Unit-6,
I/O Management and Disk Scheduling

Outline

- I/O Devices
- Organization of the I/O Function
- Operating System Design Issues
- I/O Buffering
- Disk Scheduling

1. Categories of I/O Devices

- Difficult area of OS design
  - Difficult to develop a consistent solution due to a wide variety of devices and applications

- Three Categories:
  a. Human readable
  b. Machine readable
  c. Communications

I.a Human readable

- Devices used to communicate with the user
- Printers and terminals
  - Video display
  - Keyboard
  - Mouse etc

1.b Machine readable

- Used to communicate with electronic equipment
  - Disk drives
  - USB keys
  - Sensors
  - Controllers
  - Actuators

1.c Communication

- Used to communicate with remote devices
  - Digital line drivers
  - Modems
  - I/O controllers

2. Differences in I/O Devices

- Devices differ in a number of areas
  A. Data Rate
  B. Application
  C. Complexity of Control
  D. Unit of Transfer
  E. Data Representation
  F. Error Conditions

2.A Data Rate

- May be massive difference between the data transfer rates of devices

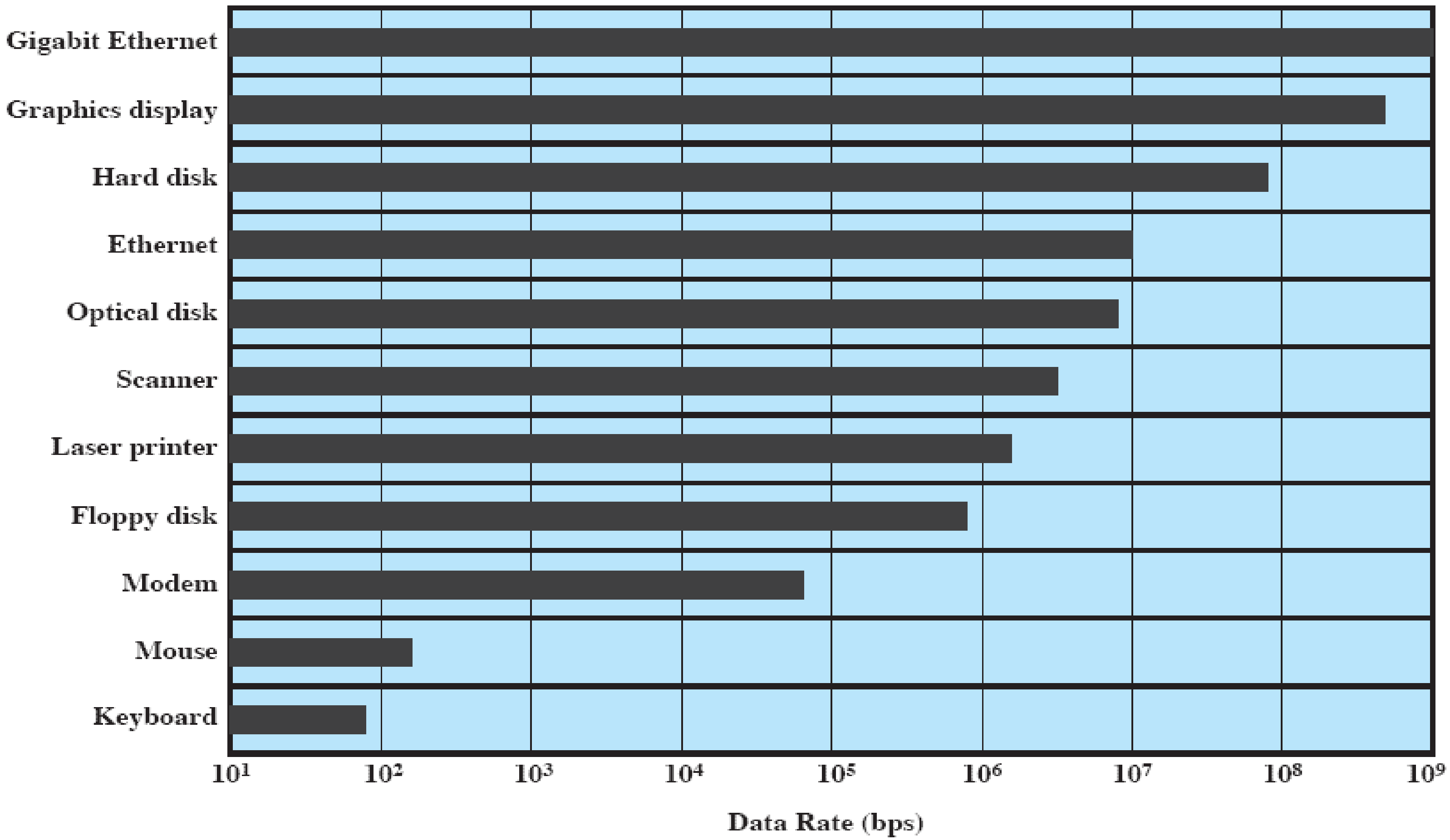

Figure 11.1 Typical I/O Device Data Rates

2.B Application

- Disk used to store files requires file management software
- Disk used to store virtual memory pages needs special hardware and software to support it
- Terminal used by system administrator may have a higher priority

2.C Complexity of control

- A printer requires a relatively simple control interface.
- A disk is much more complex.
- This complexity is filtered to some extent by the complexity of the I/O module that controls the device.

