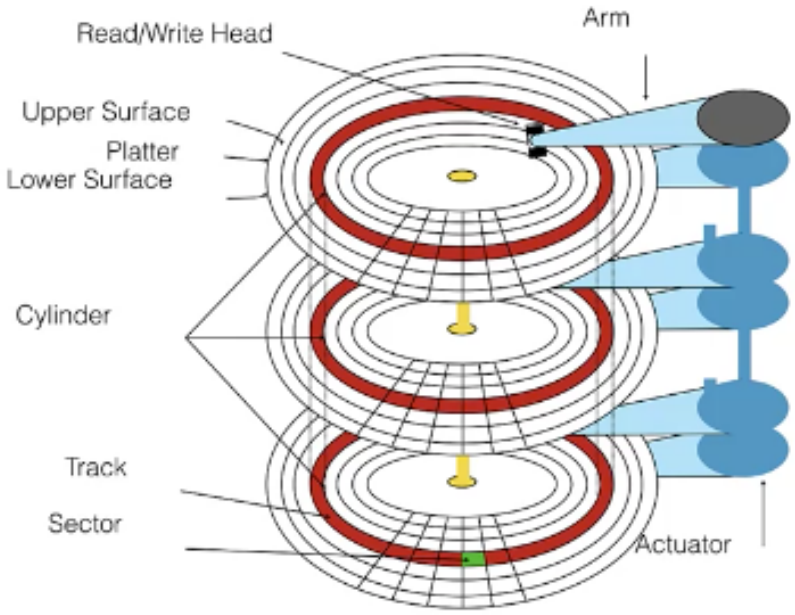
1. **Secondary Storage Devices**
    - Focus will be on hard-drives
2. **Disk Components**



- Parts
    - **Platter:**
        - Data can be stored in both upper and lower parts of the platter
    - **Cyliner:**
        - Is a set of tracks that can be read without moving the arm
    - **Sector:**
        - Size of disk block is multiple of sectors
- Disk suface crash

    - Occurs when disk arm touching surface

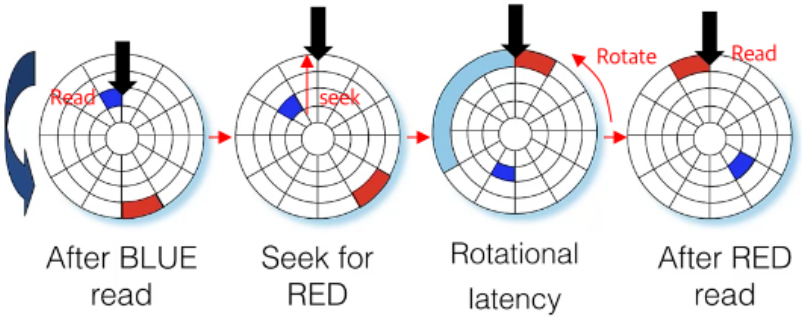
- Results in permanent loss of information on the track

3. **Disk Performance**

IMPORTANT We should know the bulk part time of how this works

- **Seek:**
  - Is the time it takes to move the disk arm to correct cylinder
  - Depends on how fast disk arm can move
  - Typical time: 1-15ms, depending on distance (avg 5-6 ms)
  - Improves very slowly (7 - 10% per year)
- **Rotation:**
  - Is the time it takes to rotate under the head to get to correct sector
  - Depends on rotation rate of disk
  - Average latency of $\frac{1}{2}$ rotation
- **Transfer:**
  - Is the time it takes to transfer data from surface to disk controller, electronics and sending it back to host
  - Depends on density
  - $\sim$ 100MB/s, average sector transfer time of $\sim 5\mu s$
  - Improves rapidly ($\sim$ 40% per year)

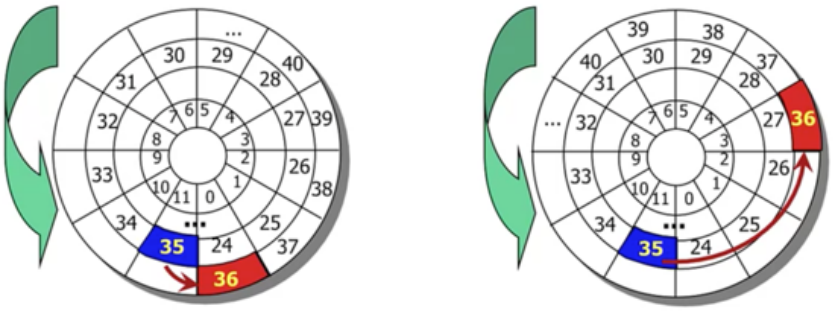
4. **Traditional Service Time Component**



- OS tries to minimize the cost of rotational latency, transfer time, and seek time
- Improvement attention especially on seek time and rotation latency

