UNIT 5

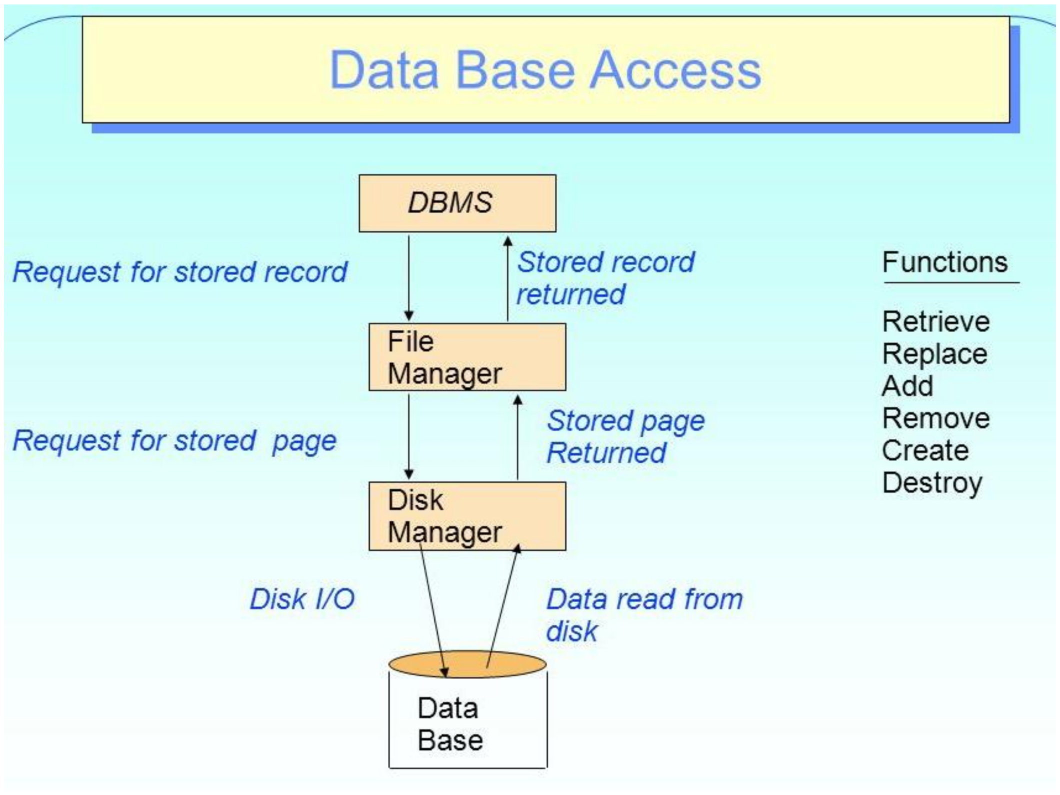
OVERVIEW OF STORAGE AND INDEXING

Unit 5 Contents at a glance:

1. Data on external storage:

- Data in a DBMS is stored on storage devices such as disks and tapes

- The disk space manager is responsible for keeping track of available disk space.
- The file manager, which provides the abstraction of a file of records to higher levels of DBMS code, issues requests to the disk space manager to obtain and relinquish space on disk.



Storage Manager Component :

A Storage Manager is a component or program module that provides the interface between the low-level data stored in the database and the application programs/queries submitted to the system. The Storage Manager Components include –

1. **File Manager-** File manager manages the file space and it takes care of the structure of the file. It manages the allocation space on disk storage and the data structures used to represent info stored on other media.
2. **Buffer Manager –** It transfers blocks between disk (or other devices) and Main Memory. A DMA (Direct Memory Access) is a form of Input/Output that controls the exchange of blocks process. When a processor receives a request for a transfer of a block, it sends it to the DMA Controller which transfers the block uninterrupted.
3. **Authorization and Integrity Manager –** This Component of storage manager checks for the authority of the users to access and modify information, as well as integrity constraints (keys, etc).
4. **Disk Manager-** The block requested by the file manager is transferred by the Disk Manager.

