Lecture 13

Mass-Storage Structure

Lecture Information

Ceng328 *Operating Systems* at May 18, 2010

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- Reliability
  - RAIDs (Redundant Array of Inexpensive Disks): various levels, level 0 is disk striping).

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Magnetic Disks I

Magnetic disks provide the bulk of secondary storage for modern computer systems. Conceptually, disks are relatively simple (see Fig. 1).

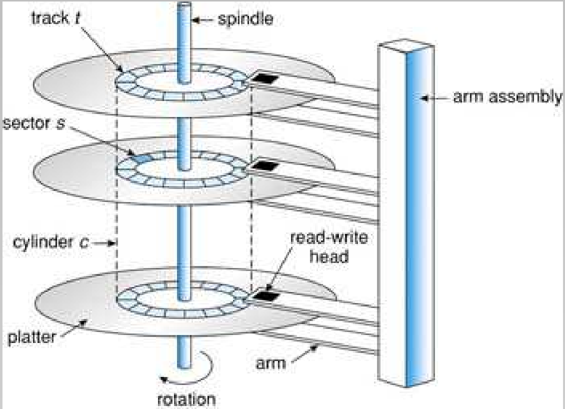

Figure: Moving-head disk mechanism.

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- When the disk is in use, a drive motor spins it at high speed.
- Most drives rotate 60 to 200 times per second (3600 to 12000 rpm).

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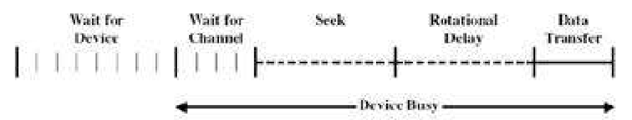
- Execution of a disk operation involves (see Fig. 2)



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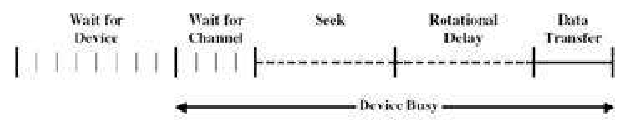

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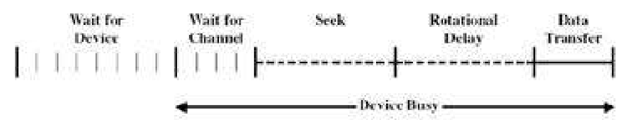

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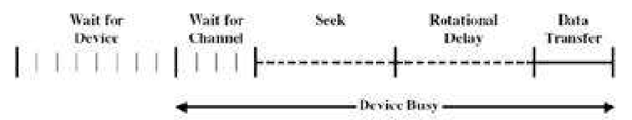

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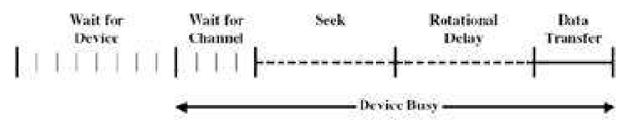

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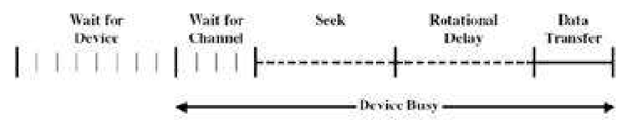

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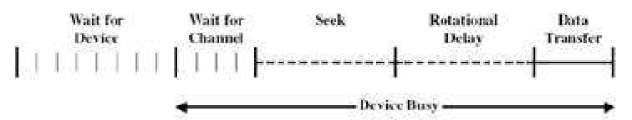

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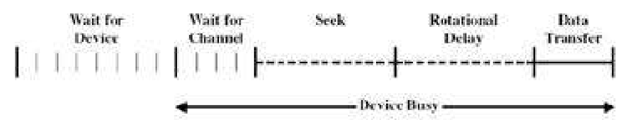

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3. **Transfer rate** is the rate at which data flow between the drive and the computer (megabytes of data per second). **Transfer time**: to transfer b bytes, with N bytes per track;

$$T = \frac{b}{rN}$$

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Average seek	2ms
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Read 320 sectors	6ms ($\frac{1}{r} = 6$, b=512*320 & N=512*320)
Total	11ms
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2. Sectors distributed randomly over the disk: Read any sector

Average seek	2ms
Rot. Delay	3ms
Read 1 sectors	0.01875ms (=(6/320); $\frac{1}{r} = 6$, b=512, N=512*320)
Total	5.01875ms
All	2560*5.01875=12848ms

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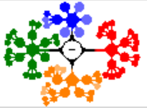

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        - between the cache and the host controller.

