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Chapter 2.2

Logical Components of the Host

Aim

To equip the students with the understanding of the logical components of the host

Instructional Objectives

After completing this chapter, you should be able to:

- Describe the disk drive performance and the impact of the disk service time
- Explain the fundamental laws of disk performance
- Elaborate each of the logical components of the host
- Identify the factors affecting disk performance

Learning Outcomes

At the end of this chapter, you are expected to:

- Outline the various measures of the disk performance
- State the fundamental laws of governing disk performance
- Outline the logical components of the host
- Identify the ways to overcome factors affecting disk performance

2.2.1 Introduction

The core of any enterprise-level storage system are the data storage components. From mundane memorandums to mission-critical sales record, everything needs to be stored appropriately. A storage system should be capable of handling the data of all levels, from being ancillary to critical.

In the previous chapter, we read about storage in disk drive and the different components of a disk drive. To quickly summarise, a disk drive is an electromechanical device, which governs the overall performance of the storage system environment. The key components of a disk drive are platter, spindle, read/write head, actuator arm assembly and controller.

This chapter focuses primarily on the performance of the disk drive and logical host components. After we are aware of the disk driver, we must also understand what factors can impact the performance of the disk drive. In the coming topics, we will discuss and understand the performance of a disk drive and impact of the disk service time. We will also discuss the logical components of the host and the fundamental laws and factor that can have an effect on the performance of the disk drive.

Let us begin with understanding the disk drive performance and disk service time.

2.2.2 Disk Drive Performance

The disk drive performance is extremely crucial for the overall speed of the system. A slow hard disk has the potential to hinder a fast running processor like no other component of the system.

The effective speed of a disk drive is determined by a number of factors. One of the most important factors amongst them is the revolution per minute (RPM) speed of the platter. RPM is considered a critical component in terms of disk performance as it directly impacts the latency and the disk transfer rate. If the platters spin faster, more data passes under the read/write head; if the RPM is slower, the mechanical latencies are higher.

(i) Disk Service Time

It refers to the amount of time taken by a disk to complete an input/output (I/O) request. Three are certain components that contribute to the disk service time on a disk drive. They are:

- Seek time
- Rotational latency
- Data transfer rate

Let us discuss each of these components in detail and understand how each one of them contribute to the disk service time.

Seek Time

The seek time describes the time taken to figure out the disk area where the specific piece of information that needs to be read or written to is stored. It is the time taken to place the read/write head across the platter with a radial movement, which is a movement along the radius of the platter and settle the arm and the head over the correct track. When the seek time is lower, the I/O operations are faster.

Seek time can be measured in the following ways:

- **Average seek time:** For a given disk, the seek time can be different and may vary because of the varying distance from the starting point to the point where the read/write operations needs to take place. An average seek time is the average time taken by the read/write head to move from such point to another. Normally, the average seek time is listed as the time for one-third of a full stroke. On a modern disk, the average seek time is generally in the range of 3 to 15 milliseconds.

- **Full Stroke:** It is the amount of time taken by the read/write head to move across the complete width of the disk drive, starting from the innermost track to the outermost track. That means, it can simply be understood as the amount of time required to seek the whole disk. A full stroke is measured in milliseconds and a seek time which is below 10 milliseconds is, generally, considered acceptable for a disk.

- **Track to track:** It is the amount of time taken by the read/write head to move between adjacent tracks in order to search or seek data. Track to track is also measured in milliseconds. It is typically 2 to 4 milliseconds and can go as low as 1 millisecond.

The impact of seek time is more on the read operation of the random tracks as compared to the adjacent tracks. In order to bring down the seek time, data can be written to just a subset of the available cylinders. This can result in lower usable capacity than the actual capacity of the drive. **Short-stroking** can be performed on the device to bring down the seek time. Short-stroking is a practice of formatting a disk in a way so that the data gets written only to the outer sectors of platters.

Short-stroking can reduce latency and increase the performance of the disk as it lessens the time taken by the actuator to spend seeking sectors on a platter. The actuator arm holding the read/write head, moves around the platter similar to a record player arm moves across a vinyl record. Short-stroking restricts the maximum distance of the read/write head from any given point on the disk by confining the read/write head to the outside edge of the disk.

Rotational Latency

Over a platter, the actuator moves the read/write head to a particular track in order to access the data. In the meanwhile, the platter spins to correctly position the requested sector under the read/write head. This particular time taken to position the data under the read/write head by rotating and repositioning the platter is known as rotational latency.

The rotational latency is dependent on the RPM speed of the spindle. It is also measured in milliseconds. The average rotational latency is half the time required for a full rotation. Like seek time, rotational latency also has its major impact on the reading and writing of random sectors than adjacent sectors. The average rotational latency is approx. 5.5 milliseconds for a 5,400 RPM drive. It is approx. 2 milliseconds for a 15,000 RPM drive.