2.D Unit of transfer

- Data may be transferred as
  - a stream of bytes or characters (e.g., terminal I/O)
  - or in larger blocks (e.g., disk I/O).

2.E Data representation

- Different data encoding schemes are used by different devices,
  - including differences in character code and parity conventions.

2.F Error Conditions

- The nature of errors differ widely from one device to another.
- Aspects include:
  - the way in which they are reported,
  - their consequences,
  - the available range of responses

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Techniques for performing I/O

- Programmed I/O
- Interrupt-driven I/O
- Direct memory access (DMA)

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)

1. Evolution of the I/O Function

1. Processor directly controls a peripheral device
2. Controller or I/O module is added
   - Processor uses programmed I/O without interrupts
   - Processor does not need to handle details of external devices

Evolution of the I/O Function cont…

3. Controller or I/O module with interrupts
   - Efficiency improves as processor does not spend time waiting for an I/O operation to be performed
4. Direct Memory Access
   - Blocks of data are moved into memory without involving the processor
   - Processor involved at beginning and end only

Evolution of the I/O Function cont…

5. I/O module is a separate processor
   - CPU directs the I/O processor to execute an I/O program in main memory.
6. I/O processor
   - I/O module has its own local memory
   - Commonly used to control communications with interactive terminals

2. Direct Memory Address

- Processor delegates I/O operation to the DMA module
- DMA module transfers data directly to or form memory
- When complete DMA module sends an interrupt signal to the processor

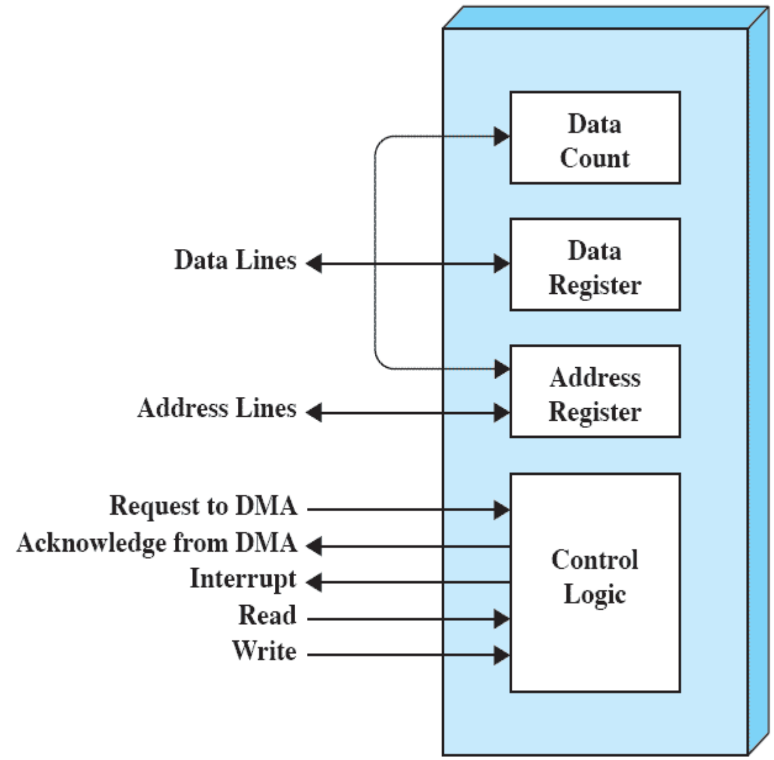
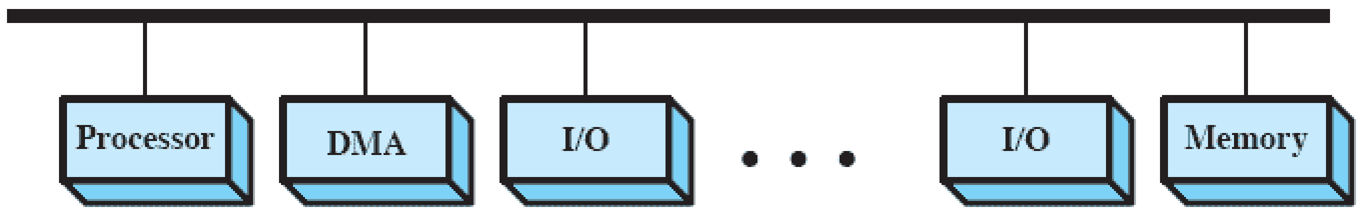


