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UNIT-4 (OS)

File Systems in Operating System

A file is a collection of related information that is recorded on secondary storage. Or file is a collection of logically related entities. From user's perspective a file is the smallest allotment of logical secondary storage.

FILE DIRECTORIES:

Collection of files is a file directory. The directory contains information about the files, including attributes, location and ownership. Much of this information, especially that is concerned with storage, is managed by the operating system. The directory is itself a file, accessible by various file management routines.

Information contained in a device directory are:

- Name
- Type
- Address
- Current length
- Maximum length
- Date last accessed
- Date last updated
- Owner id
- Protection information

Operation performed on directory are:

- Search for a file
- Create a file
- Delete a file

- List a directory
- Rename a file
- Traverse the file system

Advantages of maintaining directories are:

- **Efficiency:** A file can be located more quickly.
- **Naming:** It becomes convenient for users as two users can have same name for different files or may have different name for same file.
- **Grouping:** Logical grouping of files can be done by properties e.g. all java programs, all games etc.

Structures of Directory in Operating System

A **directory** is a container that is used to contain folders and files. It organizes files and folders in a hierarchical manner.

SINGLE-LEVEL DIRECTORY

In this a single directory is maintained for all the users.

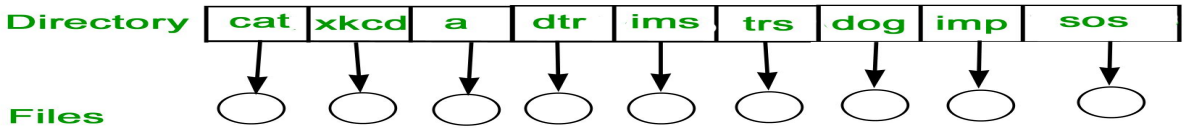
- **Naming problem:** Users cannot have same name for two files.
- **Grouping problem:** Users cannot group files according to their need.

Advantages:

- Since it is a single directory, so its implementation is very easy.
- If the files are smaller in size, searching will become faster.
- The operations like file creation, searching, deletion, updating are very easy in such a directory structure.

Disadvantages:

- There may chance of name collision because two files can have the same name.
- Searching will become time taking if the directory is large.
- This can not group the same type of files together.



TWO-LEVEL DIRECTORY

In this separate directories for each user is maintained.

- Path name:Due to two levels there is a path name for every file to locate that file.
- Now,we can have same file name for different user.
- Searching is efficient in this method.

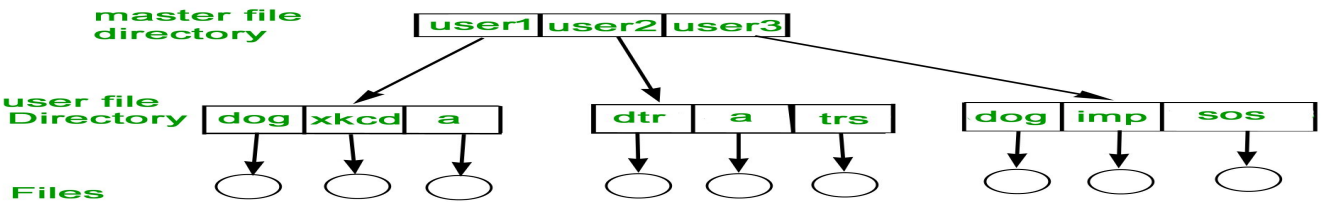
Advantages:

- We can give full path like /User-name/directory-name/.
- Different users can have the same directory as well as the file name.

- Searching of files becomes easier due to pathname and user-grouping.

Disadvantages:

- A user is not allowed to share files with other users.
- Still, it not very scalable, two files of the same type cannot be grouped together in the same user.



TREE-STRUCTURED DIRECTORY :

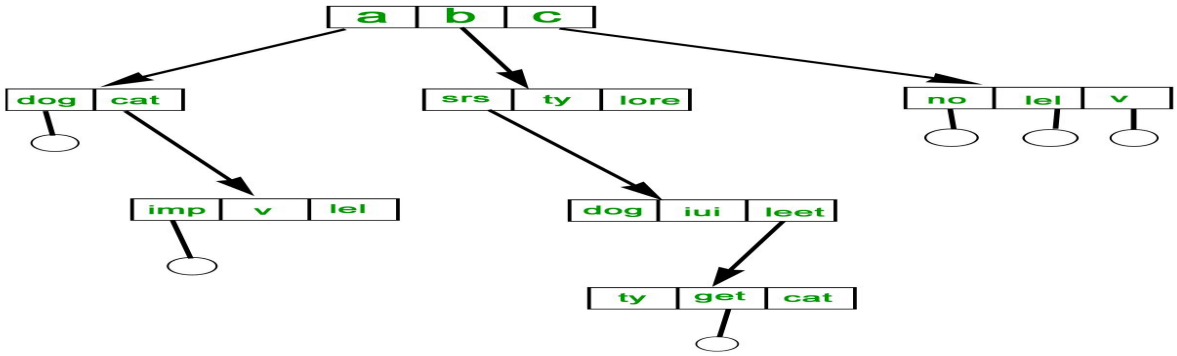
Directory is maintained in the form of a tree. Searching is efficient and also there is grouping capability. We have absolute or relative path name for a file.