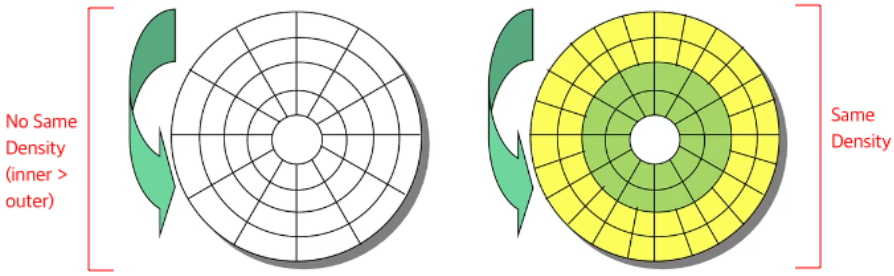
5. **Some Hardware Optimizations**

- **Track Skew**



  - Has to do with numbering on tracks
  - Is to reduce rotational latency

- **Zones**



-
  - Is to make sure data is stored with same density
  - Is done to maximize the capacity of hard drive
  - Outer tracks → holds more sectors
- **Cache**
  - Is also called **Track Buffer**
  - Is a small memory chip embedded in hard drive ($8 - 16$MB)
  - Is aware of disk geometry
  - May cache whole track
  - Boosts future reads on the same track

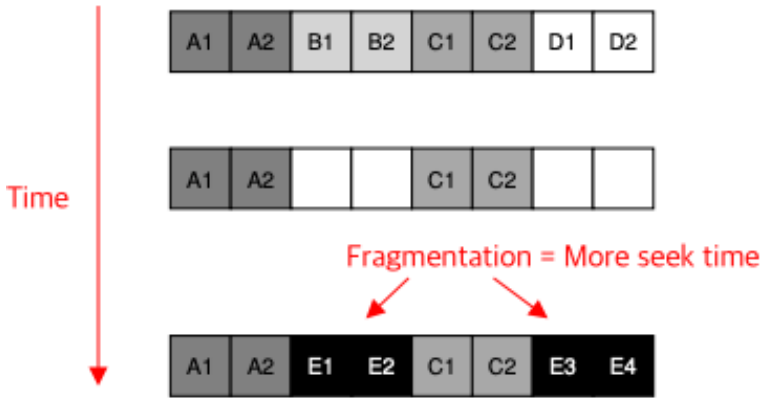
6. **Disk and the OS**

- The OS provides different levels of disk access to different clients
  - Physical disk (e.g surface, cylinder, sector)

IMPORTANT Logical disk (disk block #) ← what we will do for the first assignment

  - Logical file (e.g file block, record, or byte #)

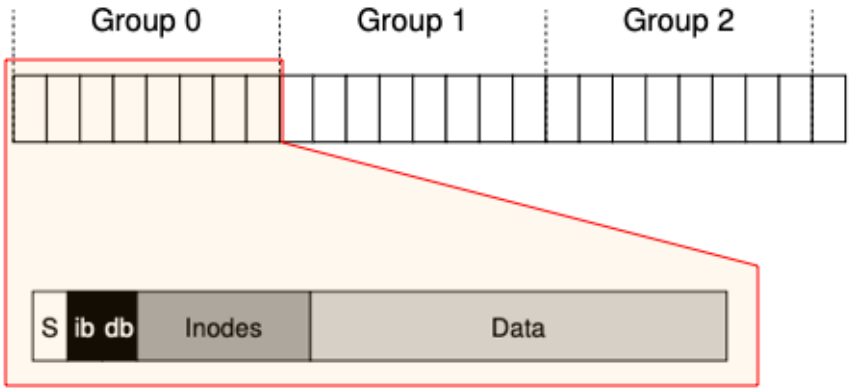
- **Enhancing Disk Performance**
  - File system needs to be aware of disk charactersistics for performance
    - **Allocation Algorithm** → enhances performance
      - e.g Extent-based allocation, indexed based allocation, linked-based allocation
    - **Request Scheduling** → reduce seek time
      - e.g. FCFS, SSTF, SCAN, C-SCAN
  - Disk characteristics yields to goals:
    - **Amortization**
      - Compensates positioning delay
      - Grabs lots of useful data while at it
      - Performance improvement upto factor of 10
    - **Closeness**
      - Done by putting things close to each other
      - Performance benefit in factors of 2
- **Allocation Strategies**
  - Disk perform best if seeks are reduced and large transfers are used
    - Done by allocating data close together
    - Reason why significant improvement in seek time and transmission time over the years
- **Original Unix File System**
  - Is simple and straightforward
  - Is slow (poor use of disk bandwidth)
  - Has 2 placement problems
    1. Fragmentation



       - Causes more seeking
    2. The travel of back and forth between inode and data blocks