Figure 11.2 Typical DMA Block Diagram

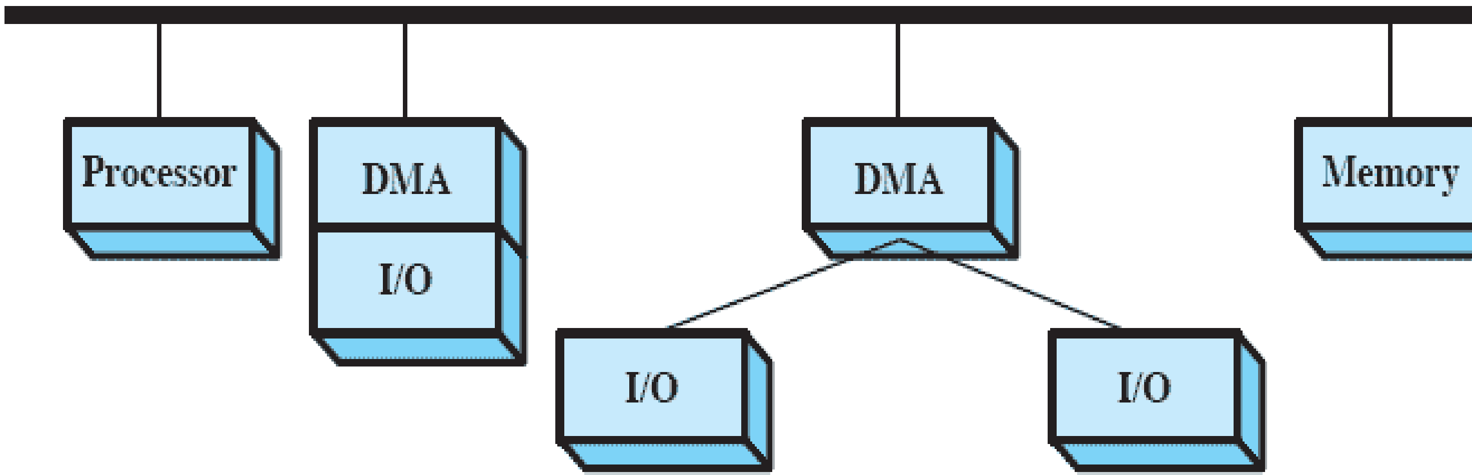
DMA Configurations: Single Bus



(a) Single-bus, detached DMA

- DMA can be configured in several ways
- Shown here, all modules share the same system bus

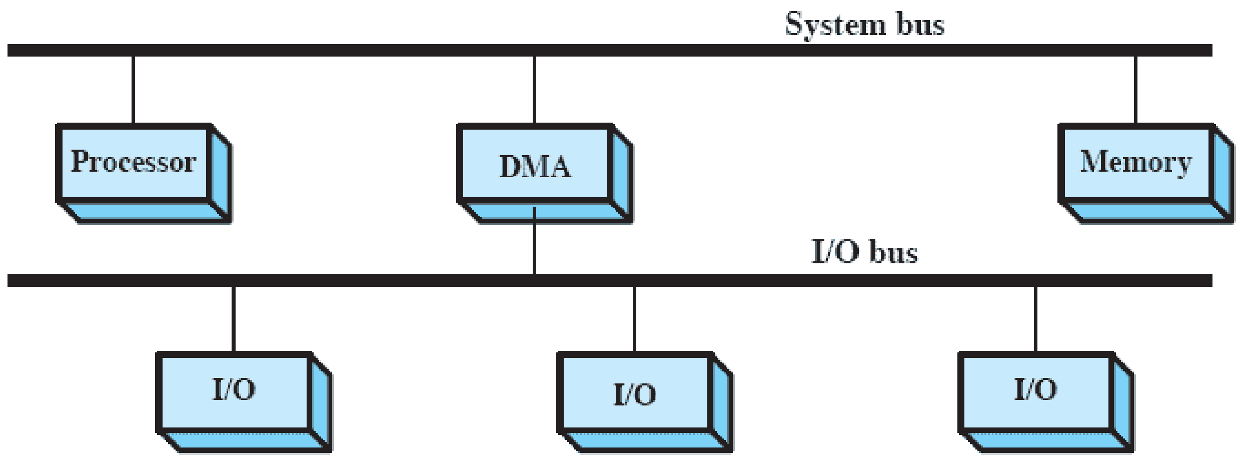
DMA Configurations: Integrated DMA & I/O



(b) Single-bus, Integrated DMA-I/O

- Direct Path between DMA and I/O modules
- This substantially cuts the required bus cycles

DMA Configurations: I/O Bus



(c) I/O bus

- Reduces the number of I/O interfaces in the DMA module

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Goals: Efficiency

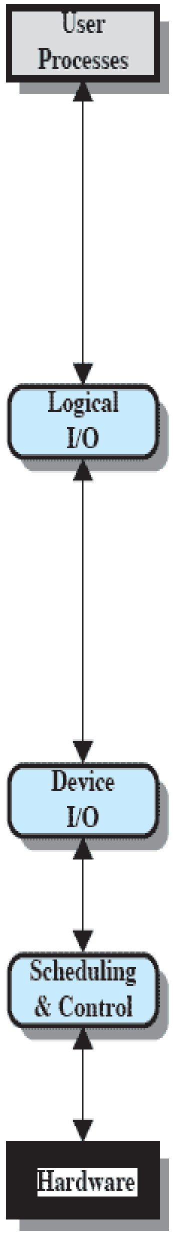
- Most I/O devices extremely slow compared to main memory
- Use of multiprogramming allows for some processes to be waiting on I/O while another process executes
- I/O cannot keep up with processor speed
  - Swapping used to bring in ready processes
  - But this is an I/O operation itself