Advantages:

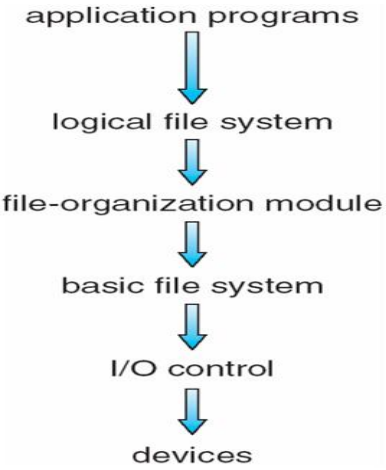
- Very general, since full pathname can be given.
- Very scalable, the probability of name collision is less.
- Searching becomes very easy, we can use both absolute paths as well as relative.

Disadvantages:

- Every file does not fit into the hierarchical model, files may be saved into multiple directories.
- We can not share files.
- It is inefficient, because accessing a file may go under multiple directories.



Layered File System



The code that's making a file request

This is the highest level in the OS, its Does protection and security

Here we read the file control block Maintained in the directory

Knowing specific block to access ,we can make request to the appropriate driver

These are device drivers and interrupt handlers

The disk/tapes

I/O Control level –

Device drivers acts as interface between devices and Os, they help to transfer data between disk and main memory. It takes block number a input and as output it gives low level hardware specific instruction.

Basic file system –

It Issues general commands to device driver to read and write physical blocks on disk. It manages the memory buffers and caches. A block in buffer can hold the contents of the disk block and cache stores frequently used file system metadata.

File organization Module –

It has information about files, location of files and their logical and physical blocks.Physical blocks do not match with logical numbers of logical block numbered from 0 to N. It also has a free space which tracks unallocated blocks.

Logical file system –

It manages metadata information about a file i.e includes all details about a file except the actual contents of file. It also maintains via file control blocks. File control block (FCB) has information about a file – owner, size, permissions, location of file contents.

Directory Implementation

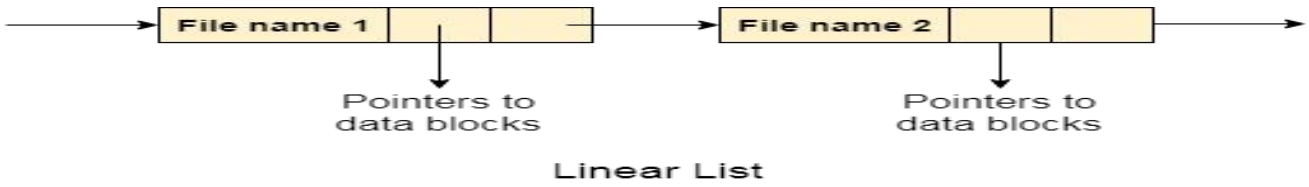
The directory implementation algorithms are classified according to the data structure they are using. There are mainly two algorithms which are used in these days.

1. Linear List

In this algorithm, all the files in a directory are maintained as singly lined list. Each file contains the pointers to the data blocks which are assigned to it and the next file in the directory.

Characteristic

1. When a new file is created, then the entire list is checked whether the new file name is matching to a existing file name or not. In case, it doesn't exist, the file can be created at the beginning or at the end. Therefore, searching for a unique name is a big concern because traversing the whole list takes time.
2. The list needs to be traversed in case of every operation (creation, deletion, updating, etc) on the files therefore the systems become inefficient.

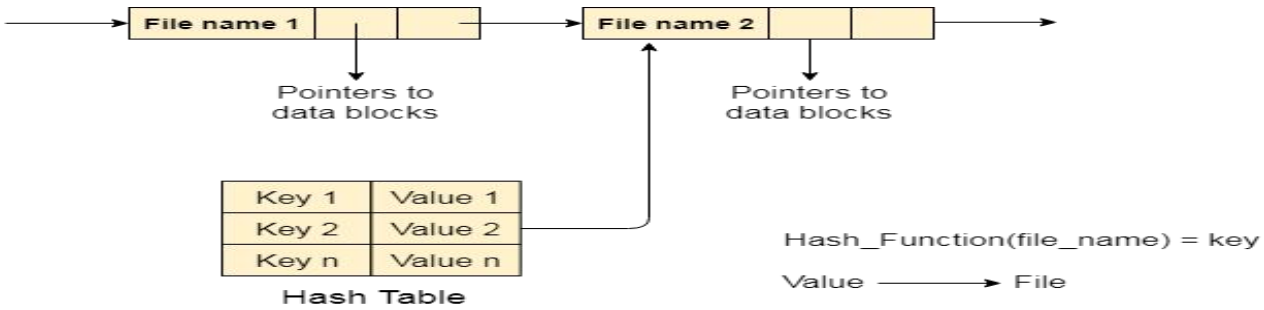


2. Hash Table

To overcome the drawbacks of singly linked list implementation of directories, there is an alternative approach that is hash table. This approach suggests to use hash table along with the linked lists.

A key-value pair for each file in the directory gets generated and stored in the hash table. The key can be determined by applying the hash function on the file name while the key points to the corresponding file stored in the directory.

Now, searching becomes efficient due to the fact that now, entire list will not be searched on every operating. Only hash table entries are checked using the key and if an entry found then the corresponding file will be fetched using the value.



