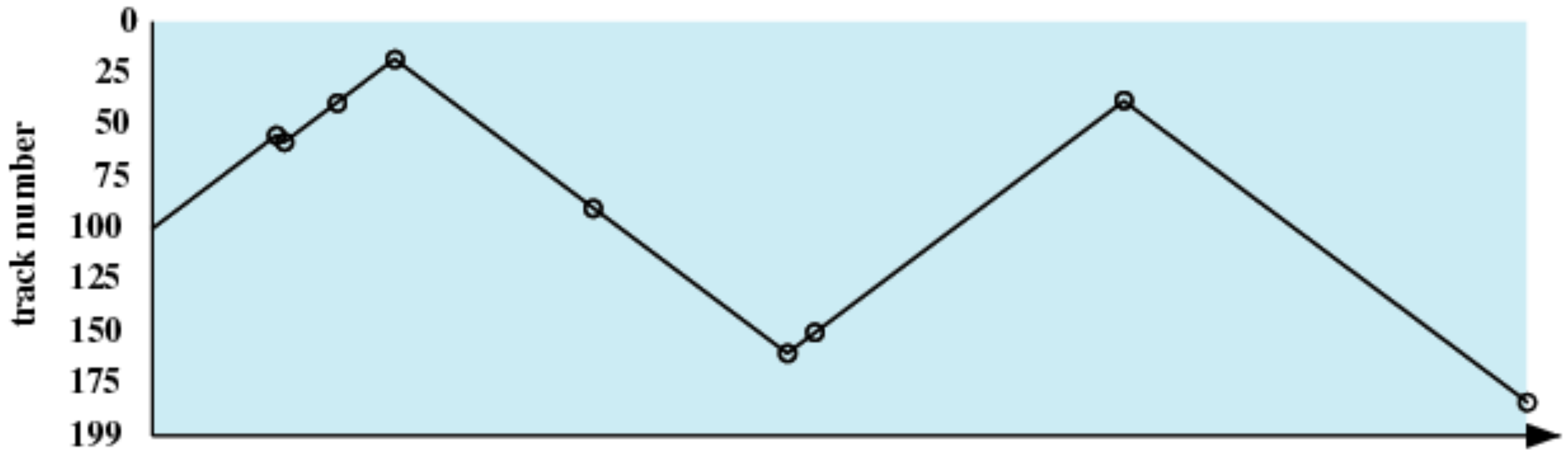
- Access time
  - Sum of seek time and rotational delay
  - The time it takes to get in position to read or write
- Data transfer occurs as the sector moves under the head
  - Transfer rate depends on rotational speed, bit density
  - Transfer rate is 1-100mB/s

Disk Scheduling Policies

- Seek time is the reason for differences in performance
- For a single disk there will be a number of I/O requests
- If requests are selected randomly, we will get poor performance

Disk Scheduling Policies

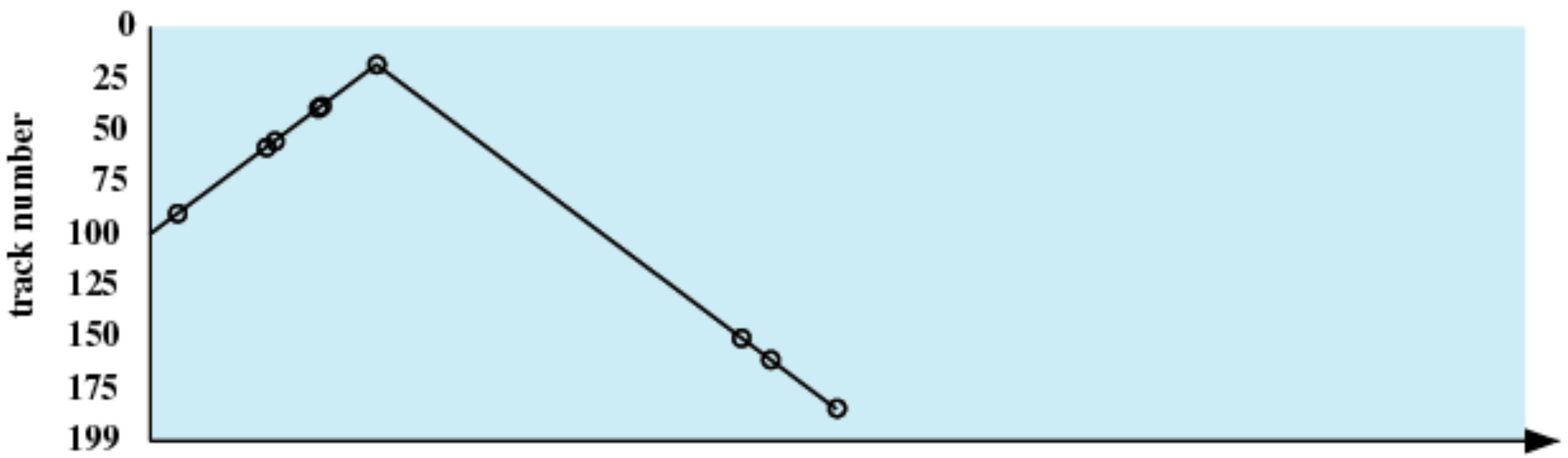
- First-in, first-out (FIFO)
  - Process request sequentially
  - Fair to all processes
  - Approaches random scheduling in performance if there are many processes