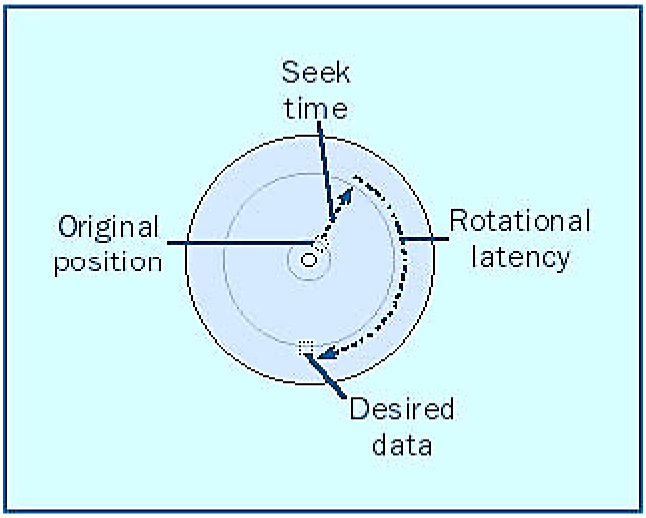

Figure 2.2.1: Seek Time and Rotational Latency

Data Transfer Rate

It is also known as transfer rate and it refers to the average amount of data per unit time that can be delivered by the drive to the host bus adapter (HBA). To understand and calculate data transfer rate better, it is important that you properly understand the process of read and write operations.

When a read operation is performed, the following happens:

- The data first moves to read/write head from the disk platters.
- Then, it moves to the internal buffer of the drive.
- Finally, the data moves to the host HBA from the buffer through the interface.

When a write operation is performed, the following happens:

- The data moves through the drive's interface from the HBA to the internal buffer of the drive.
- Then, it moves from the buffer towards to read/write head.
- Finally, the data moves to the platters from the read/write head.

During the read/write operations, the data transfer rates are measured in terms of internal and external transfer rates.

An **internal transfer rate** is the speed of the movement of data from a single track of the surface of the platter to the cache or internal buffer of the disk. Internal transfer rate takes into account the seek time factor.

An **external transfer rate** is the rate of the movement of data through the interface to the HBA. Generally, the advertised speed of the interface is the external transfer rate, such as 133 MB/s for ATA (Advanced Technology Attachment). The sustainable external transfer rate is lower than the speed of the interface.

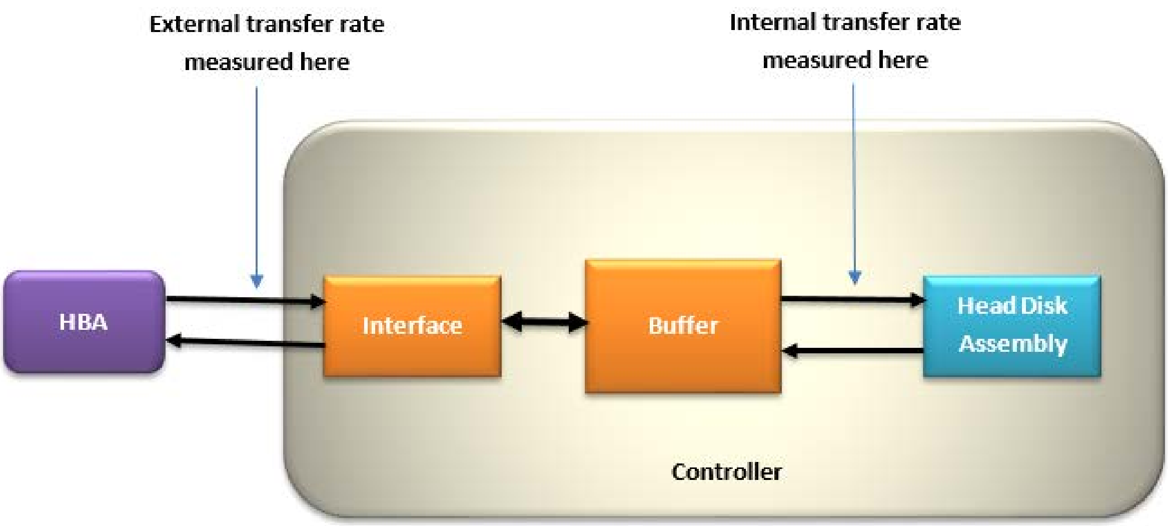

Figure 2.2.2: Data Transfer Rate

Let us understand how to calculate the data transfer rate with the help of a simple example. Although there are various online calculators available that can help you calculate in minutes, such as http://www.calctool.org/CALC/prof/computing/transfer_time and http://www.convert-me.com/en/convert/data_transfer_rate/, but if you want, you can also calculate it manually.