Generality

- For simplicity and freedom from error it is desirable to handle all I/O devices in a uniform manner
- Hide most of the details of device I/O in lower-level routines
- Difficult to completely generalize, but can use a hierarchical modular design of I/O functions

Hierarchical design

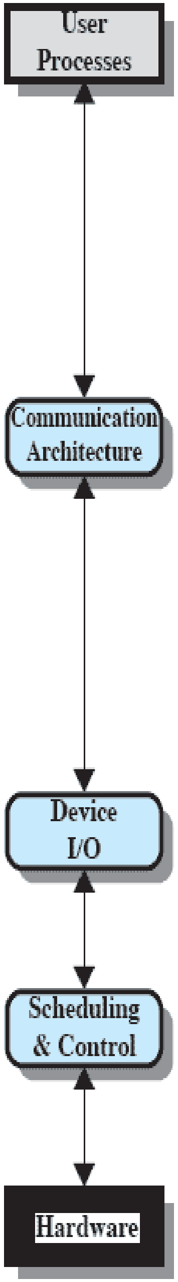
- A hierarchical philosophy leads to organizing an OS into layers
- Each layer relies on the next lower layer to perform more primitive functions
- It provides services to the next higher layer.
- Changes in one layer should not require changes in other layers



(a) Local peripheral device

Local peripheral device

- Logical I/O:
  - Deals with the device as a logical resource
- Device I/O:
  - Converts requested operations into sequence of I/O instructions
- Scheduling and Control
  - Performs actual queuing and control operations

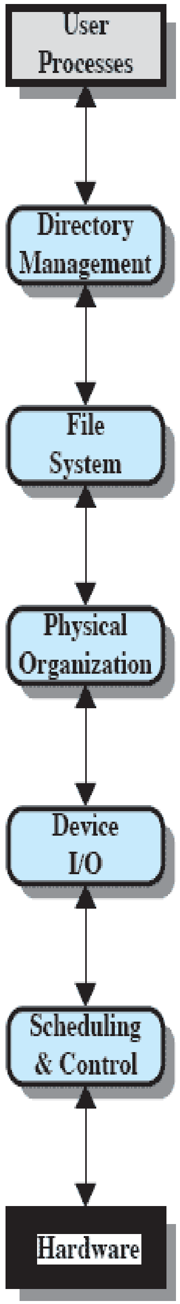


(b) Communications port

Communications Port

- Similar to previous but the logical I/O module is replaced by a communications architecture,
  - This consist of a number of layers.
  - An example is TCP/IP,

File System



(c) File system

- Directory management
  - Concerned with user operations affecting files
- File System
  - Logical structure and operations
- Physical organisation
  - Converts logical names to physical addresses

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- Raid
- Disk Cache

I/O Buffering

- Processes must wait for I/O to complete before proceeding
  - To avoid deadlock certain pages must remain in main memory during I/O
- It may be more efficient to perform input transfers in advance of requests being made and to perform output transfers some time after the request is made.

Block-oriented Buffering

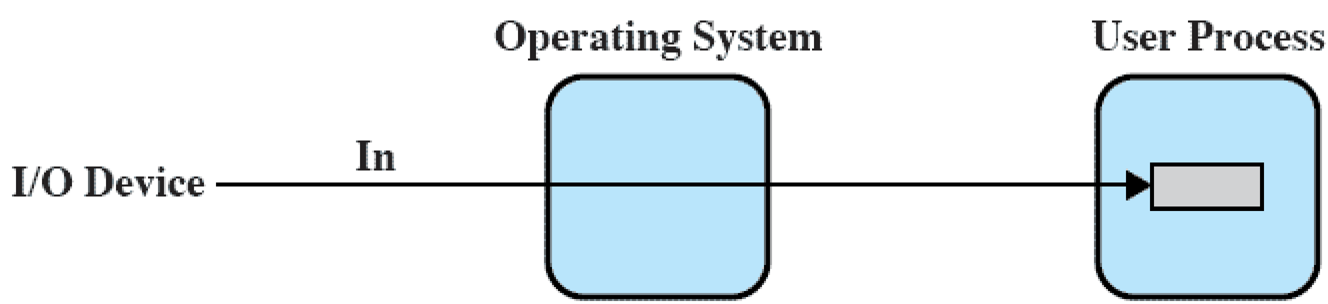
- Information is stored in fixed sized blocks
- Transfers are made a block at a time
  - Can reference data b block number
- Used for disks and USB keys

