I/O Management and Disk Scheduling

Chapter 11

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Categories of I/O Devices

- Human readable
  - Used to communicate with the user
  - Printers
  - Video display terminals
    - Display
    - Keyboard
    - Mouse

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Categories of I/O Devices

- Machine readable
  - Used to communicate with electronic equipment
  - Disk and tape drives
  - Sensors
  - Controllers
  - Actuators

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Categories of I/O Devices

- Communication
  - Used to communicate with remote devices
  - Digital line drivers
  - Modems

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Differences in I/O Devices

- Data rate
  - May be differences of several orders of magnitude between the data transfer rates

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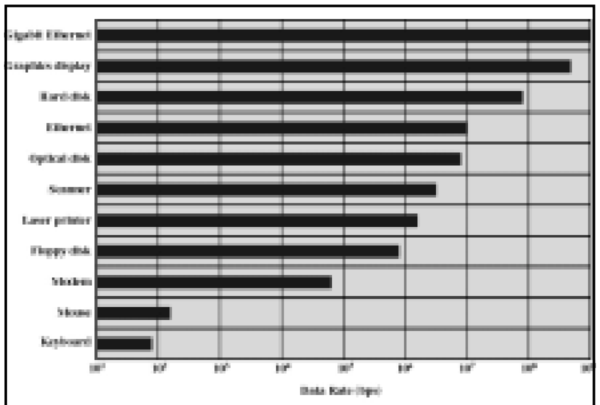

Figure 11.1 Typical I/O Device Data Rates

Differences in I/O Devices

- 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

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Differences in I/O Devices

- 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

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Differences in I/O Devices

- 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

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Techniques for 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

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Evolution of the I/O Function

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

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Evolution of the I/O Function

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

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Evolution of the I/O Function

- I/O module is a separate processor
- I/O processor
  - I/O module has its own local memory
  - Its a computer in its own right

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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

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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

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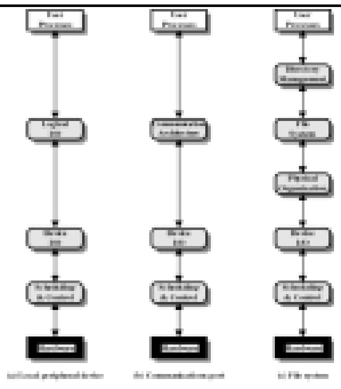

Figure 11.5 A Model of I/O Organization

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

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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-oriented
  - Transfer information as a stream of bytes
  - Used for terminals, printers, communication ports, mouse, and most other devices that are not secondary storage

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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

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Timing of a Disk I/O Transfer

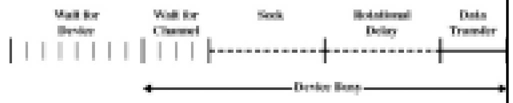

Figure 11.7 Timing of a Disk I/O Transfer

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Disk Performance Parameters

- 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

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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 the worst possible performance

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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

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Disk Scheduling Policies

- 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

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Disk Scheduling Policies

- 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
  - Possibility of starvation since a job may never regain the head of the line

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

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

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

Disk Scheduling Policies

- 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
- FSCAN
  - Two queues
  - One queue is empty for new request

Disk Scheduling Algorithms

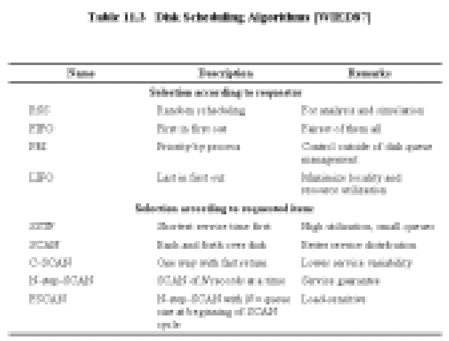
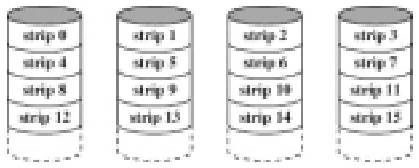


Table 11.3 Disk Scheduling Algorithms [WIED87]

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

RAID 0 (non-redundant)



(a) RAID 0 (non-redundant)

Figure 11.9 RAID Levels (page 1 of 2)