-Linear list of file names with pointer to the data blocks
Simple to program
Time-consuming to execute
Linear search time
Could keep ordered alphabetically via linked list or use B+ tree

-Hash Table – linear list with hash data structure
Decreases directory search time
Collisions – situations where two file names hash to the same location
Only good if entries are fixed size, or use chained-overflow method

Next Topic

The allocation methods define how the files are stored in the disk blocks. There are three main disk space or file allocation methods.

- *Contiguous Allocation*
- *Linked Allocation*
- *Indexed Allocation*

The main idea behind these methods is to provide:

- Efficient disk space utilization.
- Fast access to the file blocks.

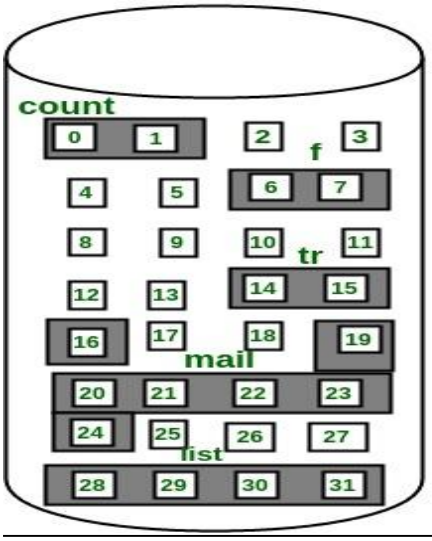
All the three methods have their own advantages and disadvantages as discussed below:

1. Contiguous Allocation

In this scheme, each file occupies a contiguous set of blocks on the disk. For example, if a file requires n blocks and is given a block b as the starting location, then the blocks assigned to the file will be: b, b+1, b+2,……b+n-1. This means that given the starting block address and the length of the file (in terms of blocks required), we can determine the blocks occupied by the file.
The directory entry for a file with contiguous allocation contains

- Address of starting block
- Length of the allocated portion.

The file 'mail' in the following figure starts from the block 19 with length = 6 blocks. Therefore, it occupies 19, 20, 21, 22, 23, 24 blocks.



Directory

file	start	length
count	0	2
tr	14	3
mail	19	6
list	28	4
f	6	2

Advantages:

- Both the Sequential and Direct Accesses are supported by this. For direct access, the address of the kth block of the file which starts at block b can easily be obtained as (b+k).
- This is extremely fast since the number of seeks are minimal because of contiguous allocation of file blocks.

Disadvantages:

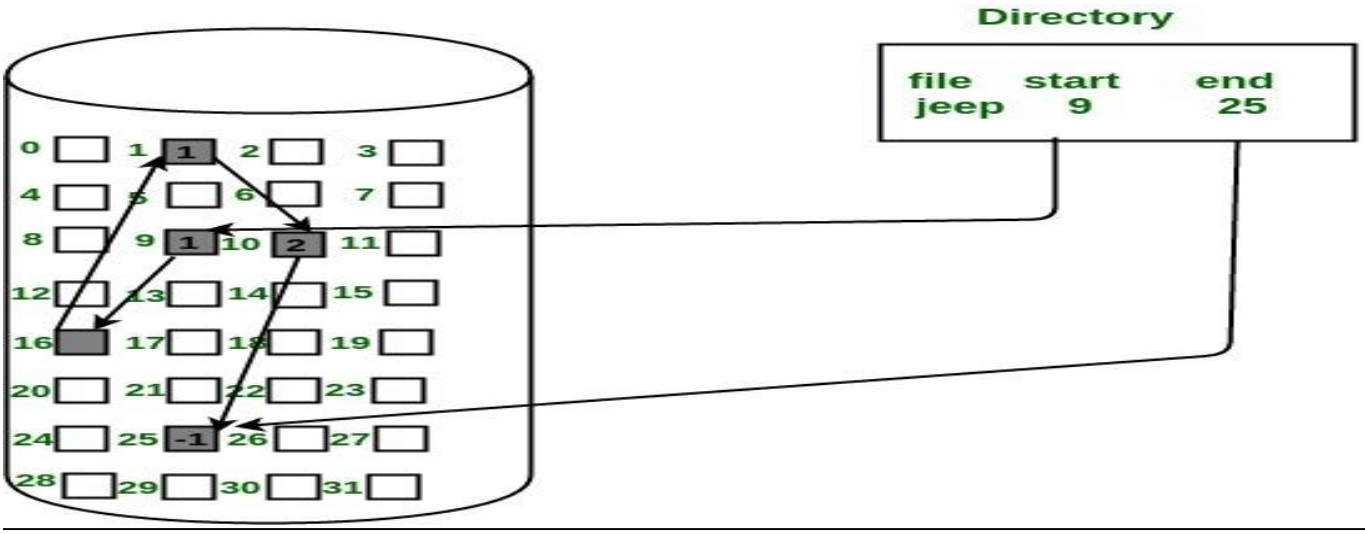
- This method suffers from both internal and external fragmentation. This makes it inefficient in terms of memory utilization.
- Increasing file size is difficult because it depends on the availability of contiguous memory at a particular instance.

2. Linked List Allocation

In this scheme, each file is a linked list of disk blocks which **need not be** contiguous. The disk blocks can be scattered anywhere on the disk.

The directory entry contains a pointer to the starting and the ending file block. Each block contains a pointer to the next block occupied by the file.

