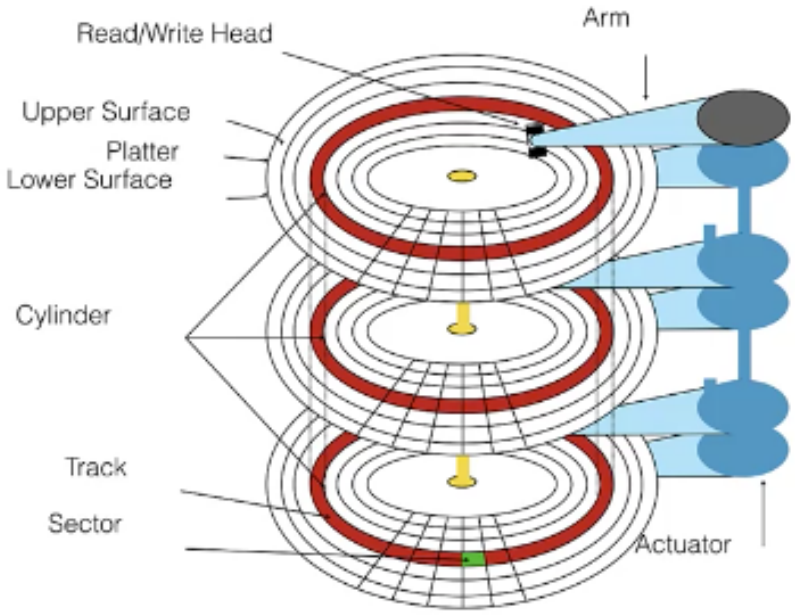
1. **Secondary Storage Devices**
    - Focus will be on hard-drives
2. **Disk Components**



- 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

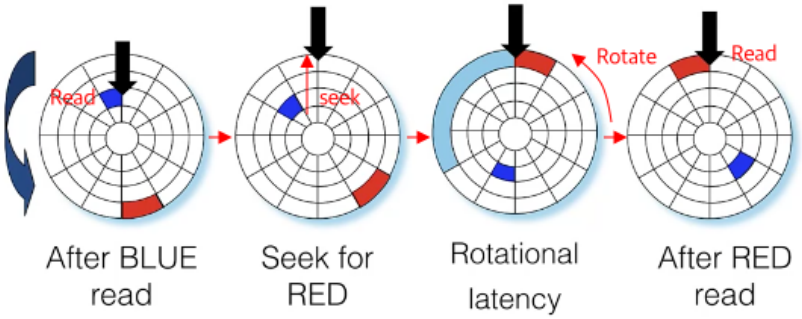
- Results in permanent loss of information on the track

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)

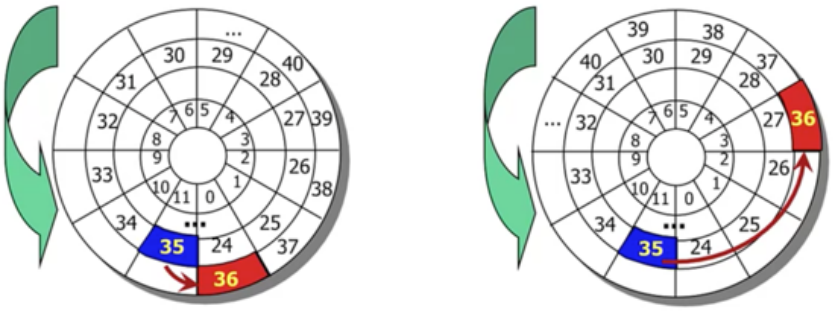
4. **Traditional Service Time Component**



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

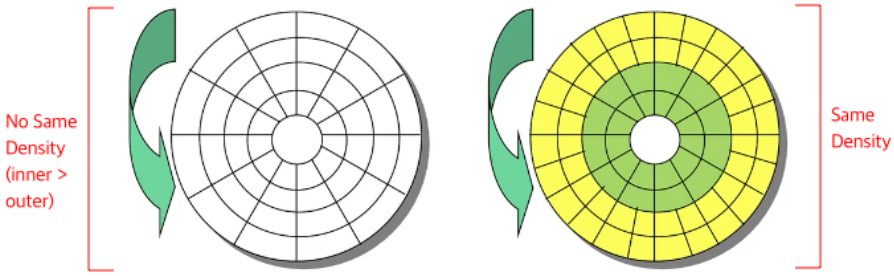
5. **Some Hardware Optimizations**

- **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

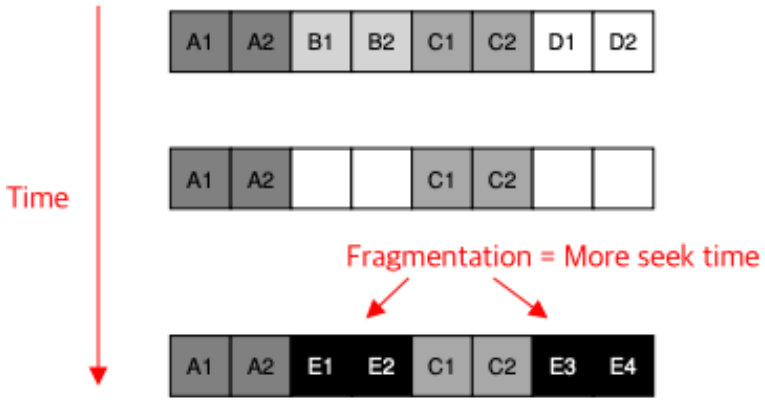
6. **Disk and the OS**

- 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 #)

