This chapter discusses how mass storage - the nonvolatile storage system of a computer is structured. The main mass-storage system in modern computers is the secondary storage, which is usually provided by hard disk drives (HDD) and nonvolatile memory (NVM) devices.

Hard Disk Drives (HDDs)

- Hard disk drives (HDDs) and nonvolatile memory (NVM) devices are the major secondary storage I/O units on most computers. The secondary storage is structured as large one-dimensional arrays of *logical blocks*
- Drives of either type may be attached to a computer system in one of three ways: (1) through the local I/O ports on the host computer, (2) directly connected to motherboards, or (3) through a communications network or storage network connection
- Requests for secondary storage I/O can be generated by file systems or virtual memory system (e.g., page faults). Each request specifies the address on the device to be referenced in the form of a *logical block number*
- The surface of a disk **platter** is divided into circular **tracks**, which is further subdivided into **sectors** (hundreds of them). The set of tracks (thousands or tens of thousands of those) that at one arm position (on multiple plates) makes up a **cylinder**.
- **Transfer rate** is the rate at which data flows between drive and computer, typically several gigabits per second or hundreds of megabytes per second
- **Positioning time** (random-access time) is the time to move the disk arm to the desired cylinder (**seek time**, typically measured by **seek distance** in term of number of cylinders) and the time for the desired sector to rotate under the disk head (**rotational latency**), usually in several milliseconds. Average seek time calculated based on 1/3 of tracks and average rotational latency is ½ rotation time (1/rps)

Disk Scheduling

- **FCFS**: this is intrinsically fair, but the performance can suffer depending on the request orders.
- **SSTF**: the shortest-seek-time-first. Usually, better performance in term of the average seek time than FCFS, but can result in starvation.
- **SCAN** and **LOOK** service requests in both directions, while **C-SCAN** and **C-LOOK** service requests in one direction.
- There could be a variety of factors affecting the selection of disk scheduling algorithms such as directory and file allocation (discussed in Chapters 13-14). Under a given set of requests, an optimal scheduling can be derived, though that could be computationally expensive; also, this can be of little practical use as requests come dynamically. Typically, SSFT and LOOK are default choices.
- Disk-scheduling algorithms can improve the effective bandwidth of HDDs, the average response time, and the variance in response time. Algorithms such as SCAN and C-SCAN are designed to make such improvements through strategies

for disk-queue ordering. Performance of disk scheduling algorithms can vary greatly on hard disks. In contrast, because solid-state disks have no moving parts, performance varies little among different scheduling algorithms, and quite often a simple FCFS strategy is used

RAID

- This provides high reliability via *redundancy* and performance improvement in term of high data-transfer rate through *parallelism*.
- Bit-level or block-level striping can be used for performance improvement (parallelism).