Let us consider the file size is 2 GB file and the transfer speed is 50 Mbps. Note that we are considering there is no latency and no additional packets of data are being sent along with the file.

Data transfer rate = file size in bits / transfer speed (bits per second)

The first thing that needs to be done is to convert the file size and transfer speed into bits.

We know that 8 bits = 1 byte, 1,024 bytes = 1 KB, 1,024 KB = 1 MB and 1,024 MB = 1 GB.

So, 2 GB = 2 x 1,024 x 1,024 x 1,024 x 8 bits = 17,179,869,184 bits.

Now, we need to convert the transfer speed from Megabits per second (Mbps) to bits per second (bps).

We know that 1,000 bits = 1 Kilobit (Kb) and 1,000 Kb = 1 Megabit (Mb).

So, 50 Mbps = 50 x 1000 x 1000 = 50,000,000 bps.

Data transfer rate = 17,179,869,184 bits / 50,000,000 bps = 343.59738368 seconds.

You should also note the usage of MB or KB and Mb or Kb. An uppercase B should always be the unit of bytes and the lowercase b should always be the unit of bits.

There are a variety of hard disks available in the market. Visit some online stores and compare 2-3 hard disk drives along with their specifications. Try to figure out which amongst them will provide the best disk drive performance.

Did You Know?

Seek time is also known as access time and it is generally measured as an average seek time.

Self-assessment Questions

1) Which of the following is an important factor in determining the effective speed of the disk drive?

   a) RMP b) RPM

   c) HBA d) HAB

2) What is the minimum amount of time taken by the read/write head to move between adjacent tracks for seeking data?

   a) 1 millisecond b) 2 milliseconds

   c) 5 milliseconds d) 4 milliseconds

3) Which of the following should be performed on a disk to bring down the seek time?

   a) Rotational latency b) Internal data transfer

   c) Short-stroking d) External data transfer

2.2.3 Fundamental Laws Governing Disk Performance

In order to understand the fundamental laws governing the disk performance, let us view a disk drive as a black box that consists of the following two elements:

- **Queue:** Before an I/O request is processed by the I/O controller, the I/O request waits at a location. That location can be understood as a queue.
- **Disk I/O Controller:** One after another, it processes the I/O requests that are waiting in the queue.

The rate at which the I/O requests arrive at the controller is known as the **arrival rate**. This arrival rate is generated by the application. These requests take place in the I/O queue and henceforth, the I/O controller starts processing the requests one after another.

The performance of the disk system is measured by the I/O arrival rate, the length of the queue and the time taken by the I/O controller to process each request in the queue. The performance of the disk system is measured in terms of response time.

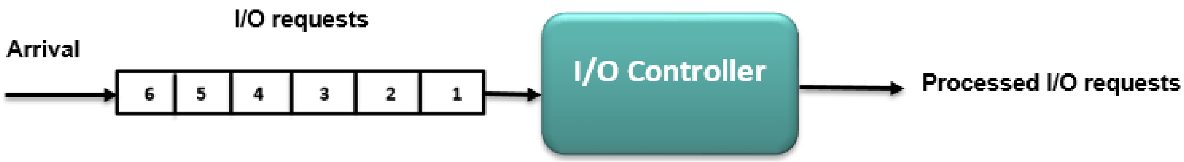

Figure 2.2.3: I/O Processing

The relationship between number of requests in a queue and the response time is described by a fundamental law known as the Little's Law.

According to Little's law:

N = a x R

Where,

N = Total number of requests in the queue system, which means total number of requests in the queue + total number of requests in the I/O controller

a = Arrival rate of the I/O requests

R = Average response time or the turnaround time for an I/O request

The I/O controller utilisation is defined by another important law, known as the Utilisation Law.

According to the Utilisation Law:

$U = a \times R_S$

Where,

U = I/O controller utilisation

a = Arrival rate of the I/O requests

R_S = Average time spent by a request on the I/O controller

Did You Know?

R_S is also known as service time and service rate can be calculated as $1/R_S$.

Service rate = $1/R_S$

Using the arrival rate, a, you can also calculate Ra or the average inter-arrival time, as follows:

$Ra = 1/a$

Similarly, you can calculate utilisation, U, as follows:

$U = R_S / Ra$

The value of this ratio will vary between 0 and 1.

In a single controller system, it is important that the arrival rate must be smaller than the service rate or you can also say that the service time should be smaller than the average inter-arrival time. If this fails to happen, then the I/O requests will arrive in the system prior to the I/O controller can process them.