The file 'jeep' in following image shows how the blocks are randomly distributed. The last block (25) contains -1 indicating a null pointer and does not point to any other block.



Advantages:

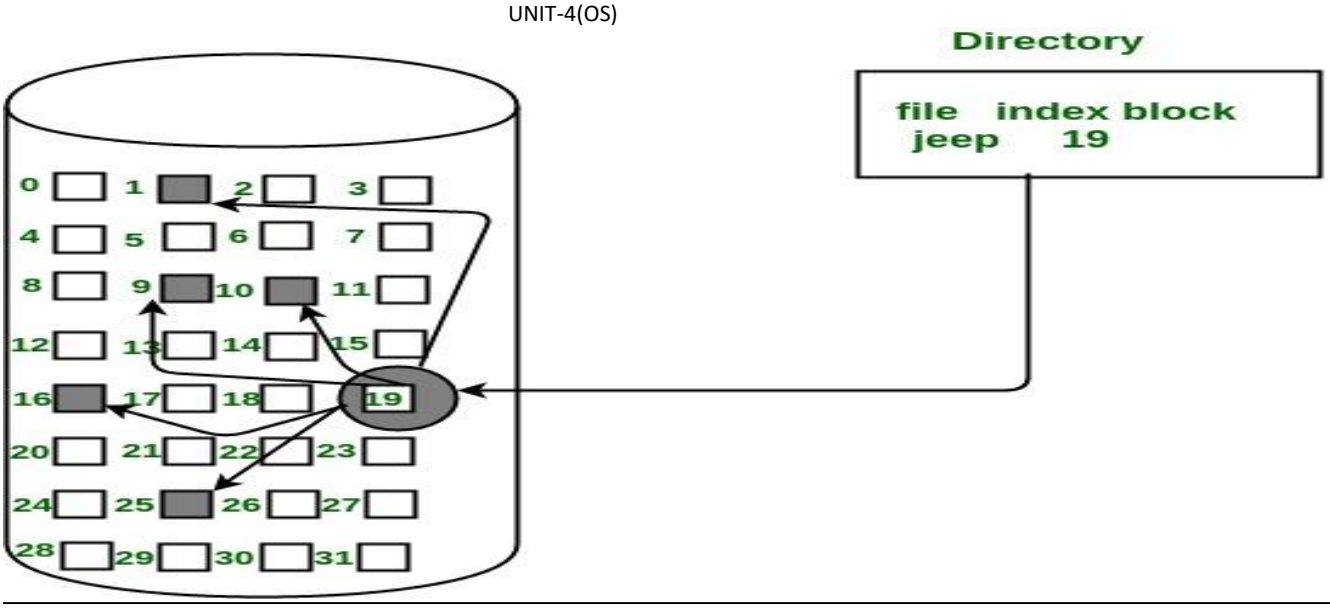
- This is very flexible in terms of file size. File size can be increased easily since the system does not have to look for a contiguous chunk of memory.
- This method does not suffer from external fragmentation. This makes it relatively better in terms of memory utilization.

Disadvantages:

- Because the file blocks are distributed randomly on the disk, a large number of seeks are needed to access every block individually. This makes linked allocation slower.
- It does not support random or direct access. We can not directly access the blocks of a file. A block k of a file can be accessed by traversing k blocks sequentially (sequential access) from the starting block of the file via block pointers.
- Pointers required in the linked allocation incur some extra overhead.

3. Indexed Allocation

In this scheme, a special block known as the **Index block** contains the pointers to all the blocks occupied by a file. Each file has its own index block. The ith entry in the index block contains the disk address of the ith file block. The directory entry contains the address of the index block as shown in the image:



Advantages:

- This supports direct access to the blocks occupied by the file and therefore provides fast access to the file blocks.
- It overcomes the problem of external fragmentation.

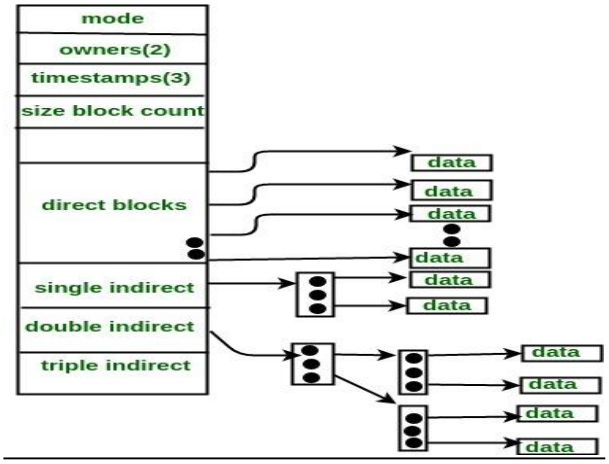
Disadvantages:

- The pointer overhead for indexed allocation is greater than linked allocation.
- For very small files, say files that expand only 2-3 blocks, the indexed allocation would keep one entire block (index block) for the pointers which is inefficient in terms of memory utilization. However, in linked allocation we lose the space of only 1 pointer per block.

