

Function: main secondary data storage; also permanent

Extreme speed bottleneck!

Capacity not a problem nowadays: 40 GB disks even for PC.

But backup becoming a problem.

Logical view (view of programmer):

Have a tree structure of files together with read/write operation and creation of directories

Physical view:

Just a sequence of blocks, which can be read and written

OS has to map logical view to physical view
must impose tree structure and assign blocks for each file

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Two possibilities:

- **Linked list**: Each block contains pointer to next
⇒ Problem: random access costly: have to go through whole file.
- **Indexed allocation**: Store pointers in one location: so-called index block. (cf. page table).
To cope with vastly differing file sizes, may introduce indirect index blocks.

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Caching

Disk blocks used for storing directories or recently used files cached in main memory

Blocks periodically written to disk

⇒ Big efficiency gain

Inconsistency arises when system crashes

Reason why computers must be shutdown properly

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Journaling File Systems

To minimise data loss at system crashes, ideas from databases are used:

- Define **Transaction points**: Points where cache is written to disk
⇒ Have consistent state
- Keep log-file for each write-operation
Log enough information to unravel any changes done after latest transaction point

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RAID: Redundant Array of Independent Disks

Main purpose: Increase reliability

- **Mirroring**: Store same data on different disks
- **Parity Schemes** Store data on n disks. Use disk $n + 1$ to contain parity blocks
⇒ can recover from single disk failure

Disadvantage: Parity bit needs to be re-computed for each write operation

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Disk access contains three parts:

- **Seek**: head moves to appropriate track
- **Latency**: correct block is under head
- **Transfer**: data transfer

Time necessary for Seek and Latency dwarfs transfer time

⇒ Distribution of data and scheduling algorithms have vital impact on performance

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Disk scheduling algorithms

Standard algorithms apply, adapted to the special situation:

1.) **FCFS**: easiest to implement, but: may require lots of head movements

2.) **Shortest Seek Time First**: Select job with minimal head movement

Problems:

- may cause starvation
- Tracks in the middle of disk preferred

Algorithm does not minimise number of head movements

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3.) **SCAN-scheduling**: Head continuously scans the disk from end to end (lift strategy)
⇒ solves the fairness and starvation problem of SSTF

Improvement: **LOOK-scheduling**: head only moved as far as last request (lift strategy).

Particular tasks may require different disk access algorithms

Example : **Swap space management**

Speed absolutely crucial ⇒ different treatment:

- Swap space stored on **separate partition**
- **Indirect access methods not used**
- **Special algorithms used for access of blocks**
Optimised for speed at the cost of space (e.g., increased internal fragmentation)

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Standard interface important for plethora of device types

Have a few **basic operations**:

- open
- read
- write
- close

Example: UNIX devices listed in `/dev`
different types implement different operations:
sequential vs. random access
character-stream vs. block device

Start with **Logical View**:

Devices can be classified according to **possible operations**:

- **Character devices**: transfer bytes one by one
- **Block devices**: transfer blocks of bytes as units
- **Memory mapped devices**: OS interpretes memory access as access to device
- **Network devices**: Receive packets over the network

Have **also different system calls**:

blocking vs. non-blocking (system call returns after completion / immediately)

Physical View

Interaction between device and CPU:

- **Polling**: works for fast operations (eg graphics)
- **Interrupts**: standard way, priorities important
- **Direct Memory access**: implements the memory mapping without burdening the CPU

OS support for I/O:

- **Buffers**: need intermediate storage during transfer
- **Caches**: fast memory
- **Support for spool files**

I/O can be major **performance bottleneck**

Reason: enormous number of context and state switches

Ways out:

- **Hardware support**: DMA (Direct Memory Access) chips
- **OS support**: re-implementing telnet daemon using in-kernel threads (Solaris)
- **Buffers**: cope with speed mismatch (modem, hard disk), different data-transfer size (networks)
- **Caching**: keep disk blocks in free main memory