(a) FIFO

Disk Scheduling Policies

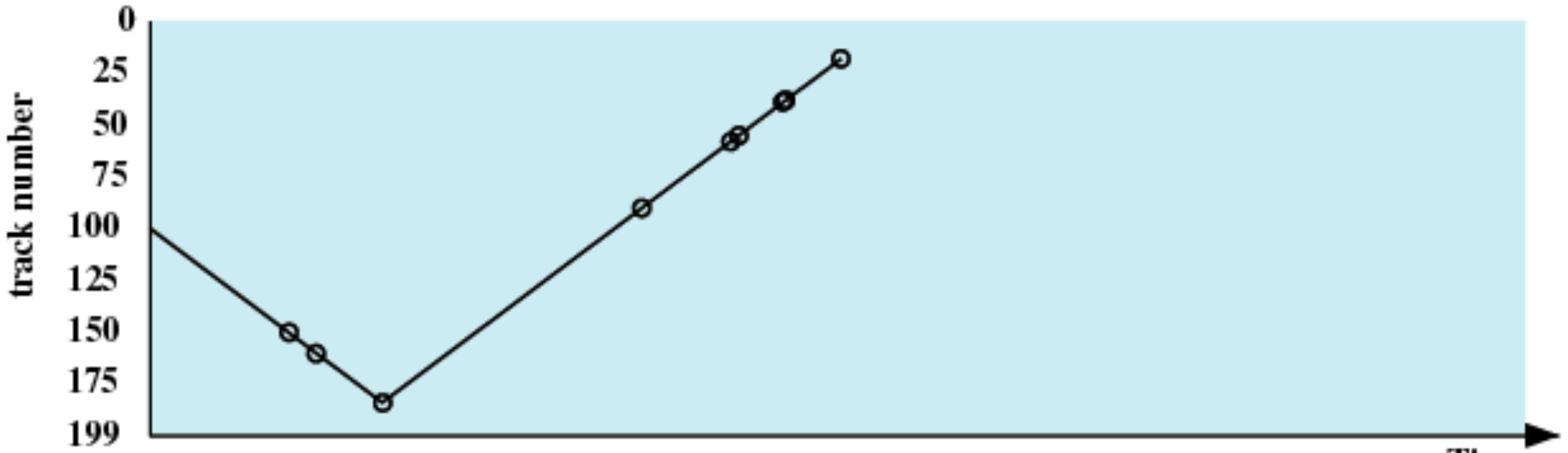
- Shortest Service Time First
  - Select the disk I/O request that requires the least movement of the disk arm from its current position
  - Always choose the minimum Seek time



(b) SSTF

Disk Scheduling Policies

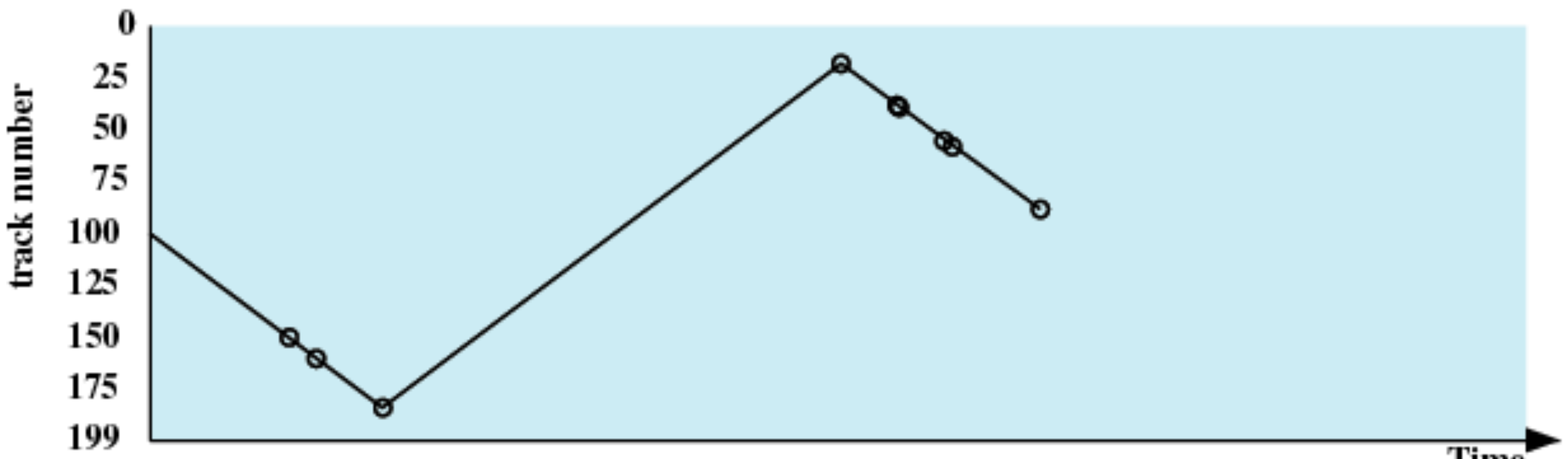
- SCAN
  - Arm moves in one direction only, satisfying all outstanding requests until it reaches the last track in that direction
  - Direction is reversed



(c) SCAN

Disk Scheduling Policies

- C-SCAN
  - Restricts scanning to one direction only
  - When the last track has been visited in one direction, the arm is returned to the opposite end of the disk and the scan begins again