Using the Little's Law and the Utilisation Law, important measures of disk performances can be derived, such as average response time, average queue length and time spent by a request in a queue.

Now, the average response rate, S, can be calculated using the following equation:

S = service rate – arrival rate

S, or average response rate, can also be defined as the reciprocal of the average response time, R.

Hence,

R = 1/ (service rate – arrival rate)

We also know the relation between the service rate and the service time, R_S;

Service rate = $1/R_S$

So, the equation for average response time, R, can also be written as:

$R = 1/ (1/R_S – a)$

$R = R_S/ (1 – a \times R_S)$

We also know the equation for utilisation, U;

$U = a \times R_S$

Replacing the value of $a \times R_S$ with U in the formula:

$R = R_S/ (1 – U)$

Or

R (Average response time) = service time/ (1 – utilisation)

As the I/O controller saturates, utilisation reaches 1; the response time then is closer to infinity. The saturated component, which is the bottleneck, forces the serialisation of I/O requests. This means each I/O request has to wait for the I/O request before it.

Utilisation can also be used to represent the average number of I/O requests on the controller.

Number of requests in the queue (NQ) = Number of requests in the system (N) - Number of requests on the controller or utilisation (U)

$N_Q = N – U$

Now, we know that $N = a \times R$

Using the same in this equation, we get:

$N_Q = a \times R - U$

We also know that $R = R_S / (1 - U)$

Using the same in this equation, we get:

$N_Q = a \times (R_S / (1 - U)) - U$

We also know that $a = 1 / Ra$

Replacing the value of a with 1/Ra and equating, we get:

$N_Q = (R_S / Ra) / (1 - U) - U$

We know that $U = R_S/Ra$; hence, replacing the value of U with this equation, we get:

$N_Q = U / (1 - U) - U$

$N_Q = U (1 / (1 - U) - 1)$

$\mathbf{N_Q = U^2 / (1 - U)}$

Did You Know?

Number of request in a queue is also known as **average queue size**.

The time spent by a request in the queue is the same as the time spent by a request in the system, or we can also say that the average response time minus the time spent by a request on the controller for processing:

$= R - R_S$

Now, we know that $R = R_S / (1 - U)$; putting the value of R as $R_S / (1 - U)$, we get:

$= R_S / (1 - U) - R_S$

$= U \times R_S / (1 - U)$

= U x average response time

$\mathbf{= U \times R}$

Let us refer to Table 2.2.1 for quickly summarising the equations learnt just now.

Important Equations	
Total number of request in the queue system (N)	= a x R
Utilisation (U)	= a x R_S
Service rate	= 1/ R_S
Average inter-arrival time (Ra)	= 1/ a
Utilisation (U)	= R_S/ Ra
Average response rate (S)	= service rate – arrival rate
Average response time (R)	= R_S/ (1 – U)
Number of request in a queue (N_Q)	= U^2 / (1 – U)
Time spent by request in a queue	= U x R

Table 2.2.1: Important Equations

Let us consider an example where we can apply all these equations.

Let us consider an I/O system of the disk. An I/O request arrives in the system at a rate of 100 I/Os per second. Rs, or the service time, is 6 ms. With this amount of information, let us calculate the following:

- Utilisation of I/O controller (U)
- Average response time (R)
- Average queue size (N_Q)
- Total time spent by a request in the queue (U X R)

Let us start calculating these now.

Arrival rate (a) = 100 I/O/s; hence, the arrival time

Ra = 1/ a = 10 ms (Note that we are changing seconds into ms here; so, 1/100 = 0.01 sec = 0.01 x 1000 = 10 ms)

R_S = 6 ms (given)

$U = R_S / Ra = 6 / 10$

$= 0.6$ or 60%

$R = R_S / (1 - U)$

$= 6 / (1 - 0.6) = 15$ ms

$N_Q = U^2 / (1 - U)$

$= (0.6)^2 / (1 - 0.6) = 0.9$

Time spent by a request in a queue = $U \times R = 9$ ms

Now, if we double the controller power, consequently, the service time will be halved;

Hence, $R_S = 3$ ms in this scenario.

$U = 3 / 10 = 0.3$ or 30%

$R = 3 / (1 - 0.3) = 4.28$ ms

$N_Q = (0.3)^2 / (1 - 0.3) = 0.12$

Time spent by a request in a queue = $0.3 \times 4.28 = 1.28$ ms

With the above example, we can conclude that if the service time is reduced by half or if the utilisation is reduced by half, the response time get reduced drastically. From the above example we can see that the response time got reduced from 15 ms to 4.28 ms when the service time was reduced to half.