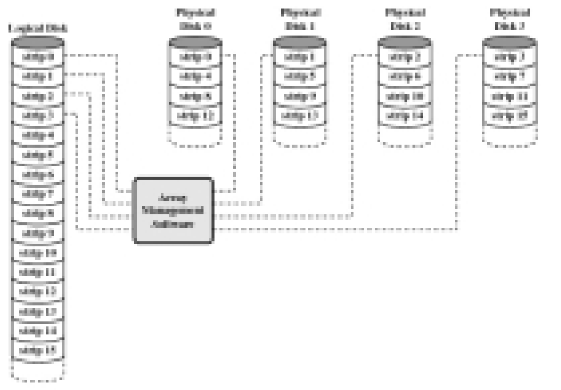
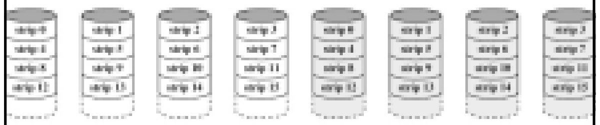


Figure 11.10 Data Mapping for a RAID Level 0 Array [MASS97]

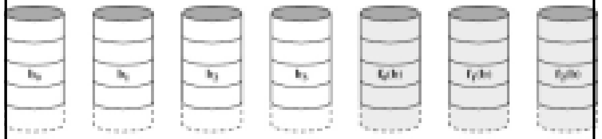
RAID 1 (mirrored)



(b) RAID 1 (mirrored)

Figure 11.9 RAID Levels (page 1 of 2)

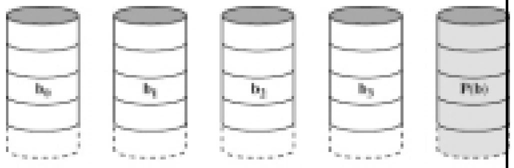
RAID 2 (redundancy through Hamming code)



(c) RAID 2 (redundancy through Hamming code)

Figure 11.9 RAID Levels (page 1 of 2)

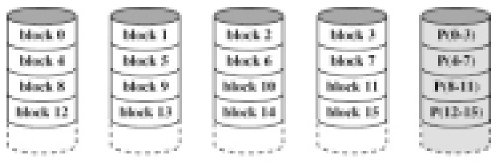
RAID 3 (bit-interleaved parity)



(d) RAID 3 (bit-interleaved parity)

Figure 11.9 RAID Levels (page 2 of 2)

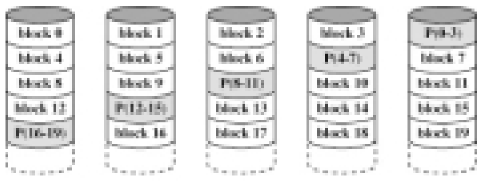
RAID 4 (block-level parity)



(e) RAID 4 (block-level parity)

Figure 11.9 RAID Levels (page 2 of 2)

RAID 5 (block-level distributed parity)



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

Figure 11.9 RAID Levels (page 2 of 2)

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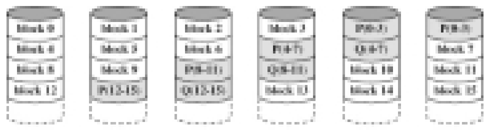
RAID 6 (dual redundancy)



(g) RAID 6 (dual redundancy)

Figure 11.9 RAID Levels (page 2 of 2)

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Disk Cache

- Buffer in main memory for disk sectors
- Contains a copy of some of the sectors on the disk

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Least Recently Used

- The block that has been in the cache the longest with no reference to it is replaced
- The cache consists of a stack of blocks
- Most recently referenced block is on the top of the stack
- When a block is referenced or brought into the cache, it is placed on the top of the stack

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Least Recently Used

- The block on the bottom of the stack is removed when a new block is brought in
- Blocks don’t actually move around in main memory
- A stack of pointers is used

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Least Frequently Used

- The block that has experienced the fewest references is replaced
- A counter is associated with each block
- Counter is incremented each time block accessed
- Block with smallest count is selected for replacement
- Some blocks may be referenced many times in a short period of time and then not needed any more

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UNIX SVR4 I/O

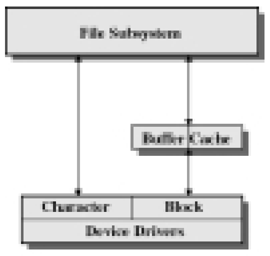

Figure 11.14 UNIX I/O Structure

Windows 2000 I/O

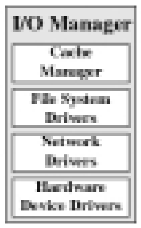

Figure 11.16 Windows 2000 I/O Manager