Stream-Oriented Buffering

- 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

No Buffer

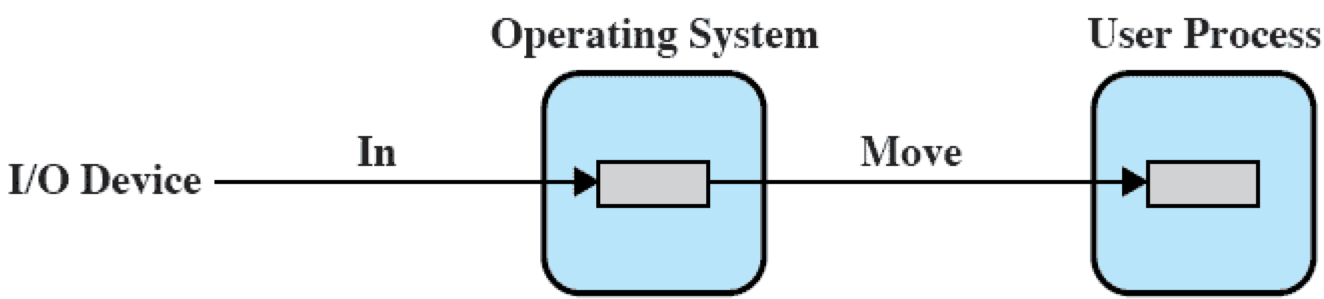
- Without a buffer, the OS directly access the device as and when it needs



(a) No buffering

Single Buffer

- Operating system assigns a buffer in main memory for an I/O request



(b) Single buffering

Block Oriented Single Buffer

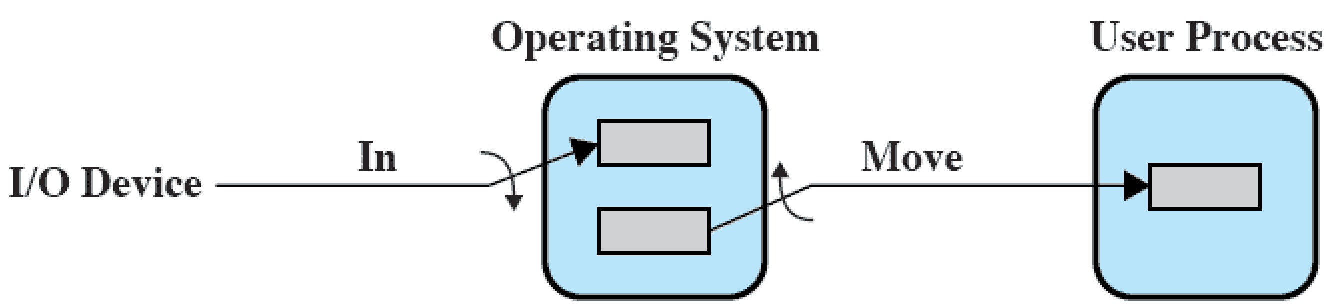
- Input transfers made to buffer
- Block moved to user space when needed
- The next block is moved into the buffer
    - *Read ahead* or *Anticipated Input*
- Often a reasonable assumption as data is usually accessed sequentially

Stream-oriented Single Buffer

- Line-at-time or Byte-at-a-time
- Terminals often deal with one line at a time with carriage return signaling the end of the line
- Byte-at-a-time suites devices where a single keystroke may be significant
  - Also sensors and controllers

Double Buffer

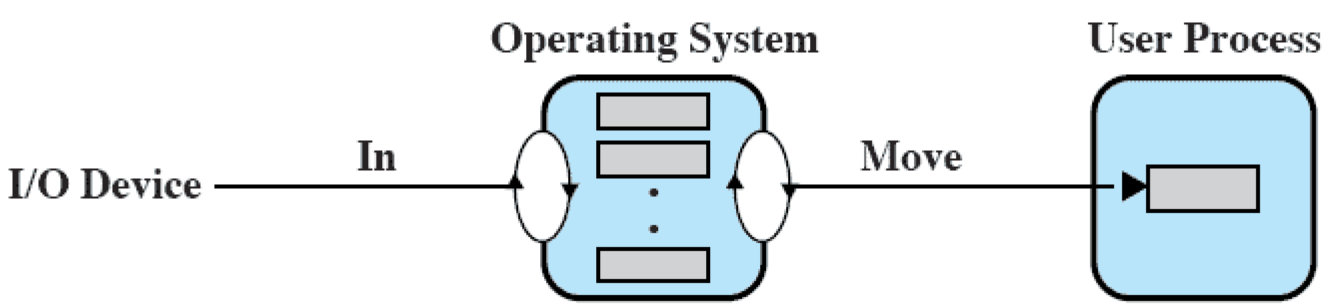
- Use two system buffers instead of one
- A process can transfer data to or from one buffer while the operating system empties or fills the other buffer



(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

Buffer Limitations

- Buffering smoothes out peaks in I/O demand.
  - But with enough demand eventually all buffers become full and their advantage is lost
- However, when there is a variety of I/O and process activities to service, buffering can increase the efficiency of the OS and the performance of individual processes.

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Disk Performance Parameters

- The actual details of disk I/O operation depend on many things
  - A general timing diagram of disk I/O transfer is shown here.

