



The storage structure in operating systems is a hierarchical, multi-level system that balances speed, cost, and capacity. It consists of volatile, fast storage (registers, cache, RAM) for active processing and non-volatile, slower storage (magnetic disks, SSDs, tape) for permanent data storage, often managed using caching to improve performance.

Storage Hierarchy

Storage devices are arranged in a hierarchy based on decreasing speed and cost, but increasing capacity:

- **Registers:** Fastest, smallest capacity, inside the CPU.
- **Cache:** Fast memory, stores frequently used data from main memory.
- **Main Memory (RAM):** Primary storage, fast, but volatile (loses data without power).
- **Secondary Storage:** Non-volatile, large capacity (e.g., HDDs, SSDs).
- **Tertiary Storage:** Very slow, archival storage (e.g., magnetic tapes).

Key Concepts

- **Volatile vs. Non-volatile:** Volatile memory (RAM, Cache) loses data when power is lost. Non-volatile (HDD, SSD, ROM) retains data.
- **Caching:** Copying data from slower secondary storage to faster main memory to improve speed.
- **Device Controllers:** Manage the interface between storage devices and the OS, handling data transfer.
- **Mass Storage Structure:** Modern systems use magnetic disks or SSDs for high-capacity storage, often with RAID (Redundant Array of Independent Disks) for reliability.

Storage Device Components

- **Magnetic Disks:** Consist of platters with read-write heads that move across the surface to access data.
- **Solid-State Disks (SSD):** Non-volatile memory technology used like a hard drive, typically faster than traditional magnetic disks.

Key Operations in Disk Management

Disk Formatting

- **Low-level (physical) formatting:** Divides the disk into sectors with headers, data, and error correction codes (ECC).
- **Logical formatting:** Creates a file system, defining free space and allocated space.
- Blocks are grouped into clusters for efficient I/O.
- Some systems allow raw I/O (direct access to disk blocks without a file system).

2. Booting from Disk

- The bootstrap program loads the OS kernel into memory when the computer is powered on.
- A small bootstrap loader resides in ROM.
- The full bootstrap code is stored in the boot block of the disk.
- A disk with a boot partition is called a boot disk (system disk).

3. Bad Block Management

Disks often have bad sectors due to manufacturing defects or usage.

Handled using:

- **Sector sparing (replacement):** faulty sectors are replaced with spare ones.
- **Error recovery:** for soft errors.
- **Manual intervention:** required for hard errors.

Severe disk failures may require replacing the disk and restoring from backup.

Some common disk management techniques used in operating systems include:

- **Partitioning:** Divides a physical disk into multiple logical partitions, each acting as a separate storage device for better organization.
- **Formatting:** Prepares a disk by creating a file system; erases all existing data.
- **File System Management:** Manages file systems (e.g., FAT, NTFS, ext4) to store and access data efficiently.
- **Disk Space Allocation:** Allocates space for files using methods like contiguous, linked, or indexed allocation.
- **Disk Defragmentation:** Rearranges scattered data blocks to improve performance.