(d) C-SCAN

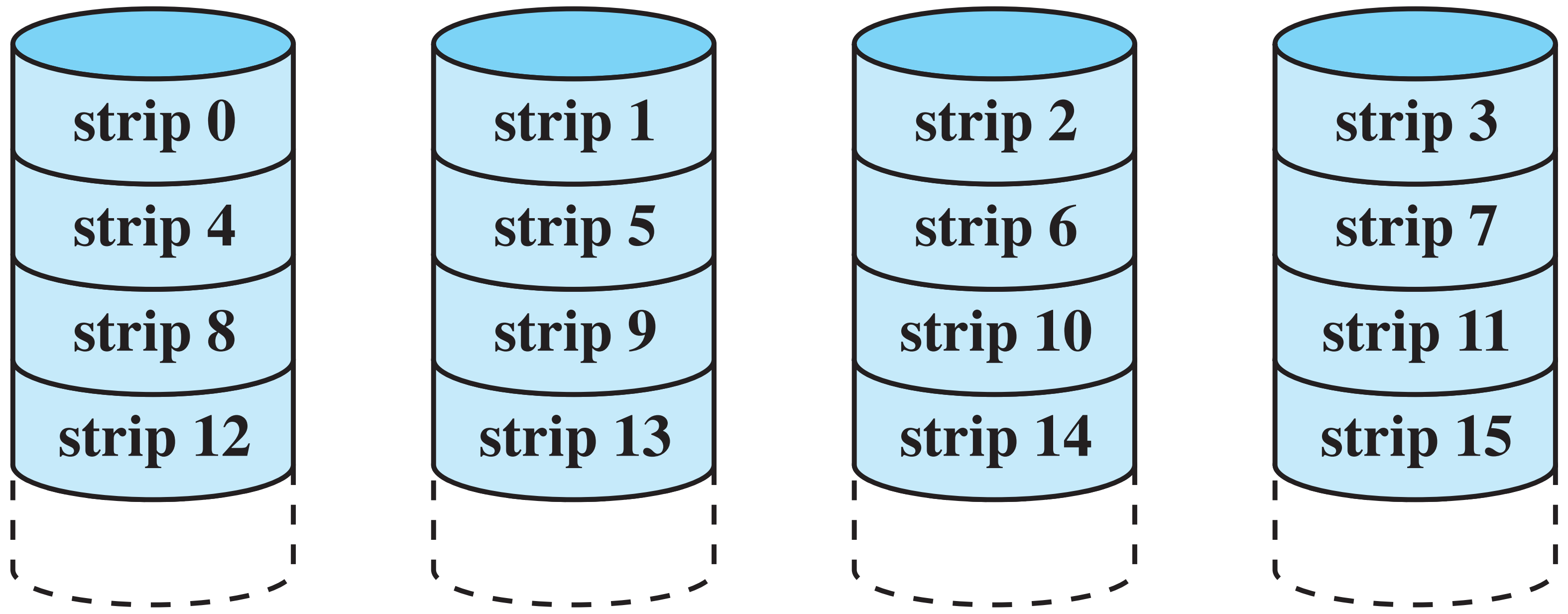
Disk Scheduling Algorithms

Table 11.2 Comparison of Disk Scheduling Algorithms

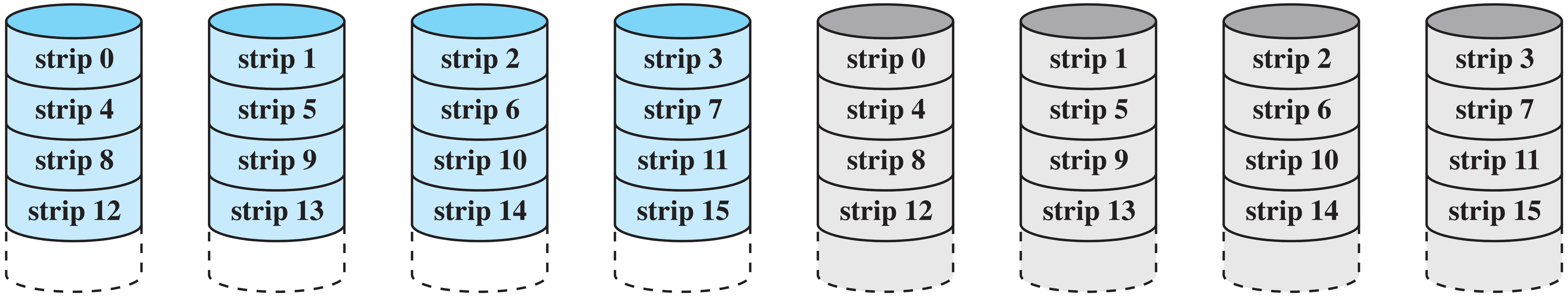
(a) FIFO (starting at track 100)		(b) SSTF (starting at track 100)		(c) SCAN (starting at track 100, in the direction of increasing track number)		(d) C-SCAN (starting at track 100, in the direction of increasing track number)	
Next track accessed	**Number of tracks traversed**	**Next track accessed**	**Number of tracks traversed**	**Next track accessed**	**Number of tracks traversed**	**Next track accessed**	**Number of tracks traversed**
55	45	90	10	150	50	150	50
58	3	58	32	160	10	160	10
39	19	55	3	184	24	184	24
18	21	39	16	90	94	18	166
90	72	38	1	58	32	38	20
160	70	18	20	55	3	39	1
150	10	150	132	39	16	55	16
38	112	160	10	38	1	58	3
184	146	184	24	18	20	90	32
Average seek length	55.3	**Average seek length**	27.5	**Average seek length**	27.8	**Average seek length**	35.8

RAID

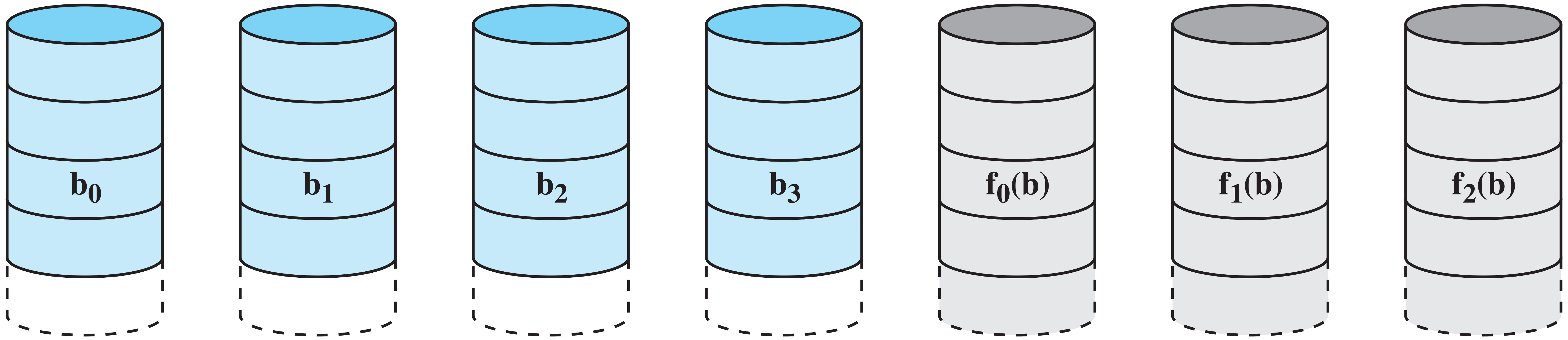
- Redundant Array of Independent Disks
- Set of physical disk drives viewed by the operating system as a single logical drive
- Data are distributed across the physical drives of an array
- Redundant disk capacity is used to store parity information
- Term was invented by Patterson and Katz (Berkeley, 1994)