Magnetic Disks VII

```
root@ozdogan:~# fdisk -l

Disk /dev/sda: 120.0 GB, 120034123776 bytes
255 heads, 63 sectors/track, 14593 cylinders
Units = cylinders of 16065 * 512 = 8225280 bytes
Disk identifier: 0x23df34d3

   Device Boot      Start         End      Blocks   Id  System
/dev/sda1               1         637     5116671   12  Compaq diagnostics
/dev/sda2   *         638        3070    19543072+   c  W95 FAT32 (LBA)
/dev/sda3            3071       14593    92558497+   5  Extended
/dev/sda5            3071       14255    89843481   83  Linux
/dev/sda6           14256       14593     2714953+  82  Linux swap / Solaris
```

Figure: System's partition table.

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  - The mapping proceeds in order through that track, then through the rest of the tracks in that cylinder, and then through the rest of the cylinders from outermost to innermost.
- By using this mapping, we can convert a logical block number into an old-style disk address that consists of a cylinder number, a track number within that cylinder, and a sector number within that track.
- In practice, it is difficult to perform this translation, for two reasons.

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  - Sector 0 is the first sector of the first track on the outermost cylinder.
  - The mapping proceeds in order through that track, then through the rest of the tracks in that cylinder, and then through the rest of the cylinders from outermost to innermost.
- By using this mapping, we can convert a logical block number into an old-style disk address that consists of a cylinder number, a track number within that cylinder, and a sector number within that track.
- In practice, it is difficult to perform this translation, for two reasons.
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- where the logical block is the smallest unit of transfer.
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    - Second, the number of sectors per track is not a constant on some drives.

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- This method is used in hard disks and is known as **constant angular velocity (CAV)**.

Disk Structure III

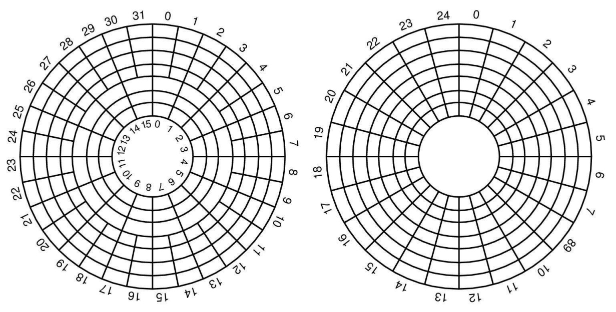

Figure: Physical geometry of a disk with two zones and a possible virtual geometry for this disk.

Disk Structure IV

- Evolution of Disk Hardware (see Fig. 5)

Parameter	IBM 360-KB floppy disk	WD 18300 hard disk
Number of cylinders	40	10601
Tracks per cylinder	2	12
Sectors per track	9	281 (avg)
Sectors per disk	720	35742000
Bytes per sector	512	512
Disk capacity	360 KB	18.3 GB
Seek time (adjacent cylinders)	6 msec	0.8 msec
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2. The other way is via a remote host in a distributed file system; this is referred to as network-attached storage.

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  - A newer, similar protocol that has simplified cabling is SATA.
  - High-end workstations and servers generally use more sophisticated I/O architectures, such as SCSI and fiber channel (FC).

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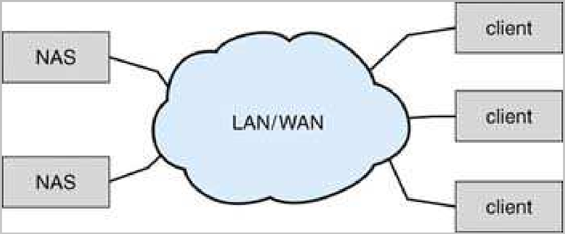
- A wide variety of storage devices are suitable for use as host-attached storage.
- The I/O commands that initiate data transfers to a host-attached storage device are reads and writes of logical data blocks directed to specifically identified storage units (such as bus ID, SCSI ID, and target logical unit).