For files that are very large, single index block may not be able to hold all the pointers.
Following mechanisms can be used to resolve this:

1. **Linked scheme:** This scheme links two or more index blocks together for holding the pointers. Every index block would then contain a pointer or the address to the next index block.
2. **Multilevel index:** In this policy, a first level index block is used to point to the second level index blocks which inturn points to the disk blocks occupied by the file. This can be extended to 3 or more levels depending on the maximum file size.
3. **Combined Scheme:** In this scheme, a special block called the **Inode (information Node)** contains all the information about the file such as the name, size, authority, etc and the remaining space of Inode is used to store the Disk Block addresses which contain the actual file as shown in the image below. The first few of these pointers in Inode point to the **direct blocks** i.e the pointers contain the addresses of the disk blocks that contain data of the file. The next few pointers point to indirect blocks. Indirect blocks may be single indirect, double indirect or triple indirect. **Single Indirect block** is the disk block that does not contain the file data but the disk address of the blocks that contain the file data. Similarly, **double indirect blocks** do not contain the file data but the disk address of the blocks that contain the address of the blocks containing

the file data.



Free space management in Operating System

The system keeps tracks of the free disk blocks for allocating space to files when they are created. Also, to reuse the space released from deleting the files, free space management becomes crucial. The system maintains a free space list which keeps track of the disk blocks that are not allocated to some file or directory. The free space list can be implemented mainly as:

1. **Bitmap or Bit vector –**

   A Bitmap or Bit Vector is series or collection of bits where each bit corresponds to a disk block. The bit can take two values: 0 and 1: 0 indicates that the block is allocated and 1 indicates a free block.

   The given instance of disk blocks on the disk in Figure 1 (where green blocks are allocated) can be represented by a bitmap of 16 bits as: **0000111000000110**.

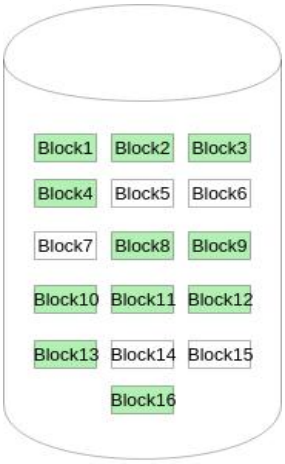


Figure - 1

2.

Advantages –

3.

1. Simple to understand.

2. Finding the first free block is efficient. It requires scanning the words (a group of 8 bits) in a bitmap for a non-zero word. (A 0-valued word has all bits 0). The first free block is then found by scanning for the first 1 bit in the non-zero word.

The block number can be calculated as:

*(number of bits per word) *(number of 0-values words) + offset of bit first bit 1 in the non-zero word .*

For the Figure-1, we scan the bitmap sequentially for the first non-zero word.

The first group of 8 bits (00001110) constitute a non-zero word since all bits are not 0. After the non-0 word is found, we look for the first 1 bit. This is the 5th bit of the non-zero word. So, offset = 5.

Therefore, the first free block number = 8*0+5 = 5.

4. **Linked List –**

In this approach, the free disk blocks are linked together i.e. a free block contains a pointer to the next free block. The block number of the very first disk block is stored at a separate location on disk and is also cached in memory.

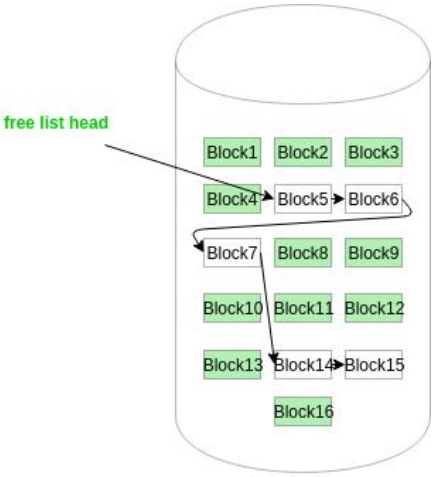


Figure - 2

;.

In Figure-2, the free space list head points to Block 5 which points to Block 6, the next free block and so on. The last free block would contain a null pointer indicating the end of free list.

A drawback of this method is the I/O required for free space list traversal.

;.

'. **Grouping –**

This approach stores the address of the free blocks in the first free block. The first free block stores the address of some, say n free blocks. Out of these n blocks, the first n-1 blocks are actually free and the last block contains the address of next free n blocks.

An **advantage** of this approach is that the addresses of a group of free disk blocks can be found easily.

8. **Counting –**

This approach stores the address of the first free disk block and a number n of free contiguous disk blocks that follow the first block.

Every entry in the list would contain:

1. Address of first free disk block
2. A number n

For example, in Figure-1, the first entry of the free space list would be: ([Address of Block 5], 2), because 2 contiguous free blocks follow block 5

Disk Scheduling Algorithms

Disk scheduling is done by operating systems to schedule I/O requests arriving for the disk. Disk scheduling is also known as I/O scheduling.

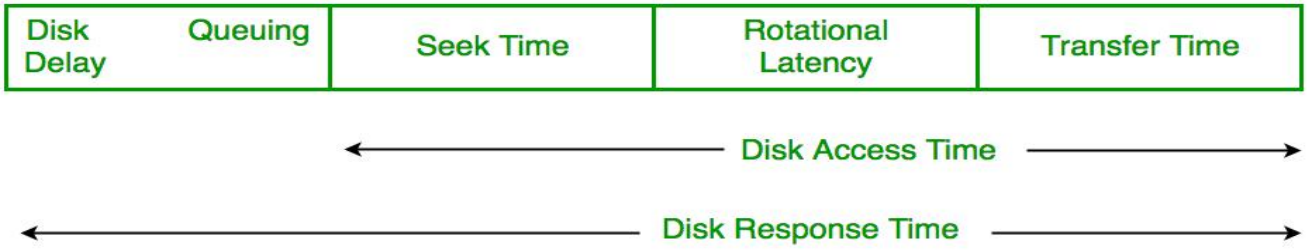
Disk scheduling is important because:

- Multiple I/O requests may arrive by different processes and only one I/O request can be served at a time by the disk controller. Thus other I/O requests need to wait in the waiting queue and need to be scheduled.
- Two or more request may be far from each other so can result in greater disk arm movement.
- Hard drives are one of the slowest parts of the computer system and thus need to be accessed in an efficient manner.