(a) RAID 0 (non-redundant)

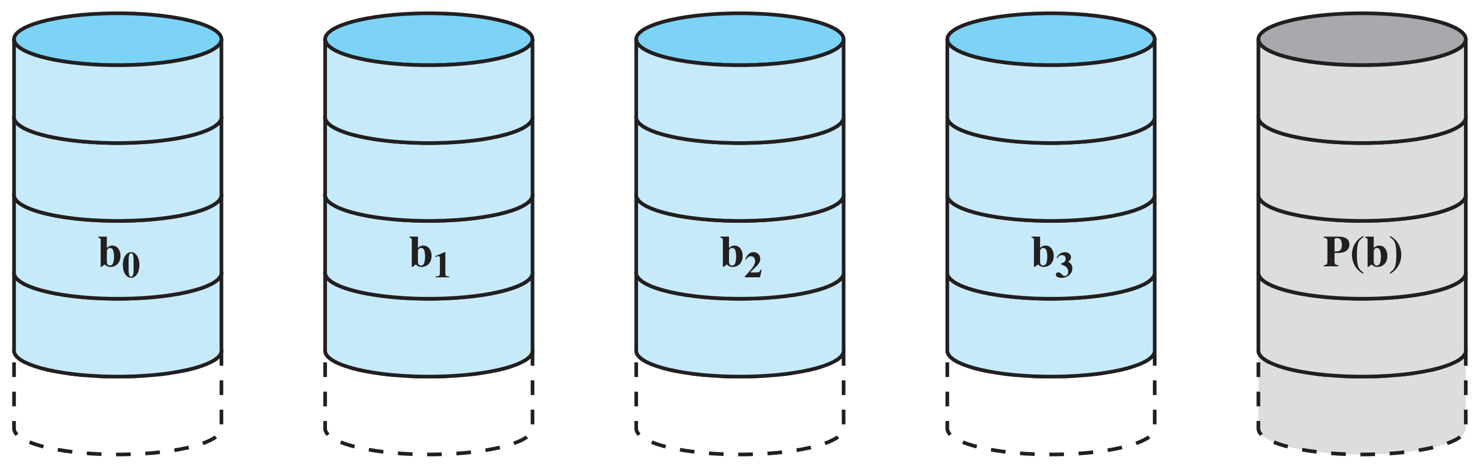


(b) RAID 1 (mirrored)

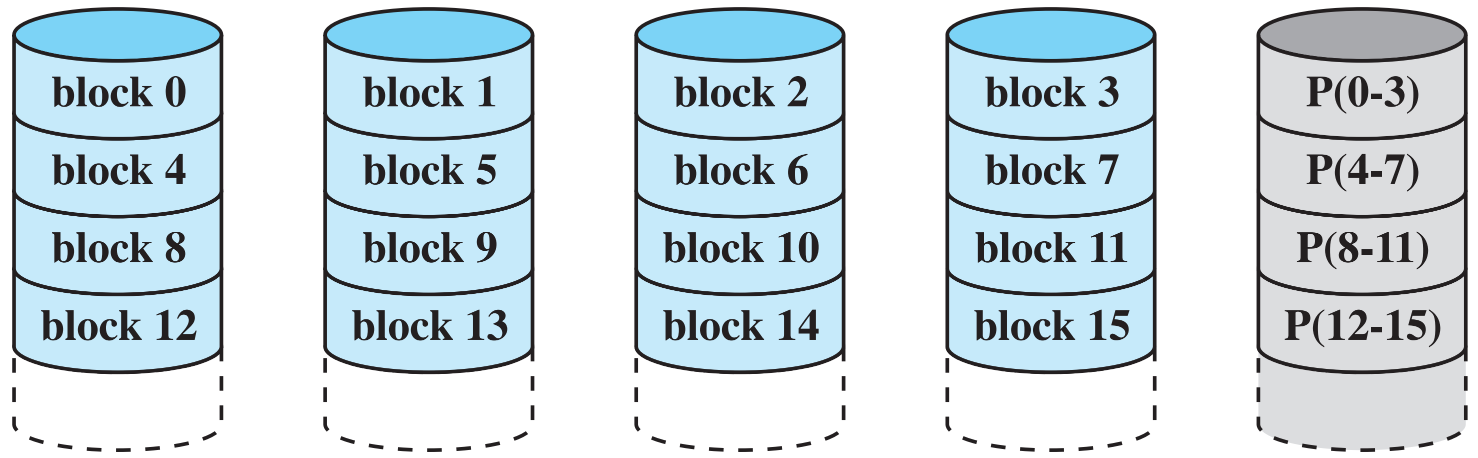


(c) RAID 2 (redundancy through Hamming code)

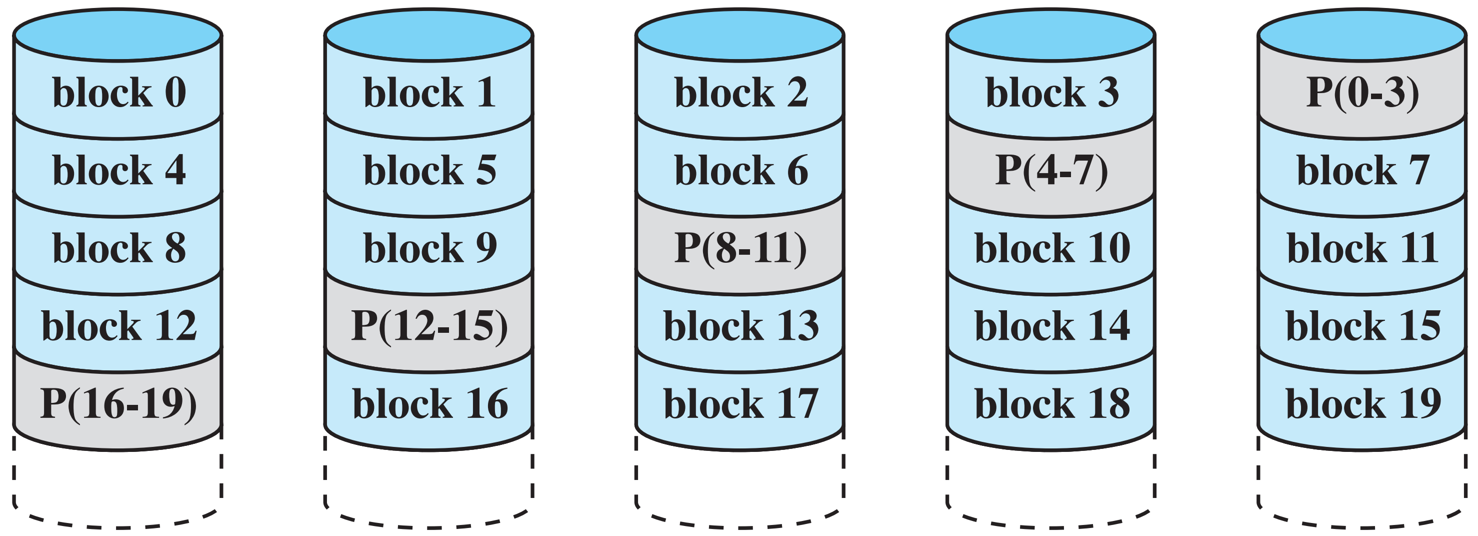
Figure 11.8 RAID Levels (page 1 of 2)