Memory Hierarchy:

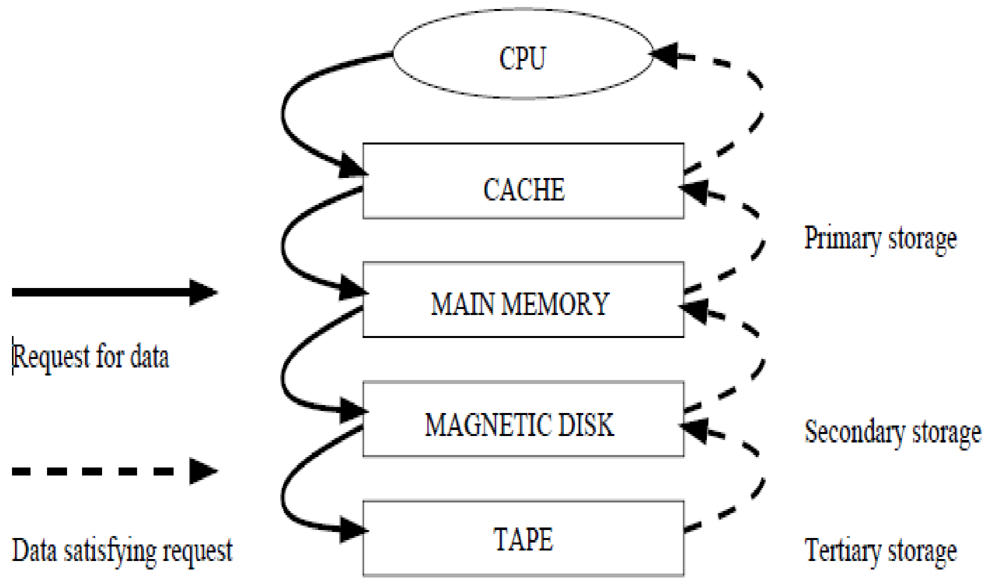


Figure: Memory Hierarchy

At the top, we have primary storage, which consists of cache and main memory , and provides very fast access to data. then comes secondary storage, which consists of slower devices such as magnetic disks. tertiary storage is the slowest class of storage devices; for example, optical disks and tapes.

Primary Storage:

1. all the primary storage level, the memory hierarchy includes at the most expensive end cache memory, which is a static RAM (Random Access Memory) cache memory is mainly used by the CPU to speedup execution programs.
2. the next level of primary storage is DRAM (Dynamic Random Access Memory), which provides the main work area for the CPU for keeping programs and data , which is popularly called as main memory .
3. the advantages of DRAM is its low cost, which continuous to decrease ; the drawback is its volatility and lower speed compared with static RAM.

Secondary Storage:

At the secondary storage level, the hierarchy includes magnetic disks, as well storage in the form of CD - ROM (Compact Disk - Read Only Memory) devices.

Secondary storage devices are used to store data for future use or as backup. Secondary storage includes memory devices that are not a part of the CPU chipset or motherboard, for example, magnetic disks, optical disks (DVD, CD, etc.), hard disks, flash drives, and magnetic tapes.

Tertiary storage:

At the tertiary storage level, the hierarchy includes optical disks and tapes as the least expensive end.

The storage capacity anywhere in the hierarchy is measured in kilobytes (k bytes or bytes), megabytes (M bytes or 1 million bytes), gigabytes (G byte or billion bytes), and even terabytes (1000 G bytes).

Explanation:

DRAM:

programs reside execute in **DRAM** . Generally, large permanent database reside on secondary storage, and portions of the database are read into and written from buffers is main memory as needed. personal computers and work stations have tens of megabytes of data in DRAM. it is become possible to load a large fraction of the database into main memory. an example is telephone switching applications, which store databases that contain routing and line information in main memory.

Flash Memory:

1. Between **DRAM and magnetic disk storage**, another form of memory resides, **flash memory**, which is becoming common, particularly because it is non - volatile.
2. flash memories are high density, high - performance memories using EEPROM (Electrically Erasable programmable Read -only Memory) technology.
3. the advantage of flash memory is the fast access speed;
4. the disadvantage is that an entire block must be erased and written over at a time.

Magnetic disk storage:

- primary medium for long-term storage.
- Typically the entire database is stored on disk.
- Data must be moved from disk to main memory in order for the data to be operated on.
- After operations are performed, data must be copied back to disk if any changes were made.
- Disk storage is called **direct access** storage as it is possible to read data on the disk in any order (unlike sequential access).
- Disk storage usually survives power failures and system crashes.