There are many Disk Scheduling Algorithms but before discussing them let's have a quick look at some of the important terms:

- **Seek Time**:Seek time is the time taken to locate the disk arm to a specified track where the data is to be read or write. So the disk scheduling algorithm that gives minimum average seek time is better.
- **Rotational Latency:** Rotational Latency is the time taken by the desired sector of disk to rotate into a position so that it can access the read/write heads. So the disk scheduling algorithm that gives minimum rotational latency is better.
- **Transfer Time:** Transfer time is the time to transfer the data. It depends on the rotating speed of the disk and number of bytes to be transferred.
- **Disk Access Time:** Disk Access Time is:

```
Disk Access Time = Seek Time +
                   Rotational Latency +
                   Transfer Time
```



- **Disk Response Time:** Response Time is the average of time spent by a request waiting to perform its I/O operation. Average Response time is the response time of the all requests. Variance Response Time is measure of how individual request are serviced with respect to average response time. So the disk scheduling algorithm that gives minimum variance response time is better.

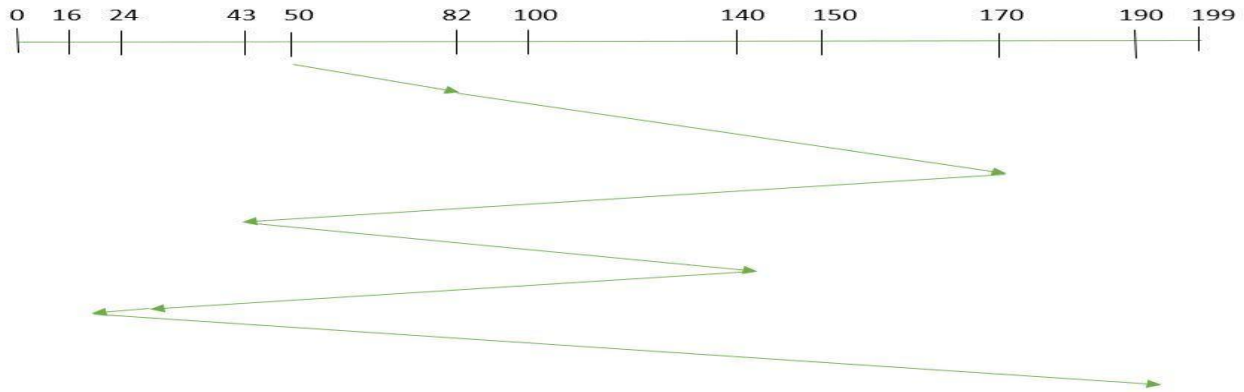
Disk Scheduling Algorithms

1. ***FCFS:*** FCFS is the simplest of all the Disk Scheduling Algorithms. In FCFS, the requests are addressed in the order they arrive in the disk queue.Let us understand this with the help of an example.

2.

Example:

1. Suppose the order of request is- (82,170,43,140,24,16,190)
   And current position of Read/Write head is : 50



1. So, total seek time:
   =(82-50)+(170-82)+(170-43)+(140-43)+(140-24)+(24-16)+(190-16)
   =642

Advantages:

- Every request gets a fair chance
- No indefinite postponement

Disadvantages:

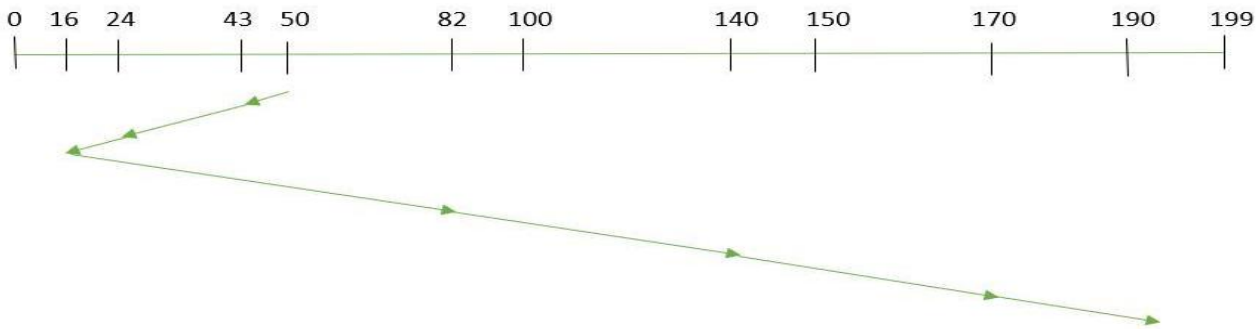
- Does not try to optimize seek time
- May not provide the best possible service

1. ***SSTF:*** In SSTF (Shortest Seek Time First), requests having shortest seek time are executed first. So, the seek time of every request is calculated in advance in the queue and then they are scheduled according to their calculated seek time. As a result, the request near the disk arm will get executed first. SSTF is certainly an improvement over FCFS as it decreases the average response time and increases the throughput of system.Let us understand this with the help of an example.