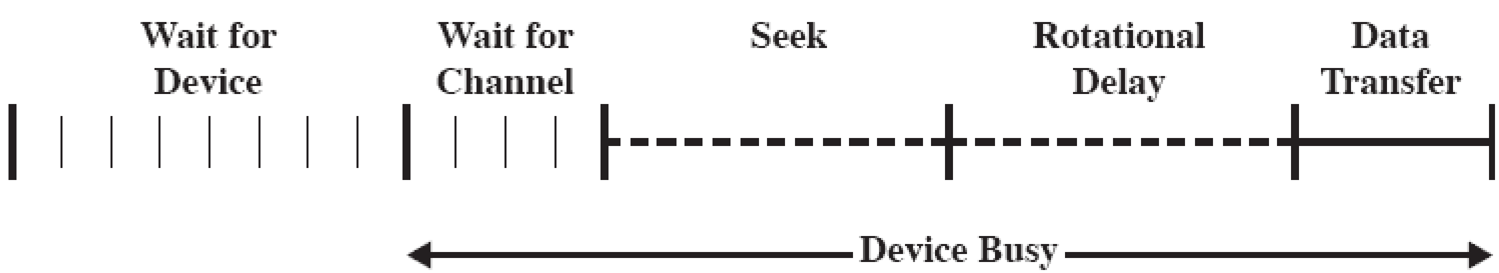


Figure 11.6 Timing of a Disk I/O Transfer

Positioning the Read/Write Heads

- When the disk drive is operating, the disk is rotating at constant speed.
- Track selection involves moving the head in a movable-head system or electronically selecting one head on a fixed-head system.

Disk Performance Parameters

- ***Access Time*** is the sum of:
  - ***Seek time:*** The time it takes to position the head at the desired track
  - ***Rotational delay*** or ***rotational latency:*** The time its takes for the beginning of the sector to reach the head
- ***Transfer Time*** is the time taken to transfer the data.

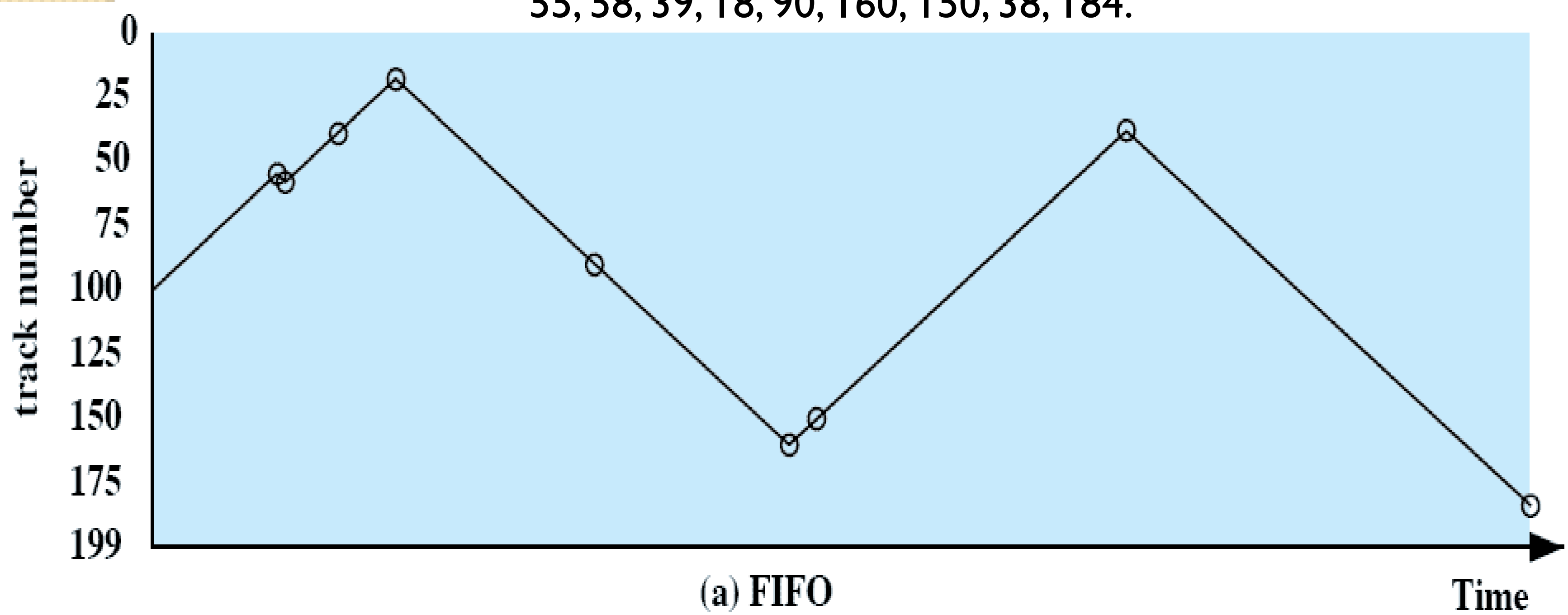
1. Disk Scheduling Policies

- To compare various schemes, consider a disk head is initially located at track 100.
  - assume a disk with 200 tracks and that the disk request queue has random requests in it.
- The requested tracks, in the order received by the disk scheduler, are
  - 55, 58, 39, 18, 90, 160, 150, 38, 184.

1.A First-in, first-out (FIFO)

- Process request sequentially
- Fair to all processes
- Approaches random scheduling in performance if there are many processes

55, 58, 39, 18, 90, 160, 150, 38, 184.