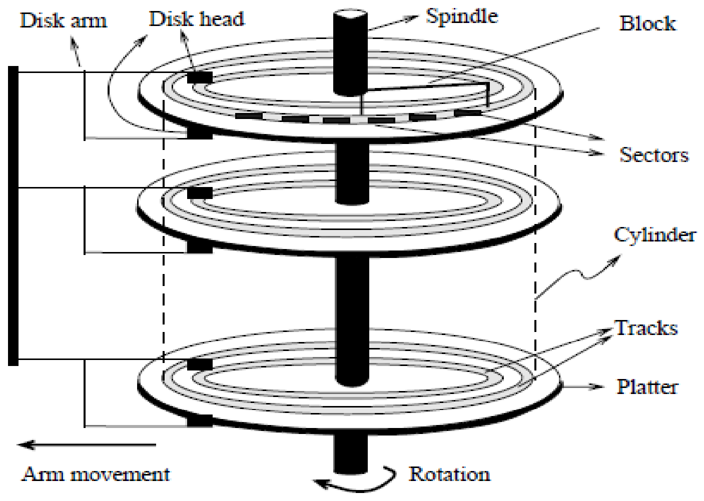


Figure 7.2 Structure of a Disk

Figure: Structure of magnetic disk

Access time: the time it takes from when a read or write request is issued to when data transfer begins.
Data-transfer rate– the rate at which data can be retrieved from or stored to the disk.
Mean time to failure (MTTF)– the average time the disk is expected to run continuously without any failure.

CD-ROM:

CD - ROM disks store data optically and are read by a laser. CD - ROM s contain pre - recorded data that cannot be overwritten. WORM (Write - Once - Read - Many disks) are a form of optical storage used for archiving data; they allow data to be written once and read any number of times without the possibility of erasing. the DVD (Digital Video Disks) is a recent standard for optical disks allowing fourteen to fifteen gigabytes of storage per disks.

Tapes:

1. Tapes are relatively not expensive and can store very large amount of data. when we maintain data for a long period but do expect to access it very often.
2. used primarily for backup and archival data.
3. Cheaper, but much slower access, since tape must be read sequentially from the beginning.
4. Used as protection from disk failures!
5. A Quantum DLT 4000 drive is a typical tape device; it stores 20 GB of data and can store about twice as much by compressing the data.

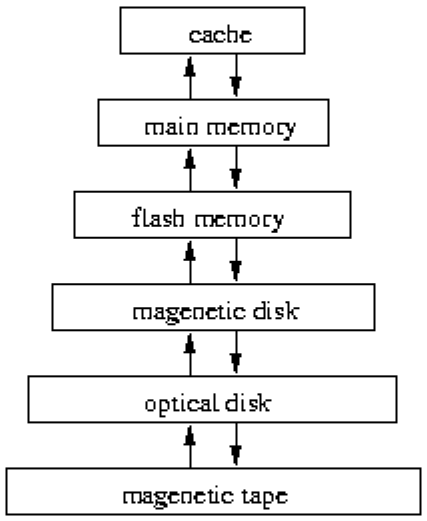


Figure: storage device hierarchy

2. File Organizations:

Storing the files in certain order is called file organization. The main objective of file organization is

- Optimal selection of records i.e.; records should be accessed as fast as possible.
- Any insert, update or delete transaction on records should be easy, quick and should not harm other records.
- No duplicate records should be induced as a result of insert, update or delete
- Records should be stored efficiently so that cost of storage is minimal.

Some of the file organizations are

1. Sequential File Organization
2. Heap File Organization
3. Hash/Direct File Organization
4. Indexed Sequential Access Method
5. B+ Tree File Organization
6. Cluster File Organization

1. Sequential File Organization:

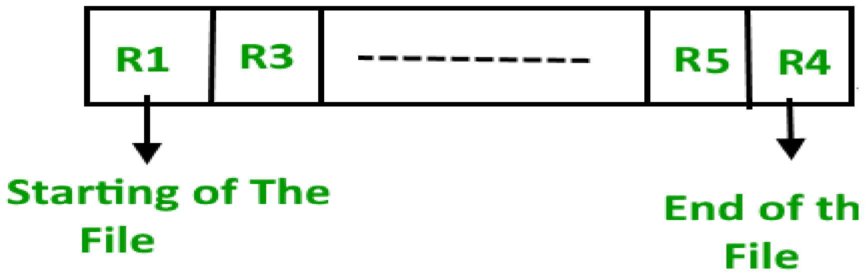
In sequential file organization, records are placed in the file in some sequential order based on the unique key field or search key.

The easiest method for file Organization is Sequential method. In this method the the file are stored one after another in a sequential manner. There are two ways to implement this method:

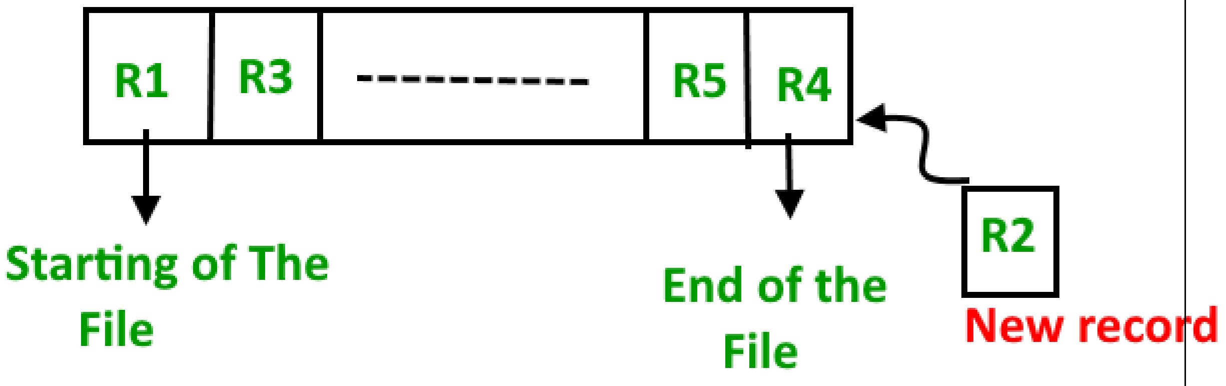
1. Pile FIle Method

2. Sorted File

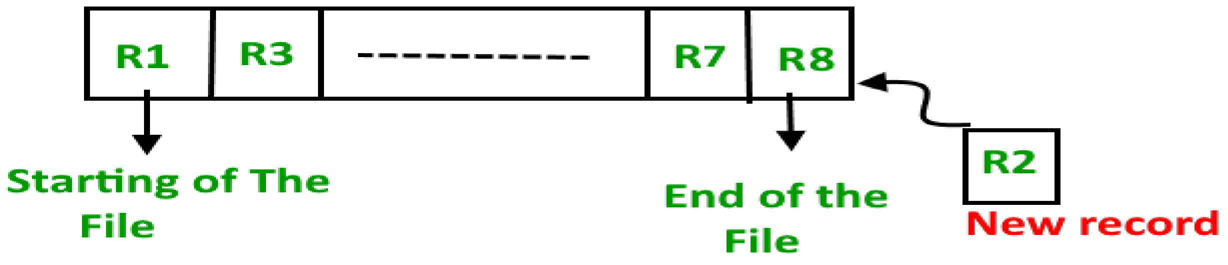
1. **Pile File Method –** This method is quite simple, in which we store the records in a sequence i.e one after other in the order in which they are inserted into the tables.



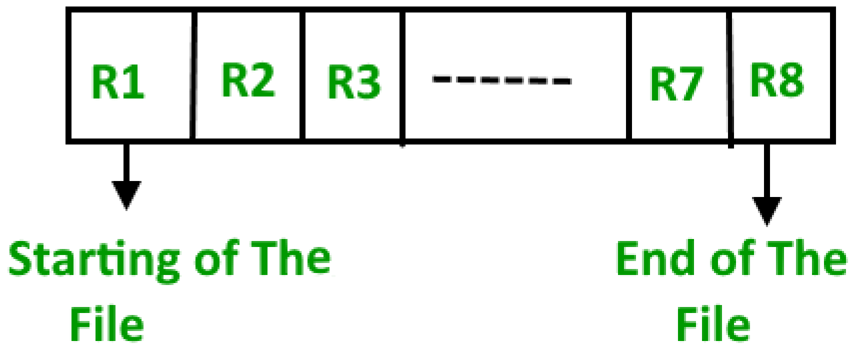
Insertion of new record –
Let the R1, R3 and so on upto R5 and R4 be four records in the sequence. Here, records are nothing but a row in any table. Suppose a new record R2 has to be inserted in the sequence, then it is simply placed at the end of the file.



2. **Sorted File Method –**In this method, As the name itself suggest whenever a new record has to be inserted, it is always inserted in a sorted (ascending or descending) manner. Sorting of records may be based on any primary key or any other key.



Insertion of new record –
Let us assume that there is a preexisting sorted sequence of four records R1, R3, and so on upto R7 and R8. Suppose a new record R2 has to be inserted in the sequence, then it will be inserted at the end of the file and then it will sort the sequence .



Pros and Cons of Sequential File Organization –

Pros –

- Fast and efficient method for huge amount of data.
- Simple design.
- Files can be easily stored in magnetic tapes i.e cheaper storage mechanism.

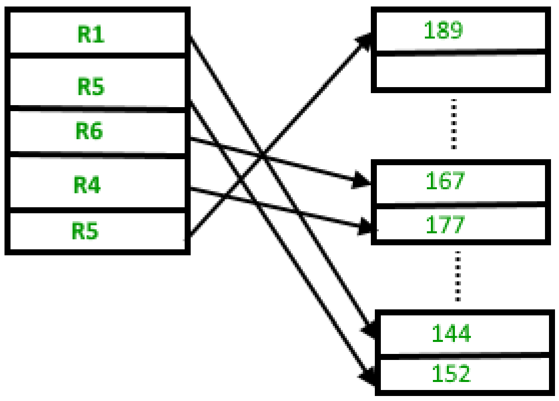
Cons –

- Time wastage as we cannot jump on a particular record that is required, but we have to move in a sequential manner which takes our time.
- Sorted file method is inefficient as it takes time and space for sorting records.