Network-Attached Storage I

- A network-attached storage (NAS) device is a special-purpose storage system that is accessed remotely over a data network (see Fig. 6).



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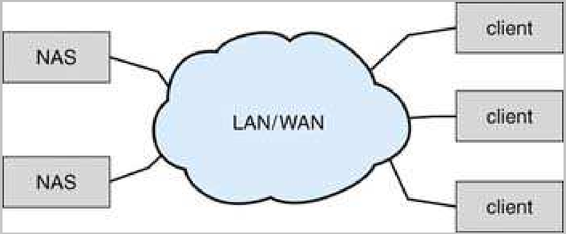

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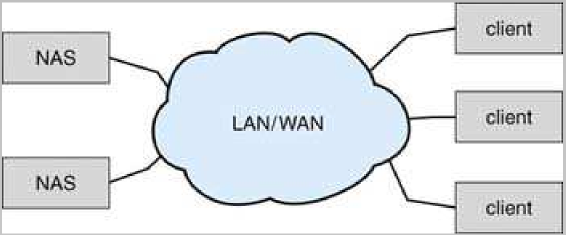

Figure: Network-attached storage.

- Clients access network-attached storage via a remote-procedure-call interface such as NFS for UNIX systems or CIFS for Windows machines.
- The remote procedure calls (RPCs) are carried via TCP or UDP over an IP network -usually the same local-area network (LAN) that carries all data traffic to the clients.

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- ISCSI is the latest network-attached storage protocol.
- In essence, it uses the IP network protocol to carry the SCSI protocol.
- Thus, networks rather than SCSI cables can be used as the interconnects between hosts and their storage.

Storage-Area Network I

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- One drawback of network-attached storage systems is that the storage I/O operations consume bandwidth on the data network, thereby increasing the latency of network communication.
- A storage-area network (SAN) is a private network (using storage protocols rather than networking protocols) connecting servers and storage units, as shown in Fig. 7.

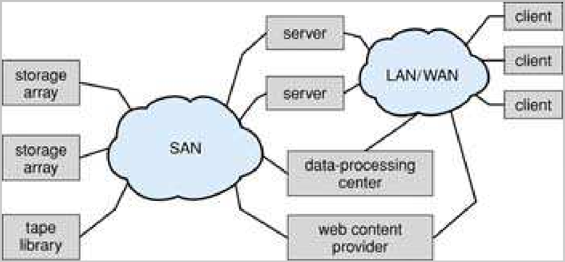

Figure: Storage-area network.

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  - Thus, when one request is completed, the OS chooses which pending request to service next.
  - How does the OS make this choice? **Disk-scheduling algorithms**.

FCFS Scheduling I

- The simplest form of disk scheduling is the first-come, first-served (FCFS) algorithm.

FCFS Scheduling II

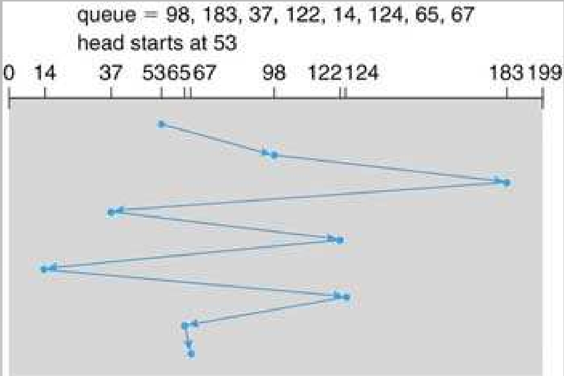

Figure: FCFS disk scheduling.

- The wild swing from 122 to 14 and then back to 124 illustrates the problem with this schedule.

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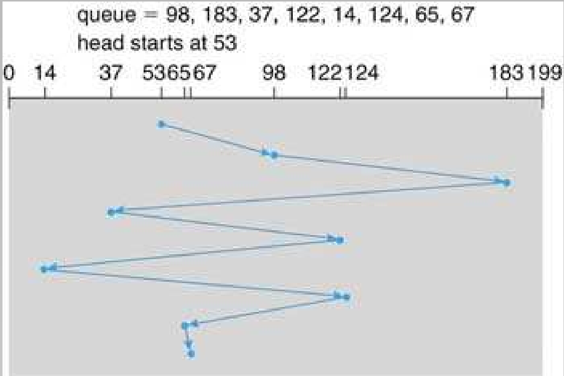

Figure: FCFS disk scheduling.