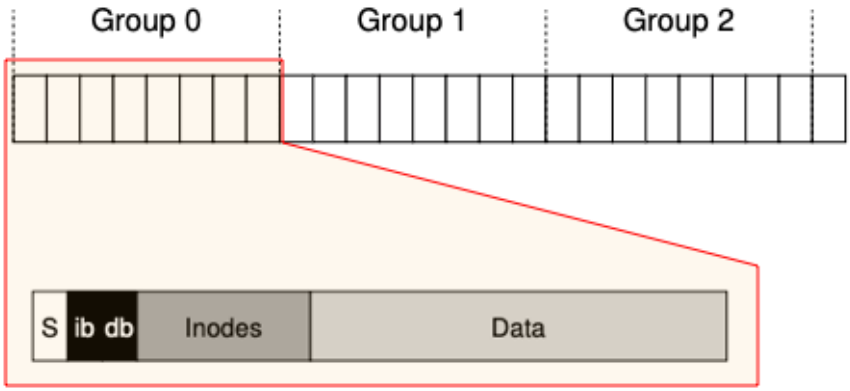
- **Enhancing Disk Performance**
  - File system needs to be aware of disk charactersistics for performance
    - **Allocation Algorithm** → enhances performance
      - e.g Extent-based allocation, indexed based allocation, linked-based allocation
    - **Request Scheduling** → reduce seek time
      - 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

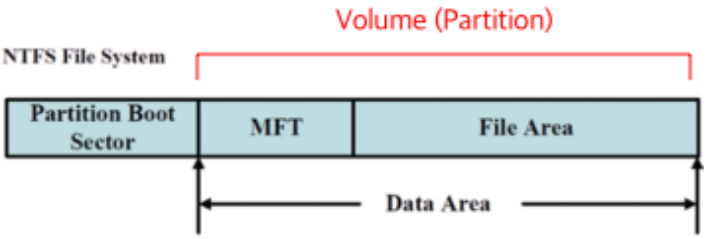
    - More seeking time

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



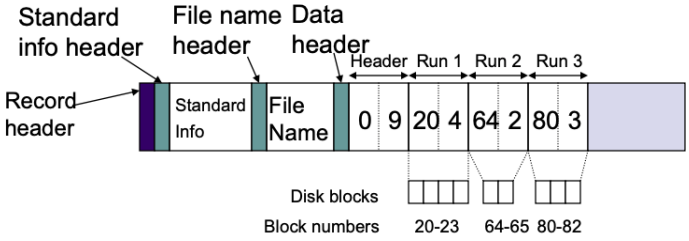
    - Steps
      - Data blocks in the same file allocated in same cylinder group
      - Files in the same directory allocated in same cylinder group
      - Inodes for files allocated in same cylinder group as file data blocks
    - Allocation in cylinder groups provide closeness → less long seeks
    - 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**



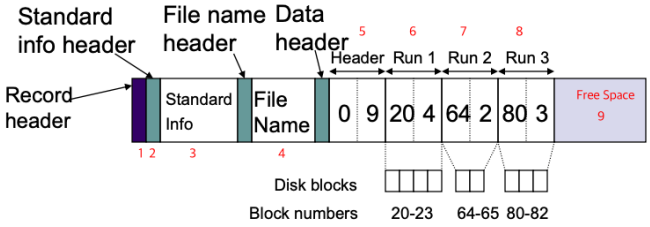
  - Is replacement of old FAT file system
  - Uses extent-based allocation
    - Tries to allocate files in consecutive blocks
  - Each volume is a linear sequence of blocks (usually 4KB in size)
  - Each has a **master file table**
    - Is 1KB (or Kib) long
    - One or more records per file or directory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

- **MFT Record**

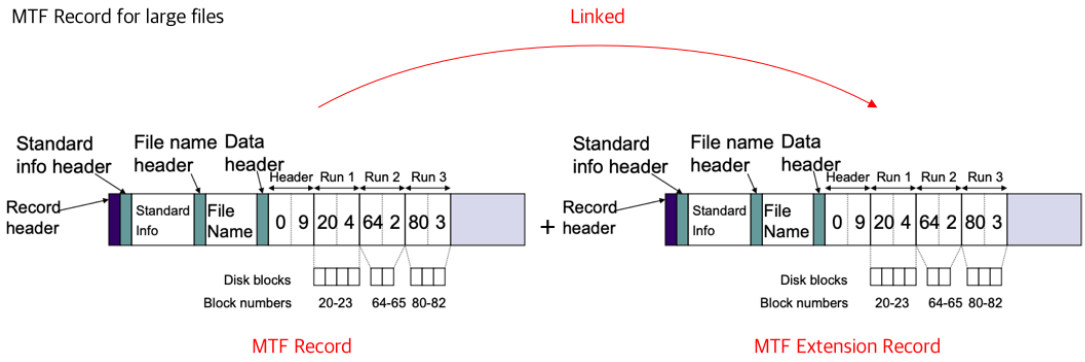


Question How does Master File Record look like when a file grows from a small to a larger file where 1 MTFR is not enough?

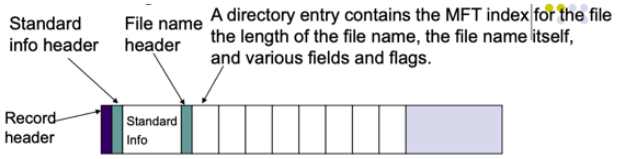
  - Is analogous to inode
  - Is a 9-run 3-block file



- 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 a Small Directory**



- Directories are stored as a simple list
- Large directories use **B+ trees**

- **MTF Small File**

- Small files can be stored directly inside MTF record