*2. **Heap File Organization:***

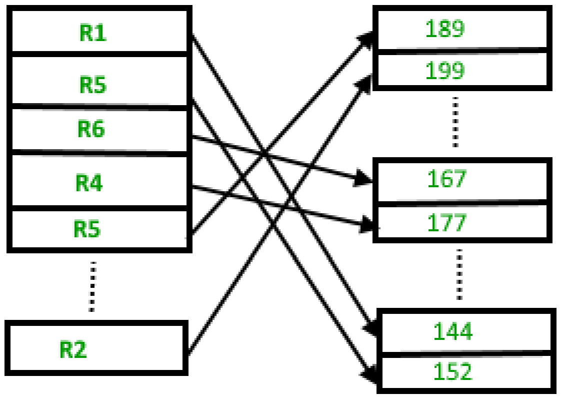
When a file is created using Heap File Organization, the Operating System allocates memory area to that file without any further accounting details. File records can be placed anywhere in that memory area.

Heap File Organization works with data blocks. In this method records are inserted at the end of the file, into the data blocks. No Sorting or Ordering is required in this method. If a data block is full, the new record is stored in some other block, Here the other data block need not be the very next data block, but it can be any block in the memory. It is the responsibility of DBMS to store and manage the new records.



Insertion of new record –

Suppose we have four records in the heap R1, R5, R6, R4 and R3 and suppose a new record R2 has to be inserted in the heap then, since the last data block i.e data block 3 is full it will be inserted in any of the database selected by the DBMS, lets say data block 1.



If we want to search, delete or update data in heap file Organization the we will traverse the data from the beginning of the file till we get the requested record. Thus if the database is very huge, searching, deleting or updating the record will take a lot of time.

Pros and Cons of Heap File Organization –
Pros –

- Fetching and retrieving records is faster than sequential record but only in case of small databases.
- When there is a huge number of data needs to be loaded into the database at a time, then this method of file Organization is best suited.

Cons –

- Problem of unused memory blocks.
- Inefficient for larger databases.

3. Hash File Organization:

Hash File Organization uses Hash function computation on some fields of the records. The output of the hash function determines the location of disk block where the records are to be placed.

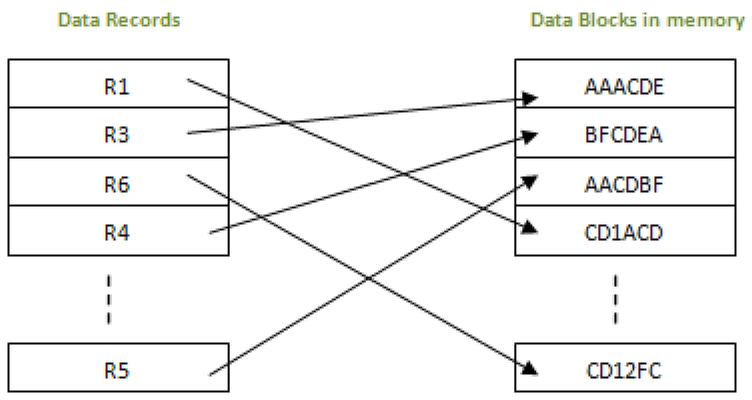
In this method of file organization, hash function is used to calculate the address of the block to store the records.

The hash function can be any simple or complex mathematical function.

The hash function is applied on some columns/attributes – either key or non-key columns to get the block address.

Hence each record is stored randomly irrespective of the order they come. Hence this method is also known as Direct or Random file organization.

If the hash function is generated on key column, then that column is called hash key, and if hash function is generated on non-key column, then the column is hash column.



When a record has to be retrieved, based on the hash key column, the address is generated and directly from that address whole record is retrieved. Here no effort to traverse through whole file. Similarly when a new record has to be inserted, the address is generated by hash key and record is directly inserted. Same is the case with update and delete.