(a) FIFO

I.B Priority

- Goal is not to optimize disk use but to meet other objectives
- Short batch jobs may have higher priority
- Provide good interactive response time
- Longer jobs may have to wait an excessively long time

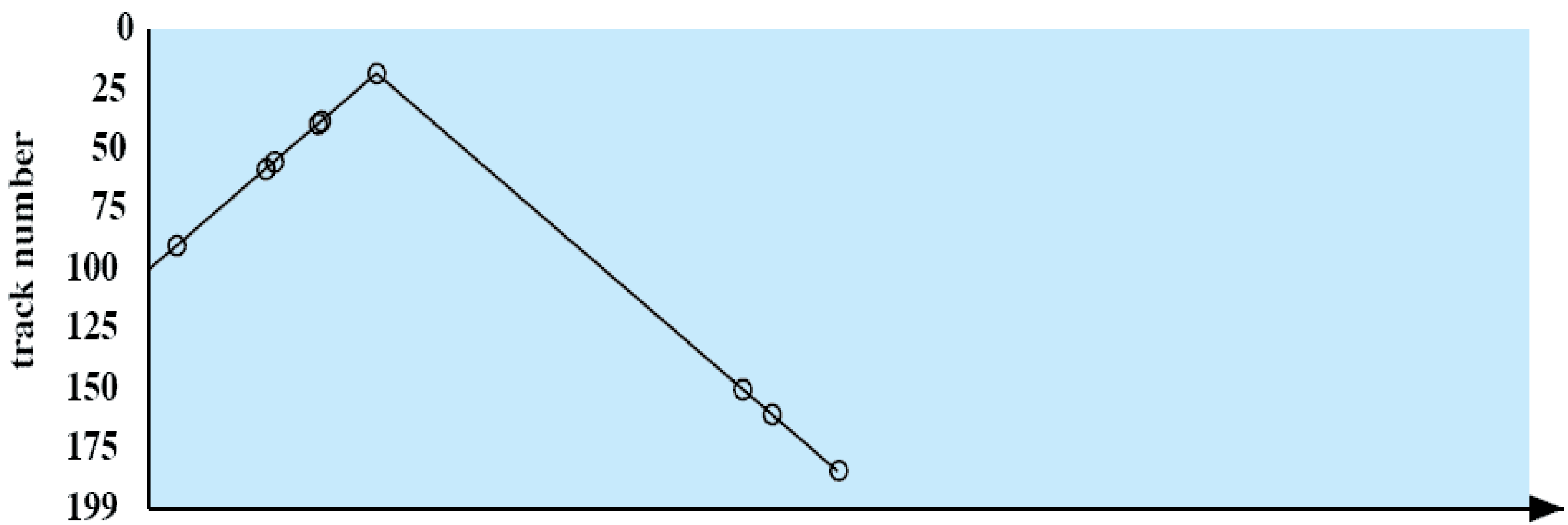
I.C

Last-in, first-out

- Good for transaction processing systems
  - The device is given to the most recent user so there should be little arm movement

I.D Shortest Service Time First

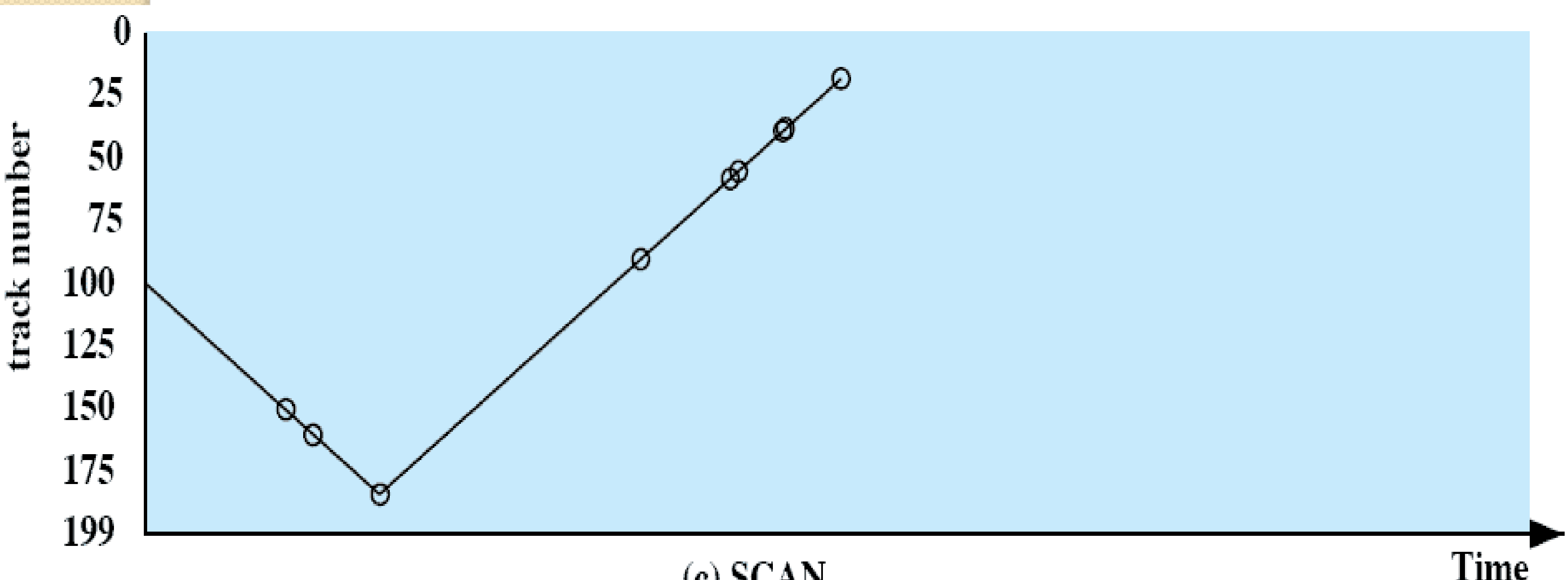
- Select the disk I/O request that requires the least movement of the disk arm from its current position
- Always choose the minimum seek time
- 55, 58, 39, 18, 90, 160, 150, 38, 184.