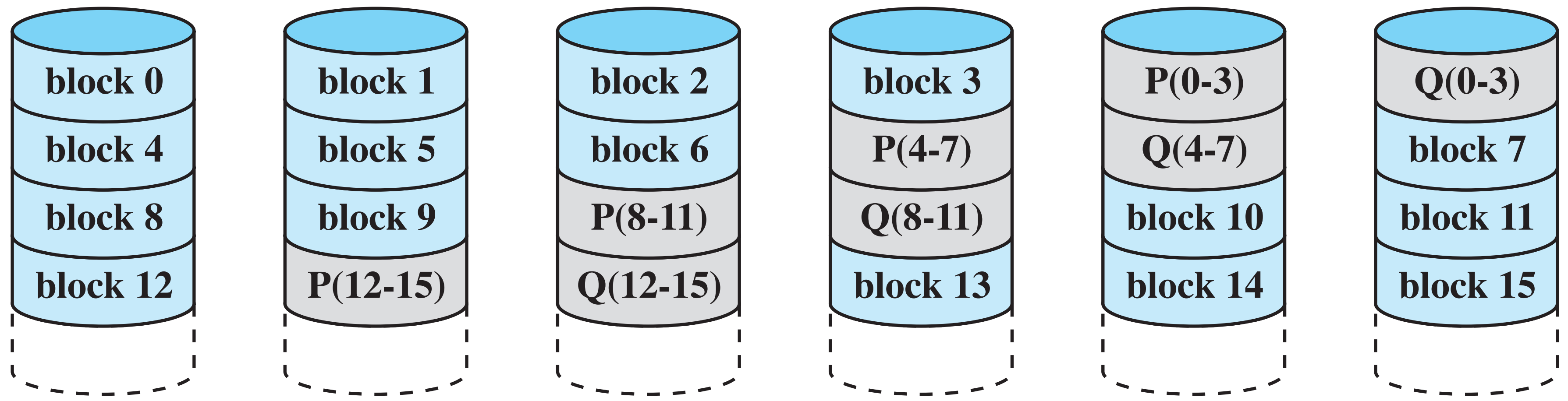
(d) RAID 3 (bit-interleaved parity)



(e) RAID 4 (block-level parity)



(f) RAID 5 (block-level distributed parity)