2.

Example:

1. Suppose the order of request is- (82,170,43,140,24,16,190)
   And current position of Read/Write head is : 50



1.

So, total seek time:

1.

=(50-43)+(43-24)+(24-16)+(82-16)+(140-82)+(170-140)+(190-170)
=208

2.

Advantages:

- Average Response Time decreases
- Throughput increases

Disadvantages:

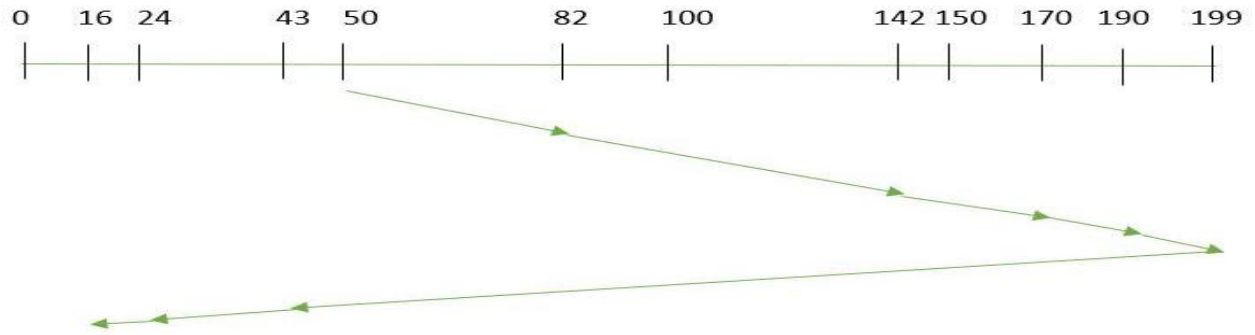
- Overhead to calculate seek time in advance
- Can cause Starvation for a request if it has higher seek time as compared to incoming requests
- High variance of response time as SSTF favours only some requests

1. ***SCAN:*** In SCAN algorithm the disk arm moves into a particular direction and services the requests coming in its path and after reaching the end of disk, it reverses its direction and again services the request arriving in its path. So, this algorithm works as an elevator and hence also known as **elevator algorithm**. As a result, the requests at the midrange are serviced more and those arriving behind the disk arm will have to wait.

2.

Example:

1. Suppose the requests to be addressed are-82,170,43,140,24,16,190. And the Read/Write arm is at 50, and it is also given that the disk arm should move "**towards the larger value**".



1.

Therefore, the seek time is calculated as:

1. =(199-50)+(199-16)
   =332

Advantages:

- High throughput
- Low variance of response time
- Average response time

Disadvantages:

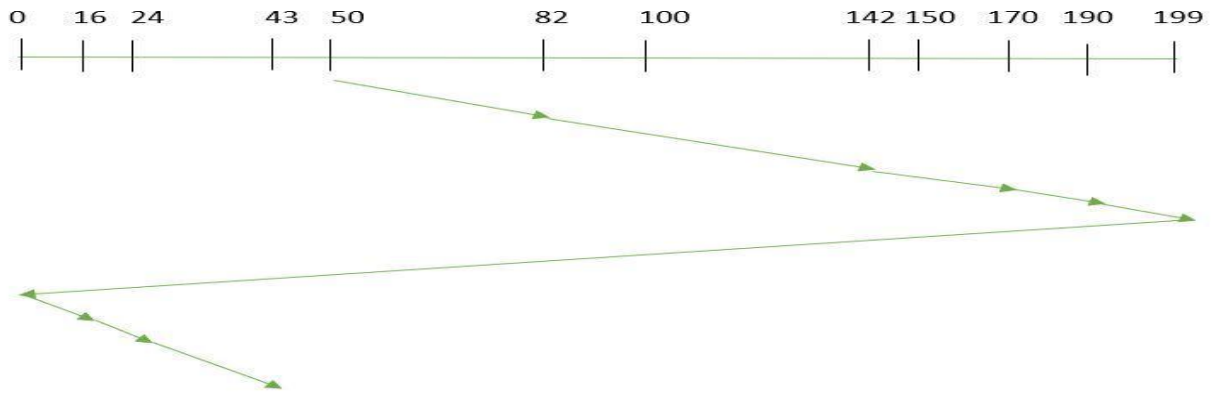
- Long waiting time for requests for locations just visited by disk arm

1. ***CSCAN***: In SCAN algorithm, the disk arm again scans the path that has been scanned, after reversing its direction. So, it may be possible that too many requests are waiting at the other end or there may be zero or few requests pending at the scanned area.

These situations are avoided in CSCAN algorithm in which the disk arm instead of reversing its direction goes to the other end of the disk and starts servicing the requests from there. So, the disk arm moves in a circular fashion and this algorithm is also similar to SCAN algorithm and hence it is known as C-SCAN (Circular SCAN).

Example:

Suppose the requests to be addressed are-82,170,43,140,24,16,190. And the Read/Write arm is at 50, and it is also given that the disk arm should move "**towards the larger value**".