(b) SSTF

I.E SCAN

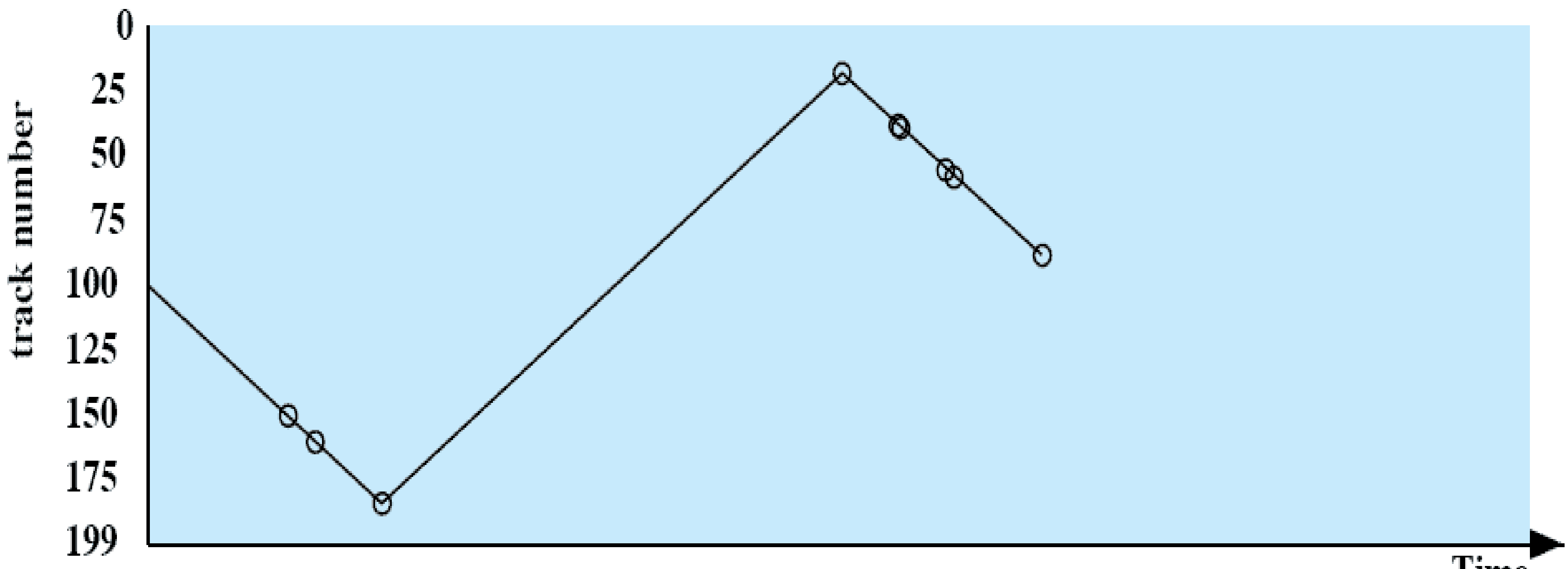
- Arm moves in one direction only, satisfying all outstanding requests until it reaches the last track in that direction then the direction is reversed
- 55, 58, 39, 18, 90, 160, 150, 38, 184.



(c) SCAN

I.F 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
- 55, 58, 39, 18, 90, 160, 150, 38, 184.



(d) C-SCAN

I.G

N-step-SCAN

- Segments the disk request queue into subqueues of length N
- Subqueues are processed one at a time, using SCAN
- New requests added to other queue when queue is processed

1.H FSCAN

- Two subqueues
- When a scan begins, all of the requests are in one of the queues, with the other empty.
- All new requests are put into the other queue.
  - Service of new requests is deferred until all of the old requests have been processed.

Performance Compared

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

Disk Scheduling Algorithms

Table 11.3 Disk Scheduling Algorithms

Name	Description	Remarks
Selection according to requestor		
RSS	Random scheduling	For analysis and simulation
FIFO	First in first out	Fairest of them all
PRI	Priority by process	Control outside of disk queue management
LIFO	Last in first out	Maximize locality and resource utilization
Selection according to requested item		
SSTF	Shortest service time first	High utilization, small queues
SCAN	Back and forth over disk	Better service distribution
C-SCAN	One way with fast return	Lower service variability
N-step-SCAN	SCAN of *N* records at a time	Service guarantee
FSCAN	N-step-SCAN with *N* = queue size at beginning of SCAN cycle	Load sensitive