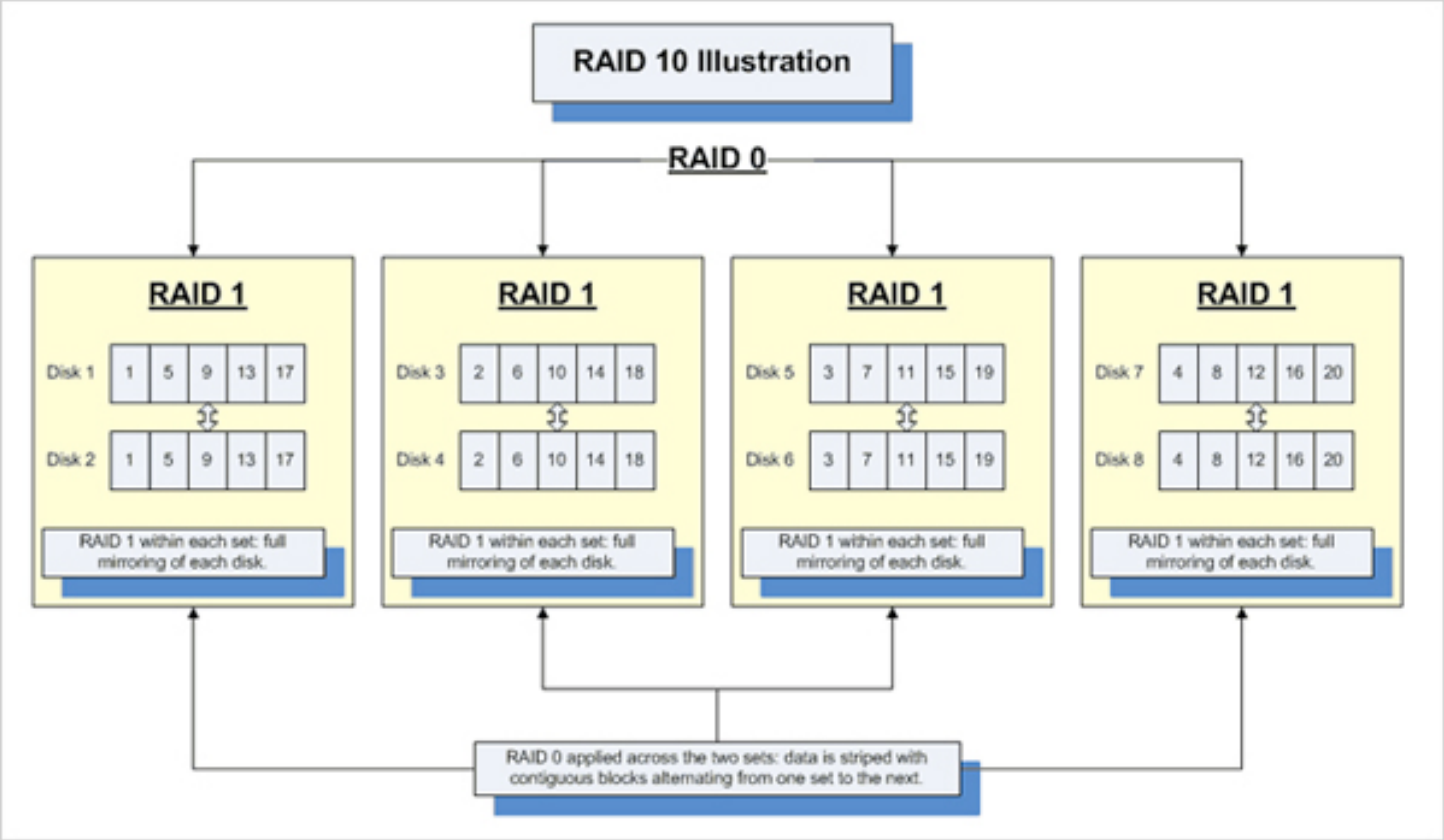


(g) RAID 6 (dual redundancy)

Figure 11.8 RAID Levels (page 2 of 2)

RAID 10

RAID 10 is sometimes also called RAID 1+0



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RAID 0+1

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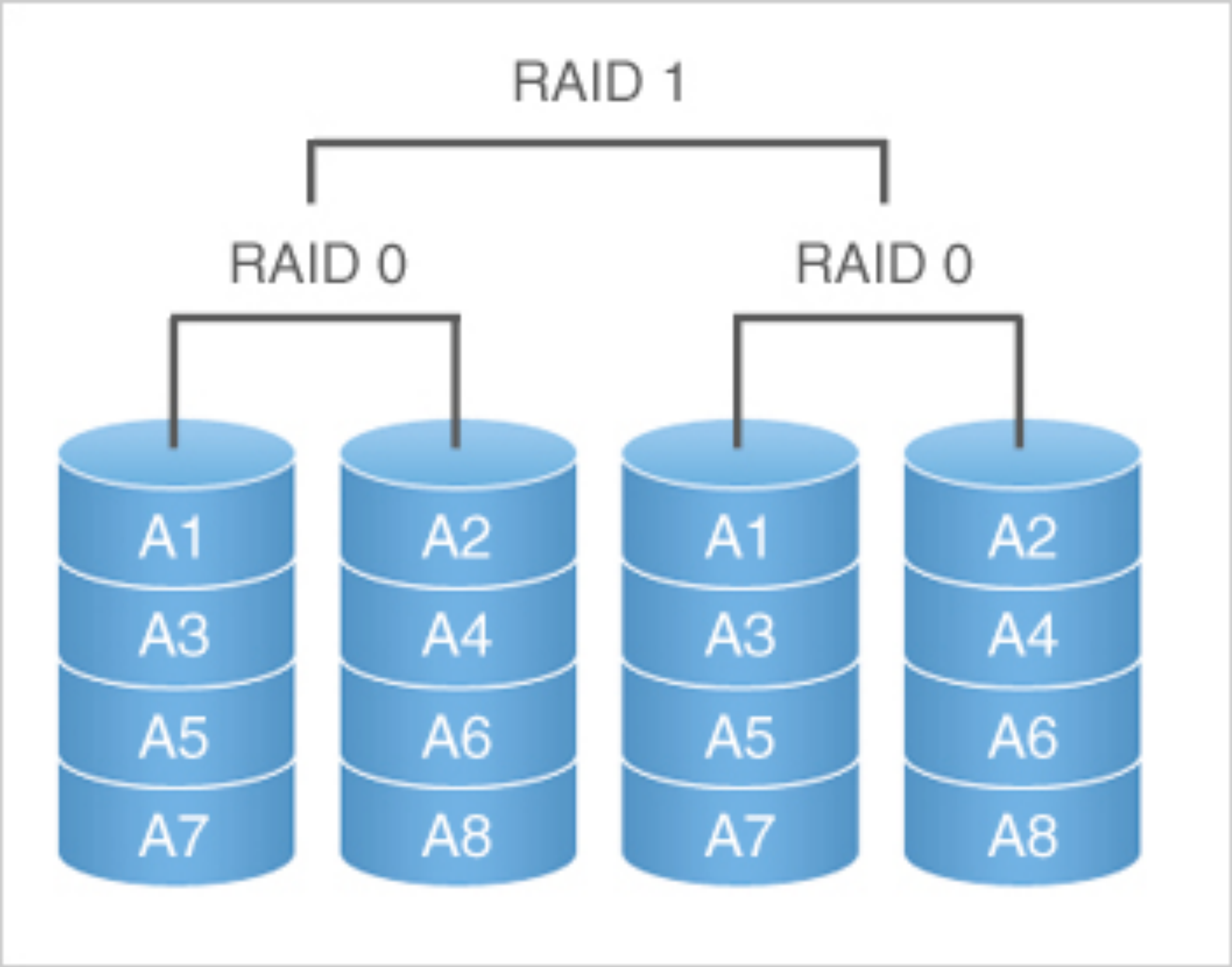

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UNIX SCR4 I/O

- Each individual device is associated with a special file
- Two types of I/O
  - Buffered
  - Unbuffered

