RAID – REDUNDANT ARRAY OF INDEPENDENT DISKS

RAID stands for **R**edundant **A**rray of **I**ndependent **D**isks. RAID is the organization of multiple disks into a large, high performance, logical disk. These disks operate independently. Since there are many disks, multiple I/O requests can be handled in parallel if the data required is on separate disks.

One of the motivating factors behind using multiple disks is somewhat the same as for using memory such as cache. Improvements in data retrieval speed and data reliability are possible by using RAID.

How is redundancy introduced into the system?

Consider a single disk drive with a mean time to failure (MTTF) of 500,000 hours. If we use an array of 100 disks, the MTTF becomes 500,000 /100 or 5000 hrs. Hence large disk arrays are vulnerable to disk failures. This problem is solved by employing redundancy in the form of error-checking codes.

Benefits of using RAID:

1. RAID prevents data loss due to disk failure since the data is mirrored on a number of disks. If one disk drive stops working, data can still be recovered from the other drive which contains mirrored data.
2. Data throughput is increased as data can be supplied by multiple disks in parallel.
3. Reliability and availability improve. **Reliability** is how well a system can work without any failures in its components. **Availability** is how well a system can work in times of failure. If a system is able to work even in the presence of failure of one or more system components, the system is said to be available.
4. RAID technology can be implemented in hardware or software.
5. Mission critical applications / server-based applications make use of RAID.

Disadvantages due to redundancy:

1. Every time there is a write operation, there is a change of data. This change must be made on all the disks. This change must also be made on

all the disks storing redundant information. This slows down the write operation.
2. Keeping the redundant information consistent in the presence of concurrent I/O operations is difficult.

Data Stripping and Redundancy:

There are two important concepts to be understood in the design and implementation of disk arrays:

1. Data stripping for improved performance, and
2. Redundancy for improved reliability.

Data Stripping transparently distributes data over multiple disks to make them appear as a single fast, large disk. Stripping improves the overall I/O performance since multiple I/O requests can be serviced in parallel. This is achieved in two ways:

- ✓ Multiple, independent requests can be serviced in parallel by separate disks. This decreases the queuing time seen by I/O requests.
- ✓ Single, multiple block requests can be serviced by multiple disks. This increases the effective transfer rate. The performance increases with the increase in the number of disks in the array. However, as the number of disks increases the overall reliability of the disk array decreases.

Redundancy: Since a large number of disks lower the overall reliability of the array of disks, it is important to have redundancy in the system to tolerate disk failures and allow for continuous operation of the system without any loss of data.

If redundancy is built into the system, it causes the following problems:

1. We must select the appropriate method for computing the redundant information. Most disks arrays use parity mechanism, but some use the Hamming code.
2. We must select a method for distribution of the redundant information across the disk array. This redundant information is distributed by using one of the two schemes:
   a. Schemes that concentrate redundant information on a small number of disks.
   b. Schemes that distribute redundant information across all the disks.

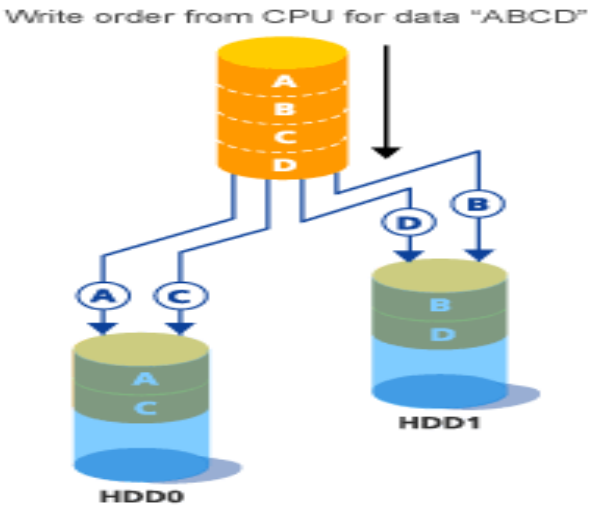
RAID Levels

There are 7 levels RAID schemes. These are called RAID 0, RAID 1, RAID 2 … RAID 6. The **common characteristics** in all these levels are:

- A set of physical disk drives.
- The operating system views these separate disks as a single logical disk.
- Data is distributed across the physical drives of the array.
- Redundant disk capacity is used to store parity information.
- Parity information can help in recovering data in case of disk failure

RAID Level 0:

- ✓ RAID level 0 divides data into block units and writes them across a number of disks.
- ✓ As data is placed across multiple disks, it is also called "data stripping".
- ✓ The advantage of distributing data over disks is that if two different I/O requests are pending for two different blocks of data, then there is a possibility that the requested blocks are on different disks.
- ✓ There is no parity checking of data. So if data in one drive gets corrupted then all the data would be lost. Thus RAID 0 does not support data recovery.
- ✓ Spanning is another term that is used with RAID level 0 because the logical disk will span all the physical drives.
- ✓ RAID 0 implementation requires minimum 2 disks.