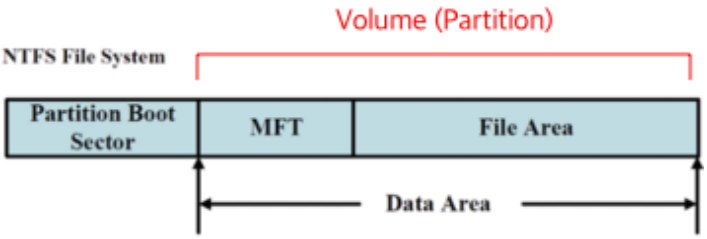
    - More seeking time

- **Fast File System**
  - Is a disk aware file system
  - Addressed placement problems using **cylinder groups**



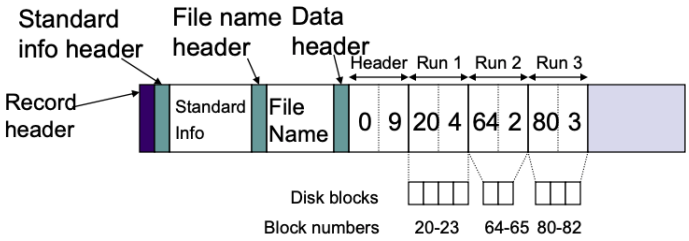
    - Steps
      - Data blocks in the same file allocated in same cylinder group
      - Files in the same directory allocated in same cylinder group
      - Inodes for files allocated in same cylinder group as file data blocks
    - Allocation in cylinder groups provide closeness → less long seeks
    - Has **Free space requirements**
      - requires free space to be scattered across disk to allocate properly using **cylinder groups**
      - 10% of total disk space in each **cylinder group** is reserverd for this
      - Doesn't like filling up one cylinder group
      - Large file is allocated by breaking into cunkhs and storing each in different cylinder groups
      - Allocates near by cylinder group if preferred cylinder group is full

- **NTFS**

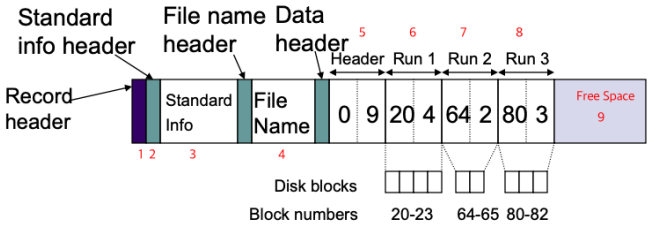


  - Is replacement of old FAT file system
  - Uses extent-based allocation
    - Tries to allocate files in consecutive blocks
  - Each volume is a linear sequence of blocks (usually 4KB in size)
  - Each has a **master file table**
    - Is 1KB (or Kib) long
    - One or more records per file or directory
      - Is analogous to **inode**
    - Long attributes can be stored externally, and a pointer kept in MFT record

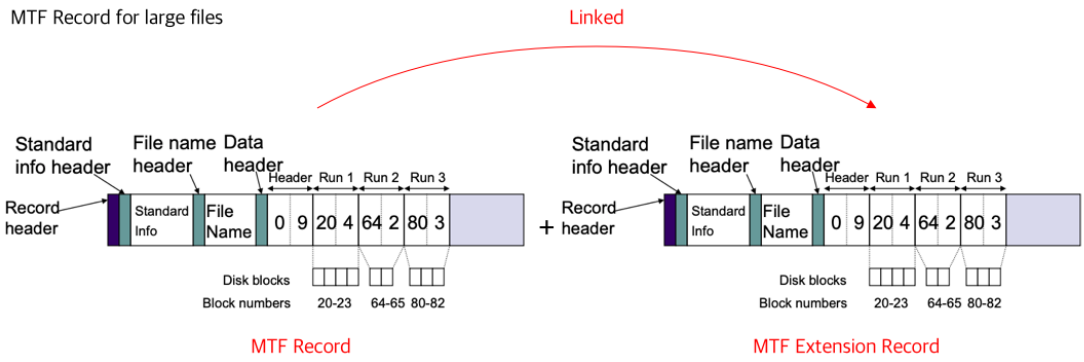
- **MFT Record**



  - Is analogous to inode
  - Is a 9-run 3-block file



  - Each data attribute indicates the starting block and the number of blocks in a run (or extent)
  - If all records are large and one MTF recrod is not enough, extension record is used to hold more


MTF Record for large files
Linked
Standard info header
File name header
Data header
Header
Run 1
Run 2
Run 3
Record header
Standard Info
File Name
0 9 20 4 64 2 80 3
Disk blocks
Block numbers
20-23
64-65
80-82
MTF Record
+
Record header
Standard Info
File Name
0 9 20 4 64 2 80 3
Disk blocks
Block numbers
20-23
64-65
80-82
MTF Extension Record