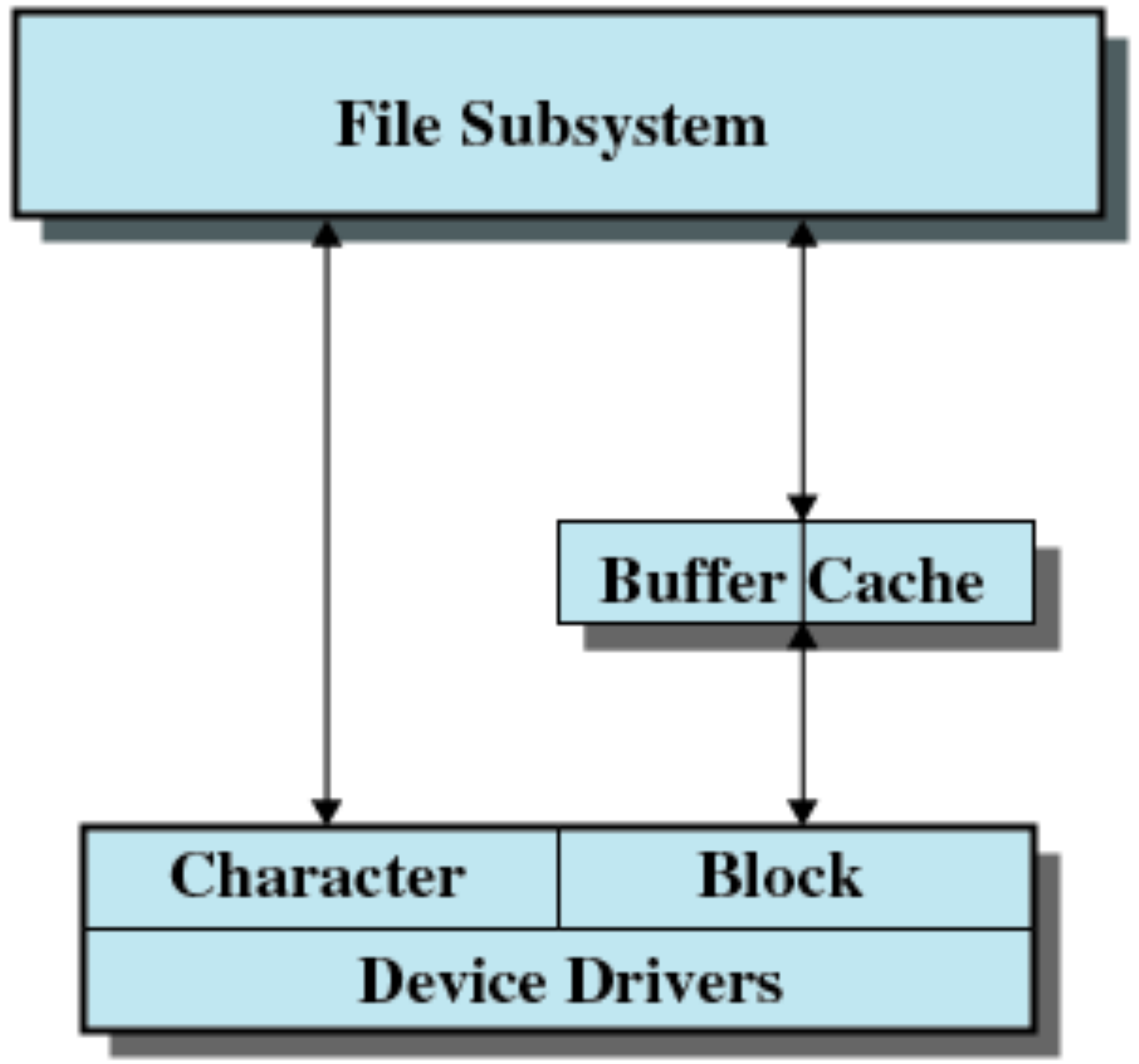

Figure 11.12 UNIX I/O Structure

Linux I/O

- Elevator scheduler
  - Maintains a single queue for disk read and write requests
  - Keeps list of requests sorted by block number
  - Drive moves in a single direction to satisfy each request

Linux I/O

- Deadline scheduler
  - Uses three queues
    - Incoming requests
    - Read requests go to the tail of a FIFO queue
    - Write requests go to the tail of a FIFO queue
  - Each request has an expiration time
    - defaults for requests:
      - 0.5s for read
      - 5s for write