- The wild swing from 122 to 14 and then back to 124 illustrates the problem with this schedule.
- If the requests for cylinders 37 and 14 could be serviced together, before or after the requests at 122 and 124, the total head movement could be decreased substantially.

SSTF Scheduling I

- It seems reasonable to service all the requests close to the current head position before moving the head far away to service other requests.

SSTF Scheduling II

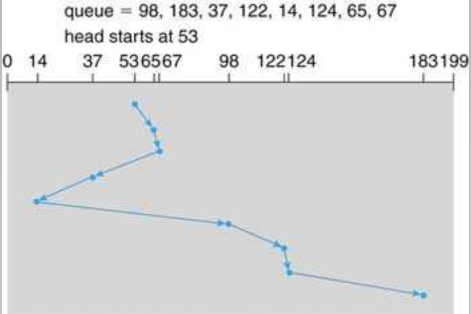

Figure: SSTF disk scheduling.

- This scheduling method results in a total head movement of only 236 cylinders-little more than one-third of the distance needed for FCFS scheduling of this request queue.

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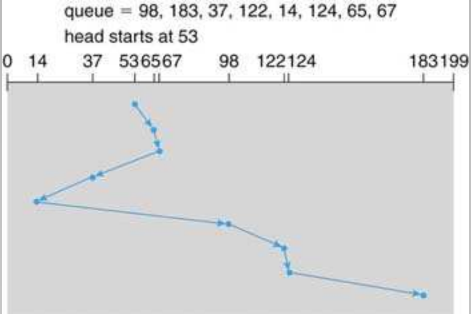

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- This scheduling method results in a total head movement of only 236 cylinders-little more than one-third of the distance needed for FCFS scheduling of this request queue.
- This algorithm gives a substantial improvement in performance.

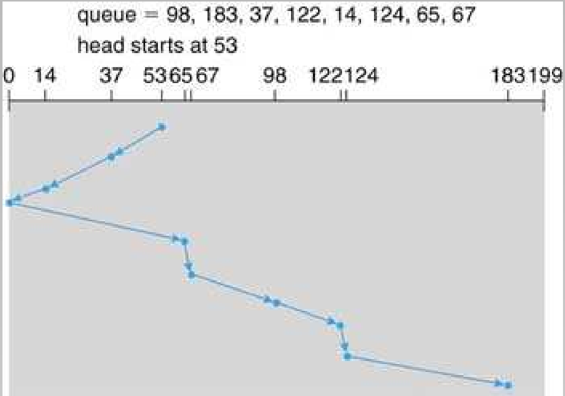
SSTF Scheduling III

- SSTF scheduling is essentially a form of shortest-job-first (SJF) scheduling;

SCAN Scheduling I

- In the SCAN algorithm, the disk arm starts at one end of the disk and moves toward the other end, servicing requests as it reaches each cylinder, until it gets to the other end of the disk.

SCAN Scheduling II



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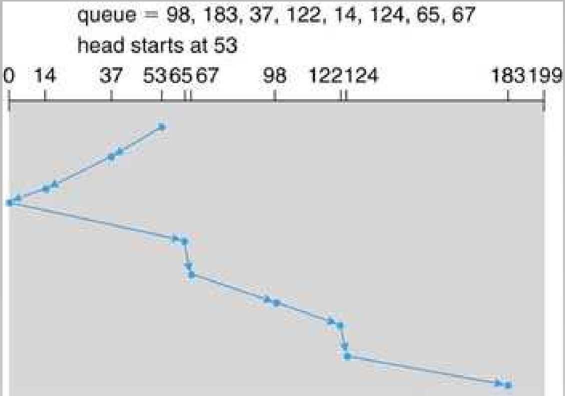

Figure: SCAN disk scheduling.

- If a request arrives in the queue just in front of the head, it will be serviced almost immediately
- If a request arriving just behind the head will have to wait until the arm moves to the end of the disk, reverses direction, and comes back.

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  - That is the idea of the next algorithm.

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- Like SCAN, CSCAN moves the head from one end of the disk to the other, servicing requests along the way.
- When the head reaches the other end, however, it immediately returns to the beginning of the disk, without servicing any requests on the return trip (see Fig. 11).