Advantages of Hash File Organization

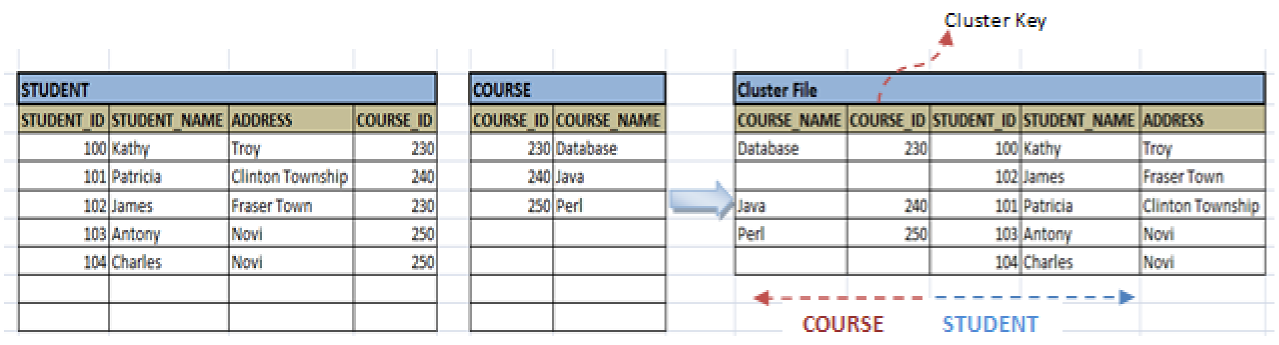
- Records need not be sorted after any of the transaction. Hence the effort of sorting is reduced in this method.
- Since block address is known by hash function, accessing any record is very faster. Similarly updating or deleting a record is also very quick.

- This method can handle multiple transactions as each record is independent of other. i.e.; since there is no dependency on storage location for each record, multiple records can be accessed at the same time.
- It is suitable for online transaction systems like online banking, ticket booking system etc.

clustered file organization:

Clustered file organization is not considered good for large databases. In this mechanism, related records from one or more relations are kept in the same disk block, that is, the ordering of records is not based on primary key or search key.

In this method two or more table which are frequently used to join and get the results are stored in the same file called clusters. These files will have two or more tables in the same data block and the key columns which map these tables are stored only once. This method hence reduces the cost of searching for various records in different files. All the records are found at one place and hence making search efficient.



STUDENT

STUDENT_ID	STUDENT_NAME	ADDRESS	COURSE_ID
100	Kathy	Troy	230
101	Patricia	Clinton Township	240
102	James	Fraser Town	230
103	Antony	Novi	250
104	Charles	Novi	250

COURSE

COURSE_ID	COURSE_NAME
230	Database
240	Java
250	Perl

Cluster File

COURSE_NAME	COURSE_ID	STUDENT_ID	STUDENT_NAME	ADDRESS
Database	230	100	Kathy	Troy
		102	James	Fraser Town
Java	240	101	Patricia	Clinton Township
Perl	250	103	Antony	Novi
		104	Charles	Novi

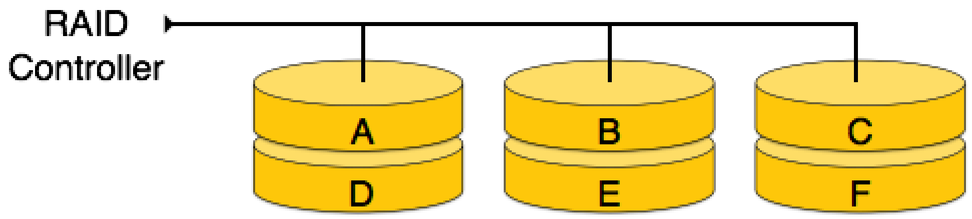
REDUNDANT ARRAY OF INDEPENDENT DISKS(RAID)

RAID or **R**edundant **A**rray of **I**ndependent **D**isks, is a technology to connect multiple secondary storage devices and use them as a single storage media.

RAID consists of an array of disks in which multiple disks are connected together to achieve different goals. RAID levels define the use of disk arrays.

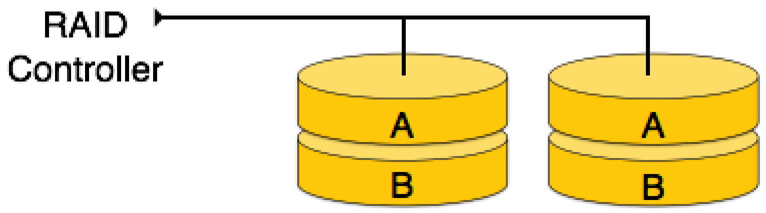
RAID 0

In this level, a striped array of disks is implemented. The data is broken down into blocks and the blocks are distributed among disks. Each disk receives a block of data to write/read in parallel. It enhances the speed and performance of the storage device. There is no parity and backup in Level 0.



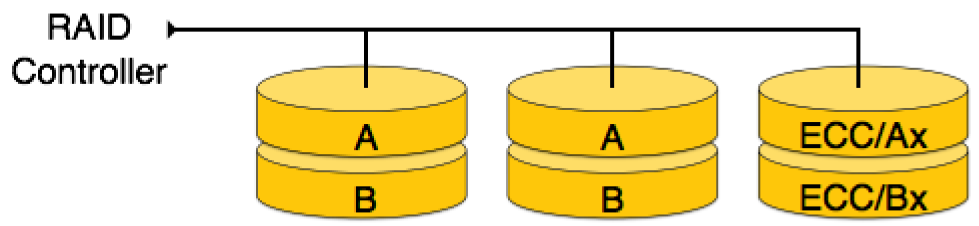
RAID 1

RAID 1 uses mirroring techniques. When data is sent to a RAID controller, it sends a copy of data to all the disks in the array. RAID level 1 is also called **mirroring** and provides 100% redundancy in case of a failure.



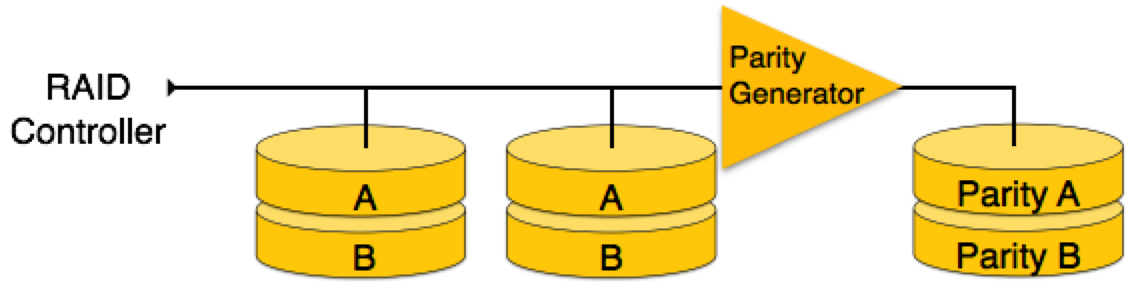
RAID 2

RAID 2 records Error Correction Code using Hamming distance for its data, striped on different disks. Like level 0, each data bit in a word is recorded on a separate disk and ECC codes of the data words are stored on a different set disks. Due to its complex structure and high cost, RAID 2 is not commercially available.



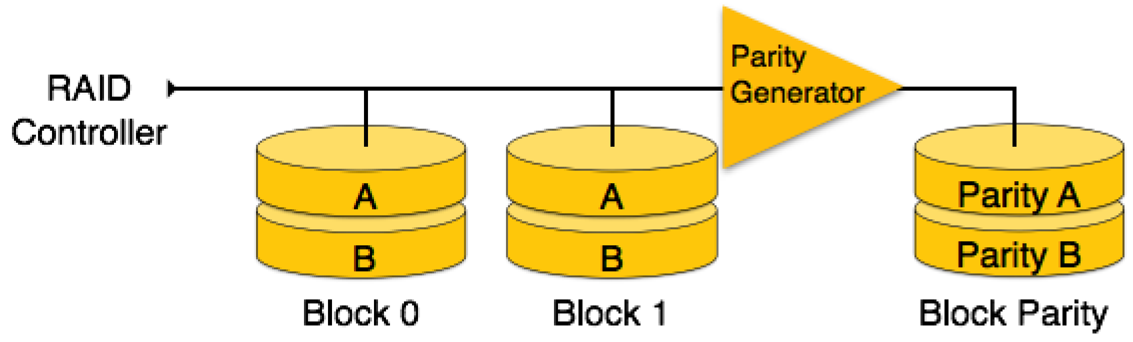
RAID 3

RAID 3 stripes the data onto multiple disks. The parity bit generated for data word is stored on a different disk. This technique makes it to overcome single disk failures.



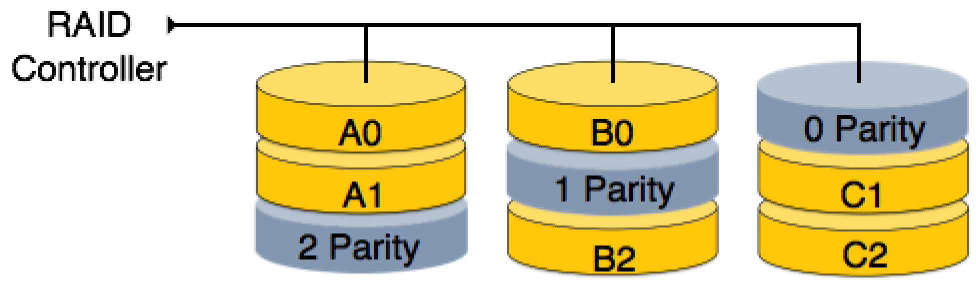
RAID 4

In this level, an entire block of data is written onto data disks and then the parity is generated and stored on a different disk. Note that level 3 uses byte-level striping, whereas level 4 uses block-level striping. Both level 3 and level 4 require at least three disks to implement RAID.