Self-assessment Questions

4) Which of the following is the rate at which the I/O requests arrive at the I/O controller?
   a) Service rate
   b) Arrival rate
   c) Average arrival rate
   d) Arrival time

5) Which of the following is the correct equation for calculating time spent by a request in the queue?
   a) 1/ RS
   b) a x R
   c) RS/ Ra
   d) U x R

6) Which of the following equation has been given by the Little's Law?
   a) N = a x R
   b) U = a x RS
   c) NQ = N – U
   d) NQ = U2 / (1–U)

2.2.4 Logical Components of the Host

The software applications and the protocols that facilitates data communication with the user as well as physical components can be understood as the logical components of the host. The logical components of the host are as follows:

- Operating system
- Device drivers
- Volume manager
- File system
- Application

Let us discuss each logical component of the host in detail.

(i) Operating System

Every aspect of the computing environment is controlled by the operating system. The operating system:

- Works between the physical components of the computer system and the applications.

- Provides data access to the applications.
- Monitors and responds back to the user actions and the environment.
- Organises and controls the hardware components.
- Manages the allocation of the hardware resources.

Basic security for the access and usage of all managed resources is provided by the operating system. It also performs the core storage management tasks while managing different underlying components, such as the volume manager, device drivers and file system.

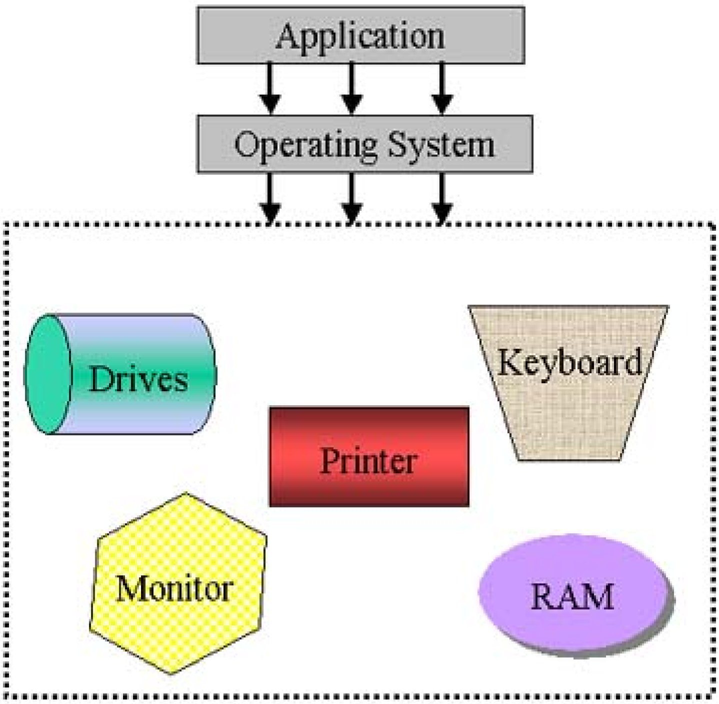

Figure 2.2.4: Operating System

(ii) Device Driver

When the operating system needs to communicate with any physical device, such as a printer, mouse, or a hard drive, it requires a device driver to enable that action. A device driver is a special software that allows the operating system to interact and connect with the physical devices. It helps the operating system in recognising the device and enables it to use a standard interface, such as an application programming interface (API), to access and control the devices. Device drivers are dependent on hardware and are specific for each operating system.

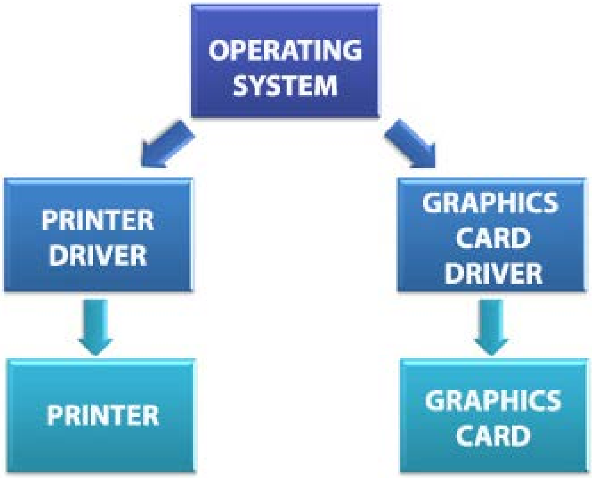

Figure 2.2.5: Device Driver

(iii) Volume Manager

A volume manager is a software within an operating system. It controls the capacity allocation for storage arrays. Volume manager allows disk partitioning that improves the flexibility and utilisation of disk drives. In partitioning, a disk drive is divided into logical containers known as **logical volumes**. Based on the file system's and the data requirement, a physical drive can be partitioned into multiple logical volumes. When the hard disk is initially set up on the host, the partitions are created from the groups of contiguous cylinders.