RAID Level 0 implementation

Advantages of RAID Level 0:

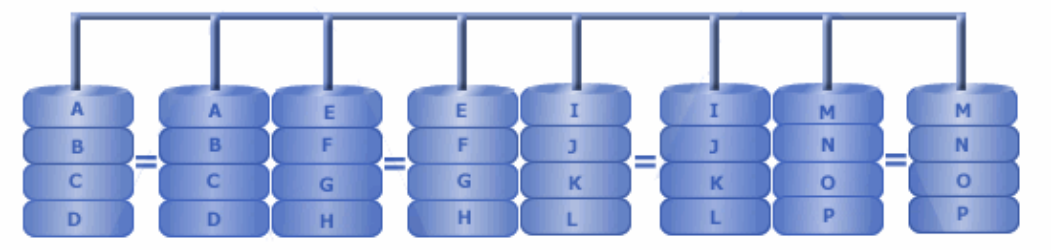
1) Advantage of RAID level 0 is that it increases speed.
2) Throughput (speed) is increased because:
   a) Multiple data requests probably not on same disk
   b) Disks seek in parallel
   c) A set of data is likely to be striped across multiple disks
3) Implementation is easy
4) No overhead of parity calculation

Disadvantages of RAID Level 0:

1) Not a true RAID because it is not fault-tolerant.
2) The failure of just one drive will result in all data in an array being lost. Implementation is easy.
3) Should not be used in mission critical environments.

RAID Level 1:

- ✓ As same data is placed on multiple disks, it is also called "data mirroring".
- ✓ The automatic duplication of the data means there is little likelihood of data loss or system downtime.
- ✓ Data stripping is used as in RAID 0, but in RAID 1, each logical strip is mapped to two separate physical drives.
- ✓ Thus every disk in the array has a mirror disk that contains the same data.
- ✓ Data can be read from either disk but is written on both disks.
- ✓ A read request can be executed by either of the two disks.
- ✓ A write request means that both the disks must be updated. This can be done in parallel
- ✓ There is no overhead of storing parity information.
- ✓ Recovery from failure is simple. If one drive fails we just have to access data from the second drive.



Advantages of RAID Level 1:

- ✓ Main advantage is RAID 1 provides fault tolerance. If one disk fails, the other automatically takes over.
- ✓ So continuous operation is maintained.
- ✓ RAID 1 is used to store systems software (such as drivers, operating systems, compilers, etc) and other highly critical files.

Disadvantage of RAID Level 1:

- ✓ Main disadvantage is cost. Since data is duplicated, storage costs increase.

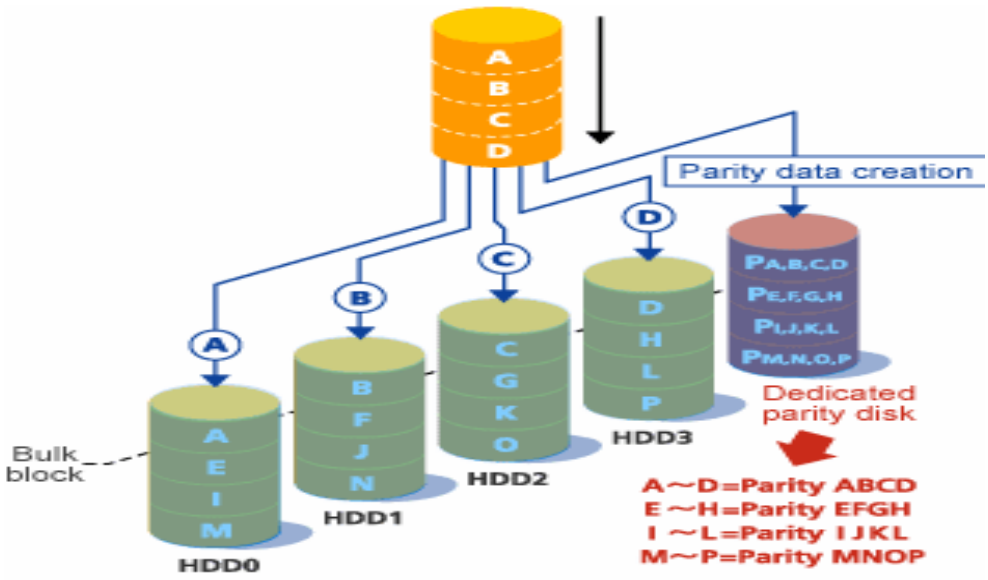
RAID Level 2:

- In RAID 2 mechanism, all disks participate in the execution of every I/O request.
- The spindles of individual disk drives are synchronized so that each disk head is in the same position on each disk at any given time.
- Data stripping is used.
- Error correcting code is also calculated and stored with data.
- Not implemented in practice due to high costs and overheads.

RAID Level 3:

- Data is divided into byte units and written across multiple disk drives.
- Parity information is stored for each disk section and written to a dedicated parity drive.
- All disks can be accessed in parallel.
- Data can be transferred in bulk. Thus high speed data transmission is possible.
- In case of drive failure, the parity drive is accessed and data is reconstructed from the remaining devices.
- Once the failed drive is replaced, the missing data can be restored on the new drive.
- RAID 3 can provide very high data transfer rates.

The diagram below illustrates the implementation of RAID level 3.



RAID Level 3 Implementation

RAID Level 4 :
This level makes use of an independent access technique in which each disk operates independently. So if there are many I/O requests, they can be satisfied in parallel. Data striping is used. Parity bits are stored on the parity disk.

RAID 5 is similar to level 4. But the difference is that parity bits are stored across all disks.

RAID Level 6: In this, two different parity calculations are carried out and stored in separate blocks on separate disks. Thus a RAID 6 array whose data require N disks consists of N + 2 disks (2 disks for storing parity information).

Advantage of RAID 6 is that it provides extremely high data availability. However write operations are slow as each write operation involves writing two parity blocks also.

IMPORTANT QUESTIONS

1. What is meant by the term RAID?
2. How does RAID improve data availability and reliability?
3. What common characteristics are shared by all RAID levels?
4. Explain the term *striped* data.
5. How is redundancy achieved in RAID system?
6. Explain the difference between reliability and availability.
7. Explain RAID level 0. What are its advantages and disadvantages?
8. Explain RAID level 1. State its advantages and disadvantages.
9. With the help of an appropriate diagram, explain RAID level 3.