Seek time is calculated as:

=(199-50)+(199-0)+(43-0)

=391

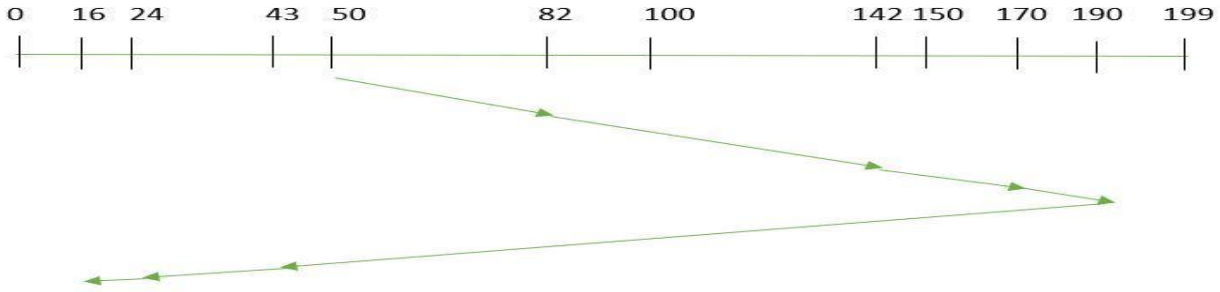
Advantages:

- Provides more uniform wait time compared to SCAN

1. **LOOK:** It is similar to the SCAN disk scheduling algorithm except for the difference that the disk arm in spite of going to the end of the disk goes only to the last request to be serviced in front of the head and then reverses its direction from there only. Thus it prevents the extra delay which occurred due to unnecessary traversal to the end of the disk.

2. **Example:**

1. Suppose the requests to be addressed are-82,170,43,140,24,16,190. And the Read/Write arm is at 50, and it is also given that the disk arm should move "**towards the larger value**".



1.

So, the seek time is calculated as:

1. =(190-50)+(190-16)

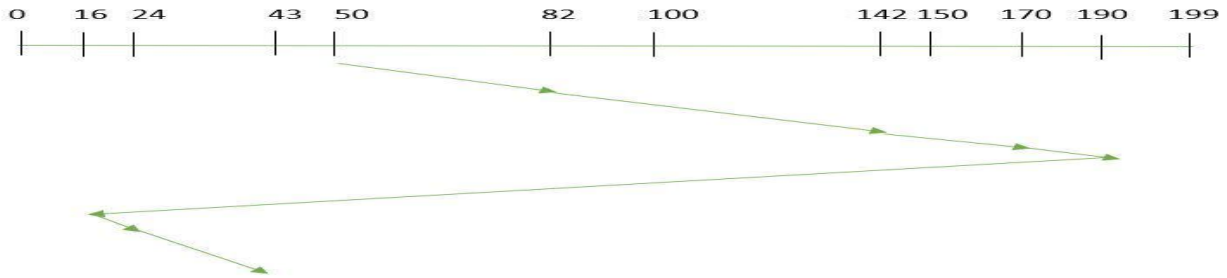
=314

1. **CLOOK:** As LOOK is similar to SCAN algorithm, in similar way, CLOOK is similar to CSCAN disk scheduling algorithm. In CLOOK, the disk arm in spite of going to the end goes only to the last request to be serviced in front of the head and then from there goes to the other end's last request. Thus, it also prevents the extra delay which occurred due to unnecessary traversal to the end of the disk.

2.

Example:

1. Suppose the requests to be addressed are-82,170,43,140,24,16,190. And the Read/Write arm is at 50, and it is also given that the disk arm should move "**towards the larger value**"



1.

So, the seek time is calculated as:

1.

=(190-50)+(190-16)+(43-16)

=341

2.

3. **RSS**– It stands for random scheduling and just like its name it is nature. It is used in situations where scheduling involves random attributes such as random processing time, random due dates, random weights, and stochastic machine breakdowns this algorithm sits perfect. Which is why it is usually used for and analysis and simulation.
4. **LIFO**– In LIFO (Last In, First Out) algorithm, newest jobs are serviced before the existing ones i.e. in order of requests that get serviced the job that is newest or last entered is serviced first and then the rest in the same order.

Advantages

5.

- Maximizes locality and resource utilization
- Can seem a little unfair to other requests and if new requests keep coming in, it cause starvation to the old and existing ones.

6. **N-STEP SCAN** – It is also known as N-STEP LOOK algorithm. In this a buffer is created for N requests. All requests belonging to a buffer will be serviced in one go. Also once the buffer is full no new requests are kept in this buffer and are sent to another one. Now, when these N requests

are serviced, the time comes for another top N requests and this way all get requests get a guaranteed service

Advantages

7.

- It eliminates starvation of requests completely

8. **FSCAN**– This algorithm uses two sub-queues. During the scan all requests in the first queue are serviced and the new incoming requests are added to the second queue. All new requests are kept on halt until the existing requests in the first queue are serviced.

Advantages

- FSCAN along with N-Step-SCAN prevents "arm stickiness" (phenomena in I/O scheduling where the scheduling algorithm continues to service requests at or near the current sector and thus prevents any seeking)

Each algorithm is unique in its own way. Overall Performance depends on the number and type of requests.

Note:Average Rotational latency is generally taken as 1/2(Rotational latency).

Exercise

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