The process of grouping several smaller physical drives together and presenting them to the host as one logical drive is known as concatenation.

Logical volume manager (LVM) is a software that enables the dynamic extension of file system capacity and efficient storage management. It runs on the host computer and manages the logical and physical storage. It is an optional, intermediate layer between the physical disk and the file system.

The basic LVM components are:

Physical volume: In terms of LVM, every single physical disk connected to the host system is a physical volume. The physical volume provides the physical storage and the LVM converts it into a logical storage. This logical storage is used by the operating system and applications.

Volume group: When we group together one or more physical drives, a volume group is created. Each physical volume is assigned a unique physical volume identifier (PVID), when it is initialised to be used by the LVM. You can dynamically add or remove the physical volumes from a volume group; however, the cannot be shared between the volume groups; the entire physical volume becomes a part of the volume group. When the volume group is created, each physical volume is partitioned into same-sized blocks known as **physical extents**.

Logical volumes: They are created within a given volume group. To understand, a volume group can be thought of as a disk and the logical volume can be thought of as a virtual disk partition. A volume group can have multiple logical volumes. The size of the logical volume depends on a multiple of physical extents. The operating system treats the logical volume as a physical device. A logical volume can span multiple physical volumes and it can be made up of non-contiguous physical partitions. A logical volume can be configured for optimal performance to the application and it can also be mirrored to provide enhanced data availability. Also, a file system can be created on a logical volume.

(iv) File System

A file system can be described as a hierarchal structure of files. A file system:

- Enables quick and easy access to data files present on the disk drive, a disk partition, or within a logical volume.
- Requires software routines and host-based logical structures that control file access.
- Provides the users the functionality to access, create, modify and delete the files.
- Maintains the permissions granted to the file by the owner and hence, helps in accessing the files on the disk.
- Organises data in a structured and hierarchal manner with the help of directories. These directories are containers for storing pointers for multiple files.
- Maintains a pointer map to the directories, subdirectories and files, which are part of the file system.

Following are some of the most common file systems:

- FAT 32 (File Allocation Table) for Microsoft Windows
- NTFS (New Technology File System) for Microsoft Windows
- UNIX File System (UFS) for UNIX
- Extended File System (EXT2/3) for Linux

A file system contains files and directories and also contains number of other related records, collectively known as **metadata**. In order for the file system to be considered healthy, the metadata of the file system has to be consistent.

A file system block is the smallest unit that contains the physical disk space allocated for data. Each file system block is the contiguous area on the physical disk and its size is fixed at the time of its creation. The block size and the total number of blocks of data stored determines the file system size. Since most files are larger than the predefined block size of the file system, a file system can span multiple file system blocks. When new blocks are added or deleted, file system blocks cease to be contiguous. A file system should be mounted before using.

A file system can be either of the two types:

- **Non-journaling file system:** It creates a potential for lost file as they may use several separate writes to updated their data and metadata. The data or the metadata may be lost, if the system crashes during the write process.

- **Journaling file system:** It uses a separate area known as a log, or journal that may contain all the data that needs to be written, also called the physical journal, or it may contain only the metadata that needs to be updated, also called the logical journal. Before changes are made to the file system, they are written to this separate area, log. If the system crashes in between, there is sufficient information in the log to complete the operation by replaying the log record.

Advantages of journaling file system

- It results in a very quick file system check as it only pays attention to the active and most recently accessed parts of a large file system.

- Since, information about the pending operation is saved, it reduces the risk of files being lost.

Disadvantage of journaling file system

- These are slower than other file systems.

It is slower as it needs to perform the extra operation on the journal every time the file system is changed. However, the filesystem integrity that the journaling file system provides and the much shortened time for file system checks far outweighs the advantage of it being slow. Today, journaling file system is being used by almost all the file system implementations.

> **Did You Know?**
>
> The file system tree starts with a root directory, which has a number of subdirectories.

(v) Application

A computer program that provides the logic for computing operations is known as an **application**. Applications provides an interface between the user and the host and among multiple hosts.

The application uses a logical block address (LBA) or the file name and a file record identifier to perform the read/write operations on a disk. Data access can be classified based on the technique used by the application to read from and write to a disk.

Block-Level Access

It is the basic mechanism for disk access, where the data is stored and retrieved from the disk by specifying the LBA. You have already read about LBA in Module 2 Chapter 1. The geometric configuration of the disk is the basis of the derivation of the block address. The basic unit of data storage and retrieval by an application is defined by the block size.