Linux I/O

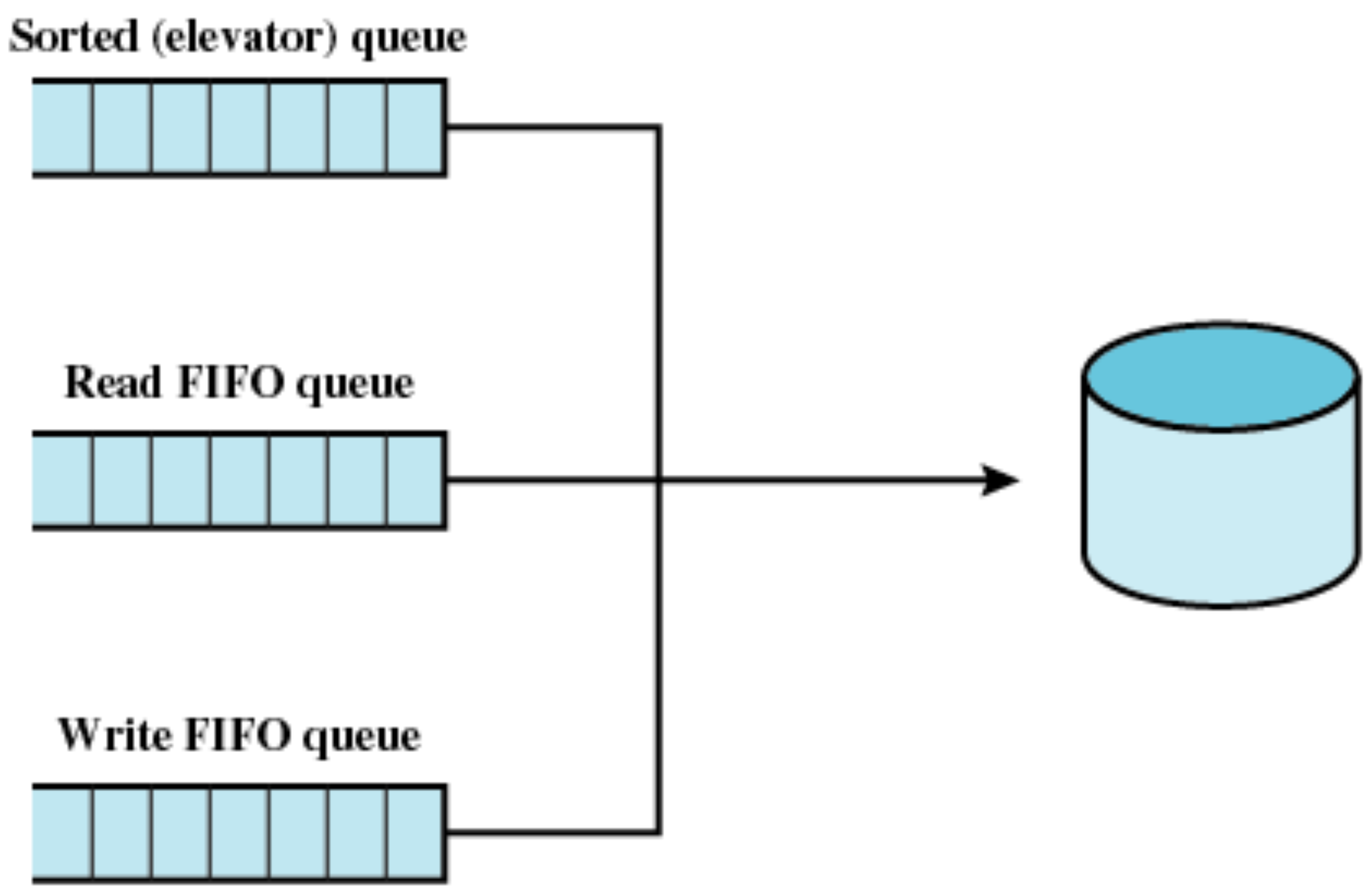

Figure 11.14 The Linux Deadline I/O Scheduler

1. Put requests in sorted queue *and* FIFO
   - remove request from both Qs when processed
- Schedule from sorted Q and check expiration date of FIFO entry.
   - if date has expired, schedule from FIFO until "caught up"

Linux I/O

- Anticipatory I/O scheduler
  - Delay a short period of time after satisfying a read request to see if a new nearby request can be made

Windows I/O

- Basic I/O modules
  - Cache manager
  - File system drivers
  - Network drivers
  - Hardware device drivers

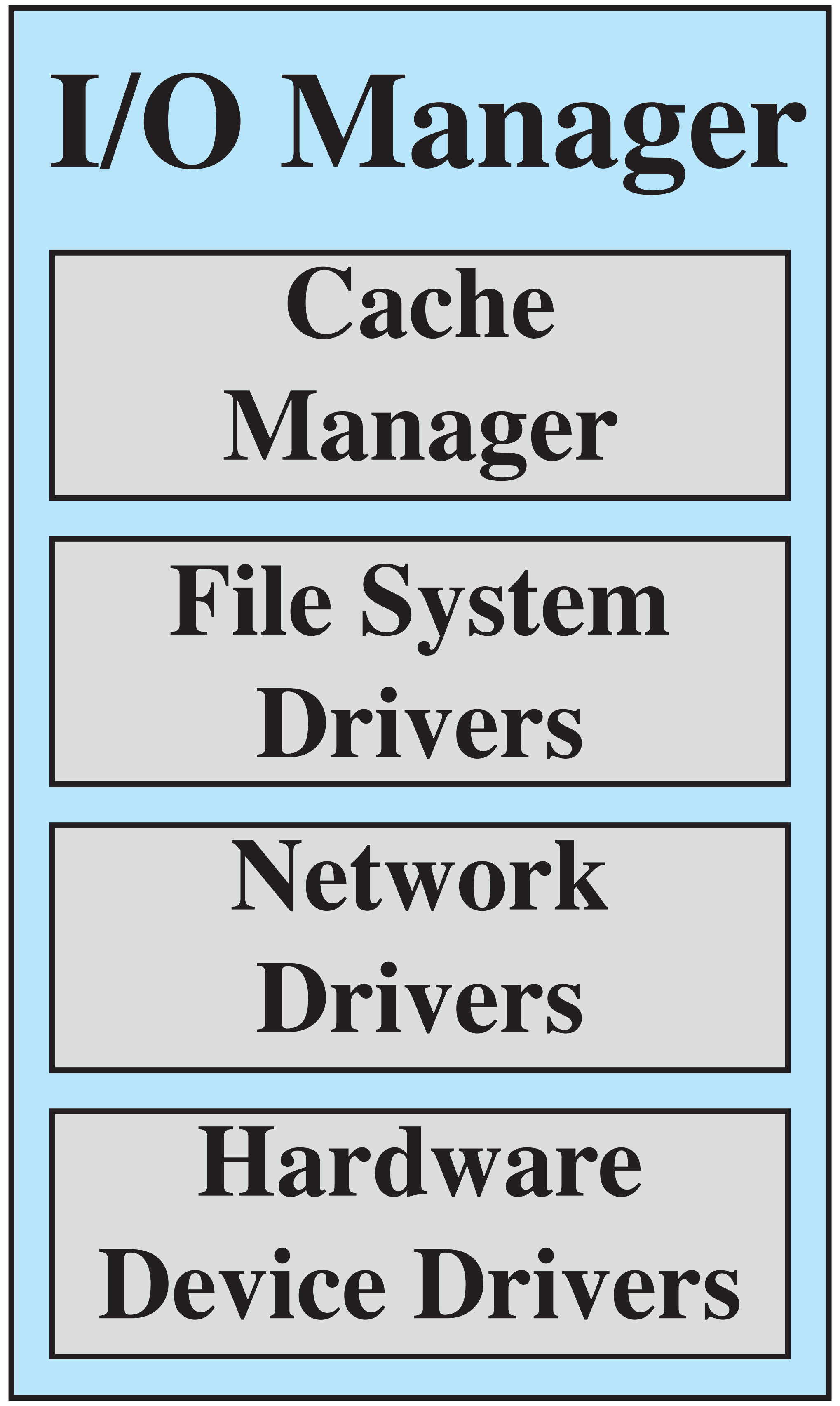

Figure 11.15 Windows I/O Manager