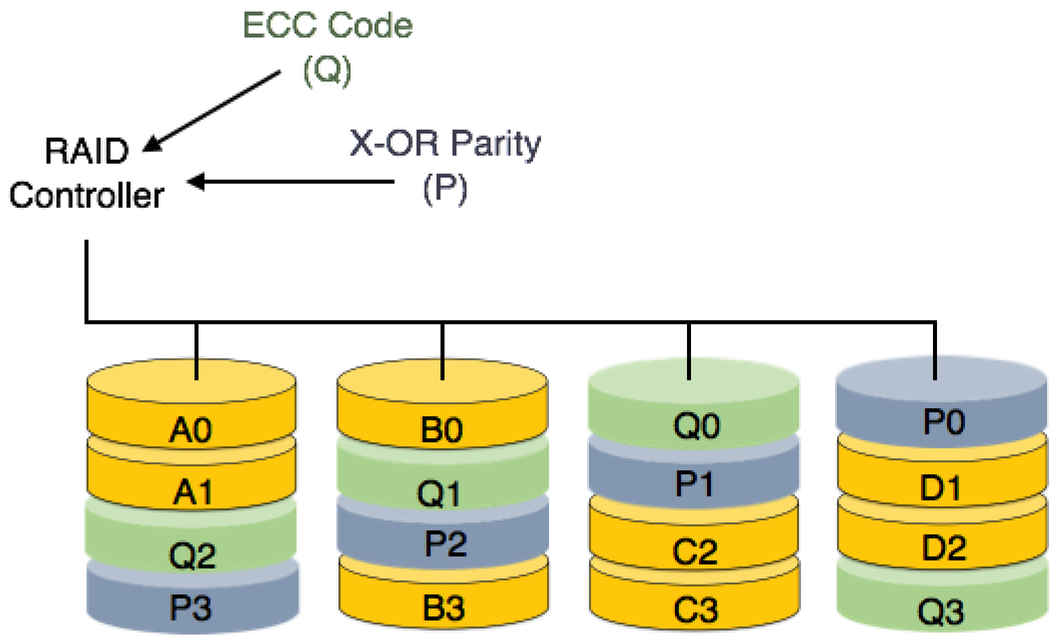
RAID 5

RAID 5 writes whole data blocks onto different disks, but the parity bits generated for data block stripe are distributed among all the data disks rather than storing them on a different dedicated disk.



RAID 6

RAID 6 is an extension of level 5. In this level, two independent parities are generated and stored in distributed fashion among multiple disks. Two parities provide additional fault tolerance. This level requires at least four disk drives to implement RAID.



Comparison of file organizations:

The operations to be considered for comparisons of file organizations are below:

- **Scan:** Fetch all records in the file. The pages in the file must be fetched from disk into the buffer pool. There is also a CPU overhead per record for locating the record on the page (in the pool).
- **Search with equality selection:** Fetch all records that satisfy an equality selection, for example, "Find the Students record for the student with *sid* 23." Pages that contain qualifying records must be fetched from disk, and qualifying records must be located within retrieved pages.
- **Search with range selection:** Fetch all records that satisfy a range selection, for example, "Find all Students records with *name* alphabetically after 'Smith.' "
- **Insert:** Insert a given record into the file. We must identify the page in the file into which the new record must be inserted, fetch that page from disk, modify it to include the new record, and then write back the modified page. Depending on the file organization, we may have to fetch, modify, and write back other pages as well.
- **Delete:** Delete a record that is specified using its rid. We must identify the page that contains the record, fetch it from disk, modify it, and write it back. Depending on the file organization, we may have to fetch, modify, and write back other pages as well.

File Type	*Scan*	*Equality Search*	*Range Search*	*Insert*	*Delete*
Heap	BD	$0.5BD$	BD	$2D$	$Search + D$
Sorted	BD	$Dlog_2B$	$Dlog_2B + \#\ matches$	$Search + BD$	$Search + BD$
Hashed	$1.25BD$	D	$1.25BD$	$2D$	$Search + D$

Figure 8.1 A Comparison of I/O Costs

B - number of data pages

R records per page

D- average time to read or write a disk page

C- average time to process a record

Indexing:

Index:

Dense Index:

Sparse Index:

Primary indexing:

secondary indexing:

cluster indexing:

multi value indexing:

ISAM

B+ trees:

Read from class notes