File-Level Access

It is an abstraction of block-level access and is provided to data by specifying the name and path of the file. It utilises the underlying block-level access to storage and conceals the complexities of LBA from the application and the database management system (DBMS).

Self-assessment Questions

7) Which of the following needs to be consistent in order for the file system to be considered healthy?

   a) Operating system   b) Volume manager

   c) Metadata   d) Logs

8) Which of the following helps the operating system to use a standard interface like API?

   a) File system   b) Device driver

   c) Application   d) Volume manger

9) Which of the following uses a separate area called logs to contain the data and metadata?

   a) Non-journaling file system   b) Journaling file system

   c) New technology file system   d) Extended file system

2.2.5 Application Requirements and Disk Performance

The analysis of application storage requirements initiates with figuring out the storage capacity. This can easily be determined by the size and number of the database components and file system that will be required by the applications. The two important measures affecting the disk performance are:

- The application I/O size
- Number of I/Os generated by the application

The layout for an application and storage design begins with the following:

- Analysis of the number of I/Os generated at the peak workload.
- Documentation of the application I/O size or block size.

The block size is dependent on the file system and the database on which the application has been built. The underlying database engine and the environment variables set determines the block size in a database environment.

Let us consider an example of a Small Computer System Interface (SCSI) that has a throughput of 200 MB/s and the disk service time, R_S = 0.2 ms. We are calculating the rate at which the application I/Os are serviced, which is termed as I/Os per second (IOPS), for block sizes 4 KB, 8 KB, 16 KB, 32 KB and 64 KB. Refer to Table 2.2.2 for the calculations.

Block Size	Transfer Time	IOPS = 1 / (RS + Transfer Time)
4 KB	4 KB / 200 MB = 0.02	1 / (0.2 + 0.02) = 4,545
8 KB	8 KB / 200 MB = 0.04	1 / (0.2 + 0.04) = 4,166
16 KB	16 KB / 200 MB = 0.08	1 / (0.2 + 0.08) = 3,571
32 KB	32 KB / 200 MB = 0.16	1 / (0.2 + 0.16) = 2,777
64 KB	64 KB / 200 MB = 0.32	1 / (0.2 + 0.32) = 1,923

Table 2.2.2: Calculating IOPS

Based on the calculations, we can conclude that the number of IOPS per controller depends on the I/O block size and, in this case, ranges from approx. 2,000 (for 64 GB) to 4,600 (for 4 KB).

One of the key measures of disk performance is the R_S or the disk service time. The I/O response time for applications is determined by R_S, along with disk utilisation rate, U.

The total disk service time (R_S) is the sum of seek time, rotational latency and the internal transfer time.

Hence,

$\mathbf{R_S = E + L + X}$

Where

E = Seek time

L = Rotational latency

X = Internal transfer time

E is determined on the basis of the randomness of the I/O request and L and X are the measures provided as the technical specifications of the disk by the disk vendors.

The application response time (R) increases with the increase in utilisation (U). If a faster response time is demanded by an application, then the utilisation for the disk should be maintained below 70 percent, or the knee of the curve. After this, the response time increases exponentially.

The storage requirements for an application are specified according to both capacity and the IOPS required to be met for the application. If an application has high I/O demands, then it can result in performance degradation as one disk might not be able to provide the required response time for I/O operations.

The total number of disks required (N) for an application is computed as follows:

N = Max (C, I)

Where,

C = Number of disks required to meet the capacity

I = Number of disks required for meeting IOPS

The disk potential in terms of IOPS is published by the disk vendors on the basis of the benchmark they carry out for different block sizes and the application environments.

Let us consider an example where the capacity requirement for an application is 1.46 TB. The peak workload generated by the application is estimated at 9,000 IOPS. The disk vendor specifies that a 146 GB, 15,000-rpm drive is capable of a maximum of 180 IOPS (U = 70%).

In this example, the number of disks required to meet the capacity requirements will be only 1.46 TB / 146 GB = 10 disks.

To meet the requirement of 9,000 IOPS, the number of disks required = 9,000 / 180 = 50 disks.

Hence, the number of disks required to meet the application demand will be Max (10, 50) = 50 disks.

In many application environments, more disks are configured to meet the IOPS requirements than to meet the storage capacity requirements. For those applications that are response time-sensitive, the number of drives required is also calculated based on the IOPS that a single disk can sustain at less than 70 percent utilisation level, to provide a better response time.