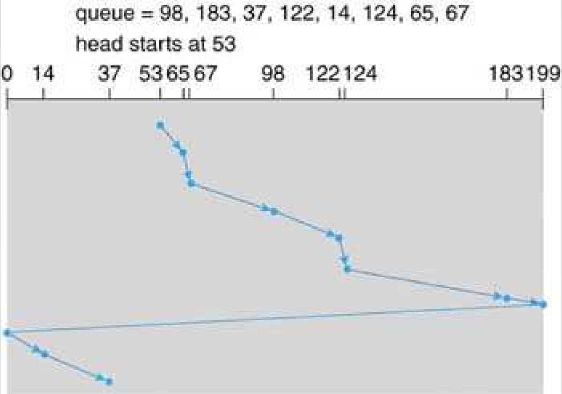

Figure: C-SCAN disk scheduling.

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- Then, it reverses direction immediately, without going all the way to the end of the disk.
- Versions of SCAN and C-SCAN that follow this pattern are called LOOK and C-LOOK scheduling, because they look for a request before continuing to move in a given direction (see Fig. 12).

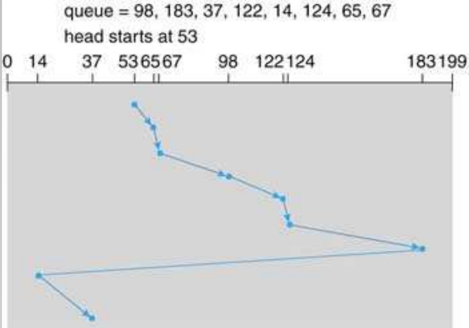

Figure: C-LOOK disk scheduling.

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   - These data structures may include maps of free and allocated space (a FAT or inodes) and an initial empty directory.

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- Disk can be formatted using a cylinder *skew* to avoid this (see Fig. 13).

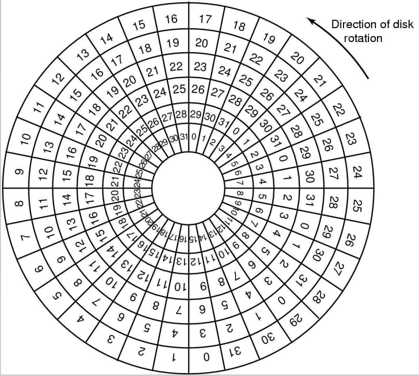

Figure: An illustration of cylinder skew.

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- Hence, the *I* in RAID now stands for "independent" instead of "inexpensive".

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- This technique is called **mirroring**.

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  2. Reduce the response time of large accesses.

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- Numerous schemes to provide redundancy at lower cost by using the idea of disk striping combined with “parity” bits have been proposed.
- These schemes have different cost-performance trade-offs and are classified according to levels called **RAID levels** (see Figs. 14 & Figs. 15).

RAID Levels II

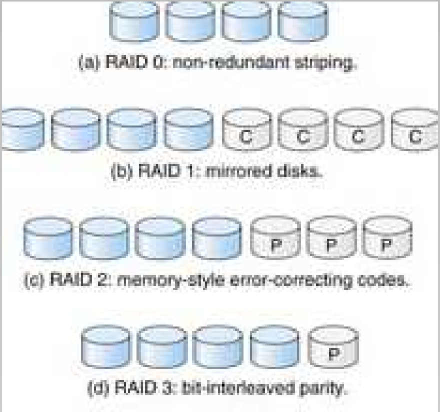

Figure: RAID levels 0-3.

RAID Levels III

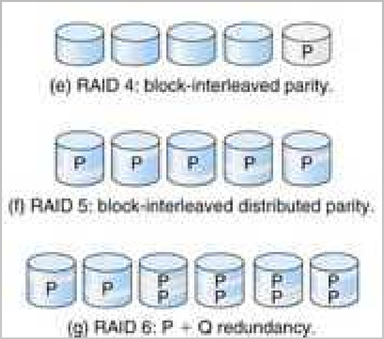

Figure: RAID levels 4-6.

In the figures, *P* indicates error-correcting bits, and *C* indicates a second copy of the data.
In all cases depicted in the figures, four disks' worth of data are stored, and the extra disks are used to store redundant information for failure recovery.