Self-assessment Questions

10) Apart from the database on which the application has been built, the block size depends on which other factor?
   a) Operating system
   b) Volume manager
   c) File system
   d) Seek time

11) Which of the following is one of the key measures of disk performance
   a) Disk service time
   b) Utilisation
   c) Rotational latency
   d) Internal transfer time

12) What is the percentage for the disk utilisation that should be maintained in order to achieve a faster response time by an application?
   a) Above 80 percent
   b) Below 70 percent
   c) Above 70 percent
   d) Below 80 percent

Summary

- The effective speed of a disk drive is determined by a number of factors. One of the most important factors amongst them is the revolution per minute (RPM) speed of the platter.
- Three are certain components that contribute to the disk service time on a disk drive, such as seek time, rotational latency and data transfer rate.
- The seek time describes the time taken to figure out the disk area where the specific piece of information that needs to be read or written to is stored.
- Short-stroking is a practice of formatting a disk in a way so that the data gets written only to the outer sectors of platters. It can be performed on the device to bring down the seek time.
- The rotational latency is dependent on the RPM speed of the spindle. It is also measured in milliseconds. The average rotational latency is half the time required for a full rotation.
- It is also known as transfer rate and it refers to the average amount of data per unit time that can be delivered by the drive to the host bus adapter (HBA).
- The rate at which the I/O requests arrive at the controller is known as the arrival rate. This arrival rate is generated by the application.
- Utilisation can also be used to represent the average number of I/O requests on the controller.
- The logical components of the host are operating system, device drivers, volume manager, file system and application.
- In partitioning, a disk drive is divided into logical containers known as logical volumes.
- A file system contains files and directories and also contains number of other related records, collectively known as metadata.
- A file system block is the smallest unit that contains the physical disk space allocated for data.

- The two important measures affecting the disk performance are the application I/O size and the number of I/Os generated by the application.
- One of the key measures of disk performance is the RS or the disk service time. The I/O response time for applications is determined by RS, along with disk utilisation rate, U.

Terminal Questions

1. If an I/O request arrives in the system with the arrival rate of 100 ms and the service time, RS, is 8 ms, what should be the total response time?
2. Which components contributes to the disk service time? Discuss each component in detail.
3. What are the logical components of the host? Discuss file system along with its types in detail.

Answer Keys

Self-assessment Questions	
Question No.	**Answer**
1	b
2	a
3	c
4	b
5	d
6	a
7	c
8	b
9	b
10	c
11	a
12	b

Activity

Activity Type: Offline **Duration:** 45 Minutes

Description:

Perform an online research. Based on the research, create a presentation which explains the logical components of the host.

Case Study

Consider a disk I/O system in which an I/O request arrives at a rate of 100 I/Os per second. The service time, RS, is 8 ms.

1. Based on the given information, calculate the following:

   - Utilisation of I/O controller (U)
   - Average response time (R)
   - Average queue size (N_Q)
   - Total time spent by a request in the queue (U X R)

2. Based on the calculation derive a relation between the service time and response time.

Bibliography

e-References

- *How to understand disk performance*. (2010). *Pcp.io*. Retrieved 27 June 2016, from http://www.pcp.io/pcp.git/man/html/howto.diskperf.html

- *Hard Disk (Hard Drive) Performance - transfer rates, latency and seek times*. (2011). *pctechguide.com*. Retrieved 27 June 2016, from https://www.pctechguide.com/hard-disks/hard-disk-hard-drive-performance-transfer-rates-latency-and-seek-times

- Larry, L. (2009). *How to calculate data transfer speeds. — Lucky Larry. Luckylarry.co.uk*. Retrieved 2 August 2016, from http://luckylarry.co.uk/programming-tutorials/how-to-calculate-data-transfer-speeds/

Image Credits

- Figure 2.2.1: http://flylib.com/books/2/510/1/html/2/images/f05wj03.jpg

- Figure 2.2.4: http://homepage.cs.uri.edu/faculty/wolfe/tutorials/csc101/pp2004/os_images/final.jpg

External Resources

- Somasundaram, G. & Shrivastava, A. (2009) *Information storage and management* - Storing, managing and protecting digital information. *Indianapolis, Ind.: Wiley Pub.*

- Dufrasne, B., Eriksson, R., Martinez, L., & Kalabza, W. (2014). *IBM XIV Storage System Architecture and Implementation* (9th ed.). International Business Machines Corporation.

Video Links

Topic	Link
How to optimise your hard disk for speed	https://www.youtube.com/watch?v=toLYV7th0L8
How to test hard drive speed	https://www.youtube.com/watch?v=tIWqN6Ux9XA
Seek time and rotational latency	https://www.youtube.com/watch?v=0MEt7CHeFzE
What is file system	https://www.youtube.com/watch?v=rD_EsiO2iGg&list=PL7bsRtZVwhUBcDrhhIMXN7F6jMhtNPsjl
Measuring Drive Performance	https://www.youtube.com/watch?v=SWn6JOgKuvU

Notes: