CHAPTER 5

UNIT V

Parallel and Distributed Databases

Syllabus

- Introduction to Database architectures: Multi-user DBMS architectures
- Case Study- Oracle Architecture
- **Parallel Databases :** Speedup and Scaleup, Architectures of Parallel Databases.
- **Distributed Databases :** Architecture of Distributed Databases, Distributed Database Design, Distributed Data Storage
- Distributed Transaction : Basics, Failure modes, Commit Protocols, Concurrency Control in Distributed Database

Syllabus Topic : Introduction To Database Architecture - Multi-user DBMS Architectures

5.1 Introduction to Database Architecture : Multi-user DBMS Architectures

The common architectures that are used to implement multi-user database management systems :

1. Teleprocessing
2. File-Server
3. Client-Server

5.1.1 Teleprocessing

- Teleprocessing is a traditional architecture for multiuser systems. This architecture has one computer with single Central Processing Unit(CPU) and multiple terminals. Here the processing is performed in one physical computer.
- The different terminal are typically "dumb", incapable of functioning on their own and cabled to the central computer.
- In this system, the terminals can access DBMS and database directly but this it also makes very heavy load to the CPU as it has to perform two operations
  - Run application programs and DBMS.
  - Formatting of data to represent on the terminals.

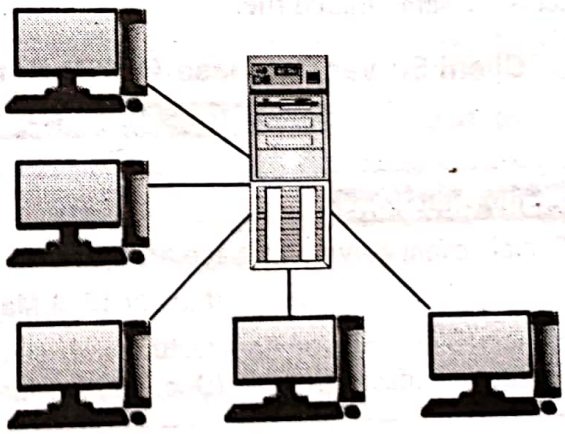


Fig. 5.1.1 : Teleprocessing architecture

5.1.2 File Server

- In the file-server architecture, there is a comput which is connected to a network and mainly serv as a shared storage.

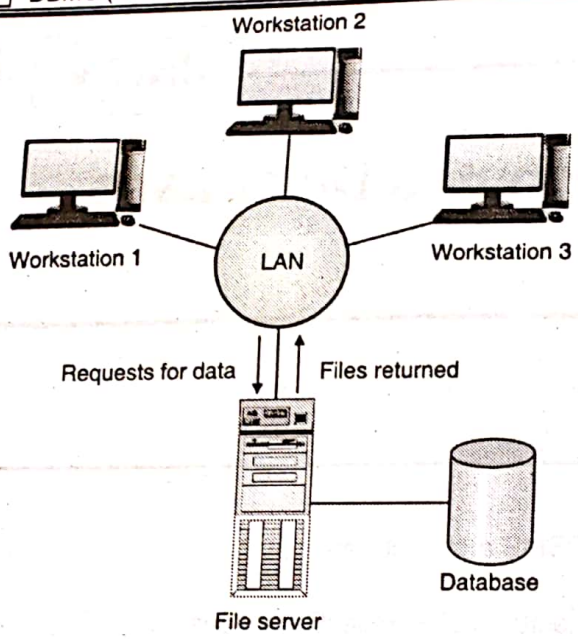


Fig. 5.1.2 : File server architecture

- The processing is distributed over the network in the file-server architecture is typically the Local Area Network (LAN). The file server stores all the files which are required to applications and DBMS. To get these files, the applications and DBMS has to make requests to file server.
- The file server works as shared data disc.

Disadvantages

- It generates heavy network traffic.
- Each workstation requires a full copy of DBMS.
- Complex integrity, concurrency, and recovery control : Multiple DBMSs may concurrently access the same shared file.

5.1.3 Client Server Database Architecture

SPPU - May 14, Dec. 15

University Questions

Q. Explain client server database architecture. **(May 2014, 3 Marks)**

Q. Explain Client Server Architecture with suitable database application. **(Dec. 2015, 5 Marks)**

- A network architecture in which each computer or process is connected in the network is client or server is known as **client server architecture**.
- Server is nothing but the powerful computer. It has more storage and processing capacity than the client machine. It manages client computers, printers, disk drivers and network traffic.
- Clients are the PC's where user can run the applications. Clients always depend on server for resources and processing power.
- In this architecture clients request data from the server and server provide all the required information to the client in response.

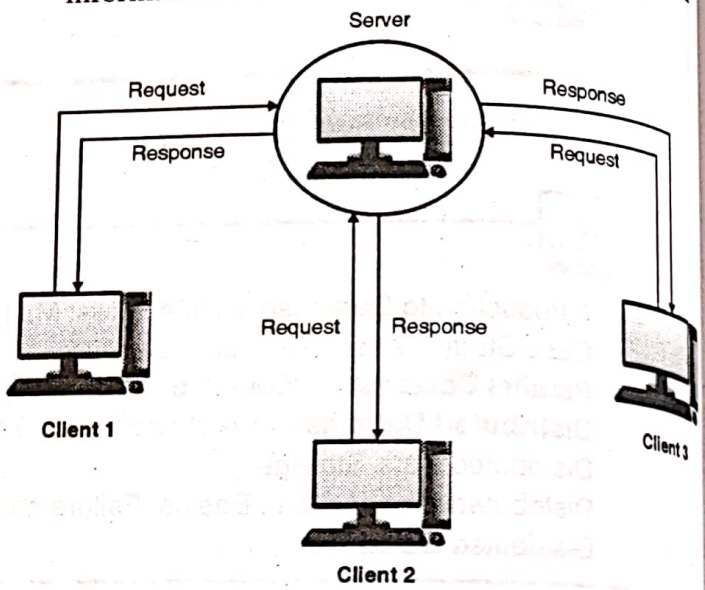


Fig. 5.1.3 : Client-server architecture

Banking Database Application of Client Server Architecture

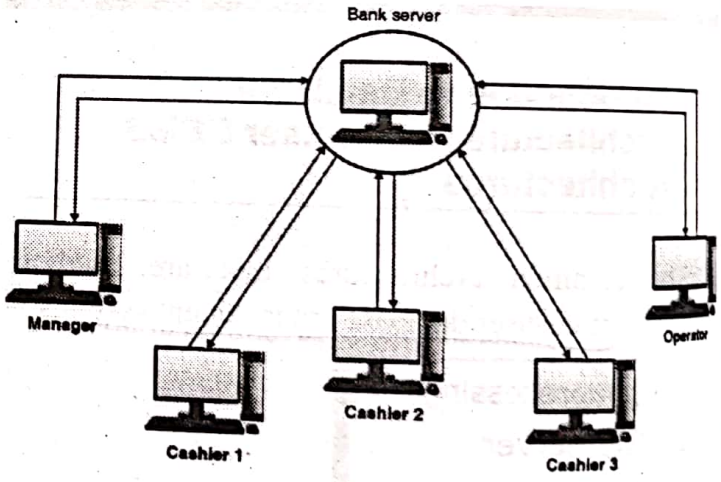


Fig. 5.1.4 : Bank database system

- Consider the Banking Database Example. In this system, the database is stored on server. From this server all clients like Manager, Operator and Cashiers in the system access the data from database. As per roles and privileges granted the data accessibility rights are decided for different clients in the bank.
- For example, the manager will have access right to whole data while the operators and cashiers can access data as per their tasks assigned.

In the banks like SBI and ICICI where the number of customers or account holders is more, it is not sifficient to keep only one cashier to reciept cash and one cashier to pay cash. For this tasks there are multiple cashiers.

Consider, account holder 'A' wants to withdraw some amount from his bank account. In this case as shown in Fig. 5.1.4, there are number of cashiers and 'A' can goto any one of them. This is possible because the data of all the account holders is available on the server. And all the cashiers can access the data. This definitely increases the efficieny of bank.

Advantages of Client Server Architecture

- Organizations always try to maintain service and quality competition to sustain its market position with the help of advanced technology where the client/server model makes an effective impact.
- Implementation of client/server architecture in an organization will definitely increase productivity through the usage of cost-effective user interfaces, enhanced data storage, strong connectivity and reliable application services.
- There are number of advantages of Client Server Architecture

1. **Centralized Database :** The database is centrly available for all the clients easily. The centralized database is easy to manage for database administrator.
2. **Security :** Rules defining security and access rights can be defined at the time of set-up of server.
3. **Back-up and Recovery possible :** As all the data is stored on server, it is easy to take periodical backup of it. Also, in case of any break-down if data is lost, it can be recovered easily and efficiently.
4. **Upgradation and Scalability :** Making Changes can is easy by just upgrading the server. The new resources and systems can be added by making required changes in server.
5. **Server Role :** Server can play different roles for different clients.

5.1.3.1 Types of Client Server Database Architecture

Now to understand types of Client Server database architecture first we have to study the concept of layers or services.

Layers or Services

A software application is created using programming languages(called as frontend) and database(called as backend). In every software we have to implement following three layers.

1. **User Layer(presentation layer)**
   - It is also called as client layer which contain User interface of our application. This layer is used for design purpose. In this data is presented to the user and also input can accepted from the user.
   - For example in banking software, the registration form of an account holder can be considerd as user layer.
2. **Business Layer**
   - This layer is also known as business layer. In this layer we can write all business logic like validation of data, calculations, data insertion etc. This acts as an interface between Client layer and Data Access Layer.
   - This layer is also called the intermediary layer helps to make communication faster between client and data layer.
3. **Data Layer**
   - In this layer actual database is comes in the picture. Data Access Layer contains methods to connect with database and to perform insert, update, delete, get data from database based on our input data.
   - Depending upon the implementation of these three layers there are types of database architecture.

A. Two tier architecture
B. Three tier architecture

A. Two Tier Architecture

SPPU - Dec. 13

University Question

Q. Explain two-tier architecture. (Dec. 2013, 2 Marks)

- The **two tier architecture** is based on the client server architecture. The direct communication takes place between client and server.
- The two tier architecture is the architecture in which user interface is run on client side and data layer is stored on the server side. In two tier architecture we can integrate business layer with either presentation layer or database layer or can be distributed in both.

i) The business layer can be integrated with presentation layer at client side. In this case the size of client application increases, hence it is known as **Fat Client.**

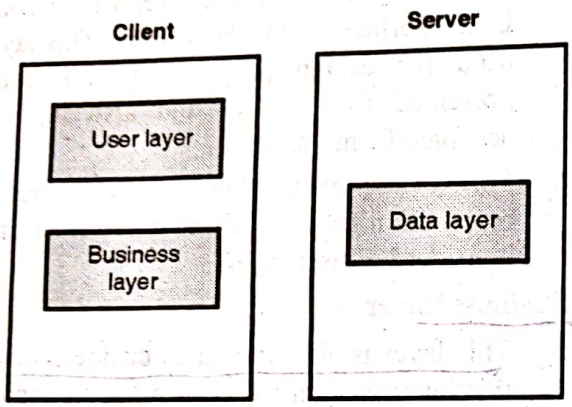


Fig. 5.1.5 : Fat client

ii) The business layer can be integrated with data layer at server side. In this case the size of server application increases, hence it is known as **Fat Server.**

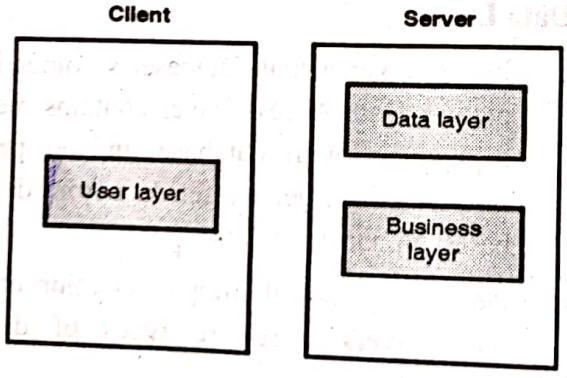


Fig. 5.1.6 : Fat server

iii) The business layer can be integrated with both user layer and data layer.

Advantages of two tier architecture

1. In two tier architecture, applications can be easily developed due to simplicity.
2. In this client and server are directly connected, due to which communication becomes faster.
3. Maximum user satisfaction is achieved with accurate and fast prototyping of applications through robust tools.
4. It contains static business rules which are easily applicable for homogeneous environment.
5. We can integrate application layer physically with the database layer as well as user interface layer

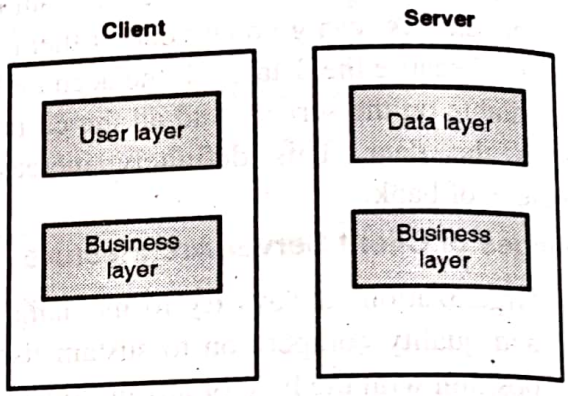


Fig. 5.1.7 : Two tier architecture

Disadvantages of two tier Architecture

1. It can only support to the limited number of users due to lack of scalability.
2. The performance of two tier architecture degrades when number of user increases.
3. Two tier architecture is cost ineffective.
4. As per security concern it is complicated.

B. Three Tier Architecture

SPPU - Dec. 13

University Question

Q. Explain three-tier architecture. **(Dec. 2013, 2 Marks)**

- **The three tier architecture** is most widely used architecture in today's world.
- In this architecture the user layer, business layer and data layer are implemented independently by three different applications.
- The data required by the business logic exists in database server.
- In three tier architecture all layers interact with each other independently.

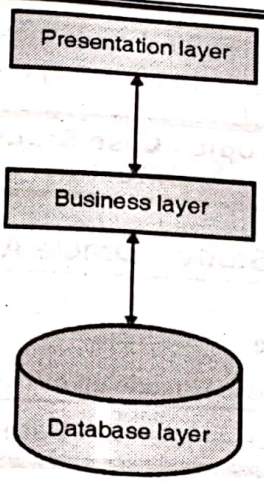


Fig. 5.1.8 : Tree tier architecture

Advantages of Three tier Architecture

1. In three tier architecture we can manage the data independently.
2. We can make the changes in presentation layer without affecting other two tiers.
3. As each tier is independent it is possible to use different groups of developers
4. It is most secure since the client doesn't have direct access to the database layer.
5. When one tier fails there is no data loss, because you are always secure by accessing the other tier.
6. Due to distributed deployment of application server, scalability is increased.
7. A similar logic can be used in various applications. It is reusable.
8. It is robust and secure due to multiple layers.

Disadvantages of three tier architecture

1. It is more complex structure.
2. More difficult to set up and maintain it.
3. The physical separation of the tiers may affect the performance.

Example : SPPU - May 15, May 16

University Question

Q. Explain 3-tier web architecture with diagram for online shopping database system? **(May 2015, May 2016, 8 Marks)**

This is the online shopping diagram for 3 Tier architecture. Here the as a frontend Dot Net environment is used while as backend database MS SQL Server 2008 is used.

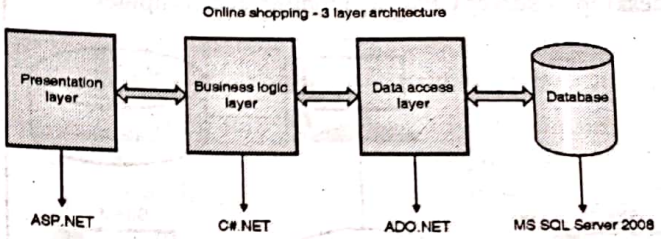


Fig. 5.1.9 : Online shopping diagram for 3-tier architecture

Fig. 5.1.9 shows three layers :

1. **Presentation layer :** This layer consist of user interface designed for the interaction with end user. This layer is created in ASP .Net. It includes the screens which will be used by the end user for shopping. Theses screen show the products with details as per their categories. User can select the product to purchase and add them into cart. This design is created with advanced controls available in ASP .Net.
2. **Business Layer** : This layer consist of validation checking code related to product selection of user. Accidently user may select wrong number of products to purchase. For example, if any user is giving order to purchase 10000 TV sets, then the order should be validate. This logical code is implemented using the C# .Net.
3. **Data Layer** : This layer contains the code interacting with database on the server. For example, accessing product details from database, inserting transaction details of user order in database etc. This database handling is implemented using the ADO .Net. Here all the three layers work independently and efficiently.

5.2 Centralized Database Architecture

SPPU - Dec. 13, May 14

University Questions

Q. Write short note on centralized database system. **(Dec. 2013, 3 Marks)**

Q. Explain centralized database architecture. **(May 2014, 3 Marks)**

A database which is located, stored and

maintained at single location is known as **centralized database architecture**. This location is most often a central computer or database system, for example a desktop or server CPU, or a mainframe computer.

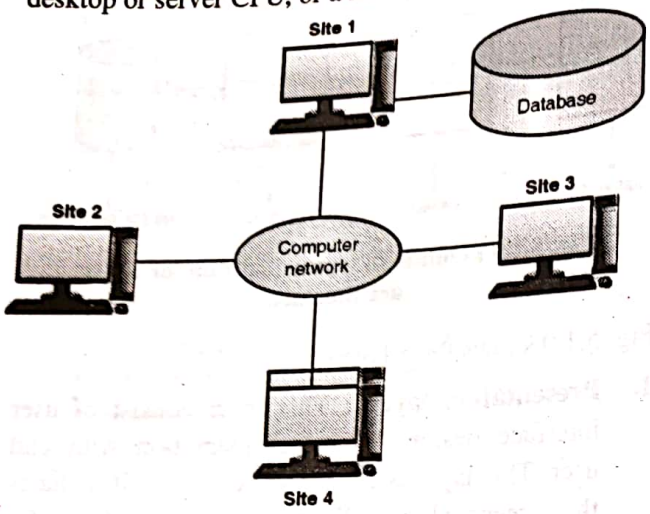


Fig. 5.2.1 : Centralized database architecture

In centralized database architecture the database physically resides on only one site and other sites can access it through the network.

Advantages of centralized database system

1. Easy to use by end-users due to its simplicity provided by storing all the data at one place. It helps to maximize Data integrity and also minimized data redundancy.
2. Data reliability is enhanced and accuracy and consistency of data is maintained.
3. It provides better security for stored data. As all the data of any organization is stored on one place, the organization can easily focus on security detail of one place rather than of multiple locations.
4. In a centralized system, information can be changed or updated easily.
5. Centralized system provides fault tolerance facility so the data is preserved in better way.
6. Also it is cost effective approach as this system requires minimum maintenance cost.

Disadvantages of centralized database system

1. It is highly dependent on network connectivity, hence if the network is slower, then the time require to access data from database is also increases.
2. It decreases the efficiency of the system, as there is only one copy of data. If more than one user want to access it then it is not possible.

Syllabus Topic : Case Study – Oracle Architecture

5.3 Case Study – Oracle Architecture

Oracle Database

Oracle database is made up of two components :

1. Instance
2. Database

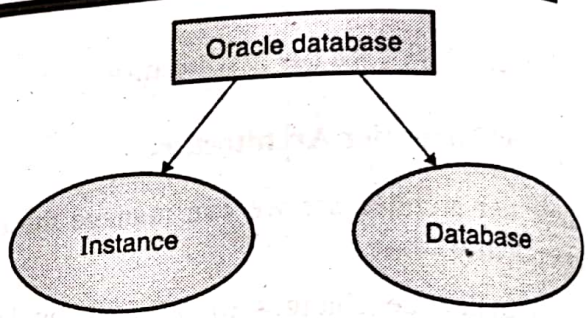


Fig. 5.3.1 : Components of oracle database

1. Instance

In database files the database structure and processes are very important. An instance is nothing but the memory structure and processes that are used to access the data from the database.

The **memory structure** is consist of

- System Global Area (SGA)
- Program Global Area (PGA)
- Optional Software Code.

The background processes are

- Database Writer (DBWn)
- Log Writer (LGWR)
- Checkpoint (CKPT)
- System Monitor(SMON)
- Process Monitor(PMON)
- Optional – Archiver (ARCn), Recoverer (RECO)

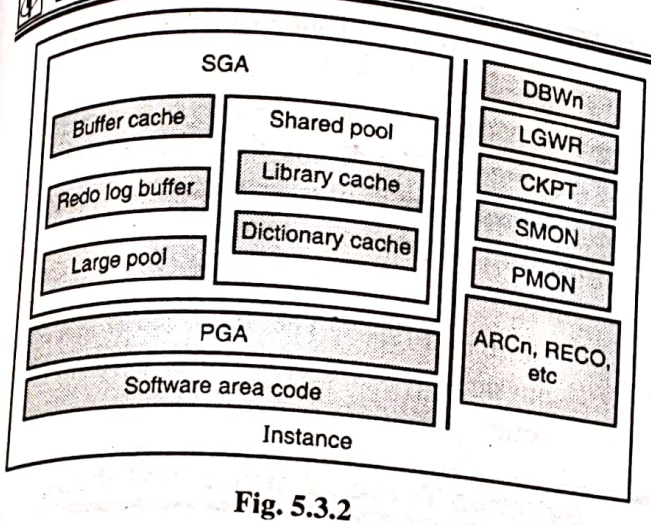


Fig. 5.3.2

Now we will discuss all these components in detail :

- **System Global Area (SGA)**

This is the primary part of oracle structure. The SGA is a memory area for structures that are shared among users. The main components of SGA are Buffer Cache, Shared Pool, Redo Log Buffer, Large Pool and Java Pool.

Buffer Cache

This cache is used to store the frequently accessed data blocks from tables and indices in memory. It reduces the need to perform physical disc IO. The size of this buffer cache can be changes as per the requirement.

Shared Pool

- Oracle is designed for multiuser systems. When multiple users executes sme SQL query then they can share the data structures that represent the execution plan for these statements. For this purpose the data the data which is local to each specific call of the statement should be kept in private memory.
- The Shared pool is used to store the sharable parts of data structures representing the SQL statement with text of the statement. This helps in reducing the compilation time since new call of a statement which is already cached does not have to go through the complete compilation process.
- The **library cache** is used to store the information about the commonly used SQL statements while the **dictionary cache** is used to store the information about object definition like table, columns, indexes, privileges etc.
- **Redo Log Buffer :** The DML statements like select, insert, update or delete generates redo entry. This redo entry is nothing but all the information about changes made by user. To store this redo entry, redo log buffer is used before it is written in to redo log files.
- **Large Pool :** This is basically optional area in the SGA. It is used for I/O processes and it also helps to relieve the burden of shared pool.
- **Program Global Area (PGA) :** When the SQL statement is parsed, its result is stored in library cache. The value of binding variable is stored in the PGA to make it private so that it should not be accessed by other users.
- **Software Area Code :** In software area code, the oracle software application resides.

- **Dedicated Server : Process Structure**

To execute Oracle server code, there are two types of processes : **Server processes** which processes the SQL statements and **background processes** that performs various performance and administrative related tasks. Some of these processes are as follows.

- **Database Write(DBWn) :** Before removing from the buffer cache, the Database Writer writes the buffer into the disc if it has been modified. It improves the performance of the system.
- **Log Writer (LGWR) :** The log Writer writes the redo entries from redo log buffer into the redo log files.
- **Checkpoint (CKPT) :** The checkpoint process updates the headers of the data file when a checkpoint occurs.
- **System Monitor (CMON) :** This process is used for crash recovery when any process fails. It also manages the space by reclaiming the unutilized space in temporary segments.
- **Process Monitor(PMON) :** This process is used for process recovery when any process fails. It releases the resources and performs various cleaning operations.
- **Archiver (ARCn) :** When the online log files fills up, the Archiver copies the online redo log file to an archived redo log.

- **Recoverer (RECO) :** This process resolves failures and conducts cleanups for distributed transactions.

2. Database

The database refers to disc resources. It is basically divided into two types : Logical and Physical structure.

A) Logical Structure : To manage the data efficiently, the oracle database is divided into smaller units like tablespace, segment, extent and data block.

- **TableSpace :** Tablespace is the collection of logical database objects.

  There are three types of tablespaces

  (a) Permanent (b) Undo

  (c) Temporary

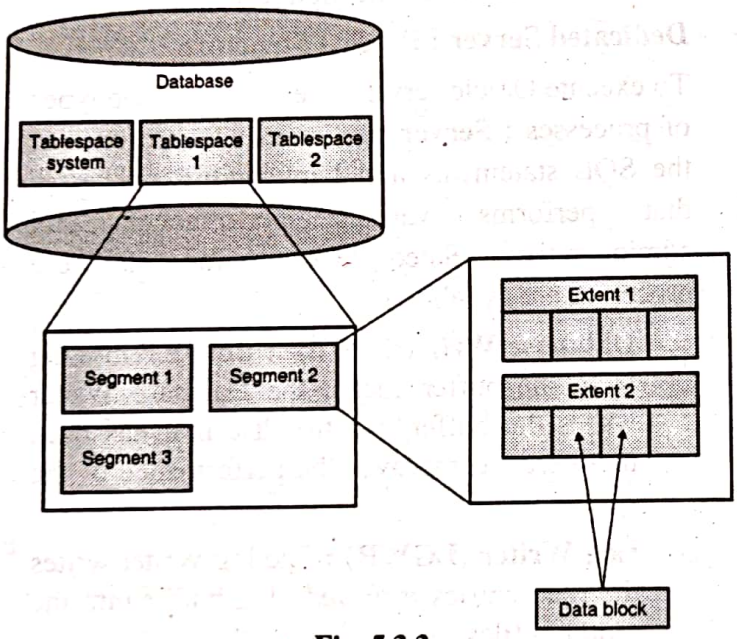


Fig. 5.3.3

- **Segment :** The tablespace is divided into segments. Same type of objects are stored in the segments. There are following types of segments in oracle :

  Table, Index, Cluster, Rollback, Temporary, Cache etc.

- **Extent :** A segment is then divided into extents. It consists of data blocks. An extent is allocated for the enlarged database object.

- **Data Block :** It is the smallest unit of storage in the oracle database.

B) Physical Structure : It consists of data files, redo log files and control files.

- **Data Files :** Data files corresponds to tablespace

- **Redo Log Files :** When a transaction is committed the details about the transaction in the redo log buffer is written into redo log file. This file helps in recovery when failure occurs.

- **Control Files** : The information about the physical structure of database is stored in the control file.

Syllabus Topic : Parallel Database

5.4 Parallel Database

Now a day organizations need to handle huge amount of data with high transfer rate. For such requirement the client server or centralized system is not efficient. The need to improve the efficiency of system, the concept of Parallel Databases comes in picture.

Parallel database improves the performance of processing of data using multiple resources simultaneously. Multiple CPU, Disks can be used simultaneously. A parallel database improves speed of data processing. A parallel server can allow access to a single database by users on multiple machines, with increased performance. By doing parallelization of loading data, building indexes and evaluating queries, the parallel database system improves the performance. In parallel database system we can use thousands of small processors.

Advantages of Parallel Database

1. **Performance Improvement :** By connecting multiple resources like CPU and disks in parallel we can significantly improve the performance of system.

2. **High Availability :** Same data can be stored on multiple locations so that the availability of data can be increased. In parallel database nodes has less contact with each other, so failure at one node does not cause for failure of entire system. One of the surviving nodes recovers the failed node and the system continues to provide data access to users. This means data is much more available than it would be with a single node upon node failure. This also amounts to significantly higher database availability.

3. **It increases Reliability :** When a site fails, the execution can continue with another available site which is having copy of the data. Due to this it becomes more reliable.

4. **It have large capacity :** In parallel database more users request access to the database due to which administrator add more computers to the parallel server. The addition of computers boosts the overall capacity.

Syllabus Topic : Speedup and Scaleup

5.4.1 Speedup and Scaleup

SPPU - May 15, May 16, Dec. 16

University Questions

Q. Explain speedup and scaleup in parallel databases in detail.
(May 2015, May 2016, 5 Marks)

Q. What is speedup and scaleup attributes in parallel database architectures?
(Dec. 2016, 4 Marks)

To measure the performance of parallel processing we can use two important properties:

1. Speedup

- The extent in which more hardware can perform the same task in less time than the original system is known as **Speedup.** It means the execution of task done in less time by increasing degree of parallelism. The time which is required to process a task is inversely proportional to the time when number of resources are used.
- With good speedup, additional processors reduce system response time. We can measure speedup is as follows:

$$\text{Speedup} = \frac{\text{time\_original}}{\text{time\_parallel}}$$

Where,

Time_Parallel is the time spent by a larger, parallel system on the given task

- For example, If the original system took 60 seconds to perform a task, and two parallel systems took 30 seconds, then the value of speedup would be 60/30 = 2.

Linear Speedup

We can say that speedup is linear when speedup is equal to N. That is the elapsed time of small system is N times larger than the elapsed time of large system where N is the number of resources.

Sub-linear Speedup

When speedup is less than N then it is called as sub-linear speedup.

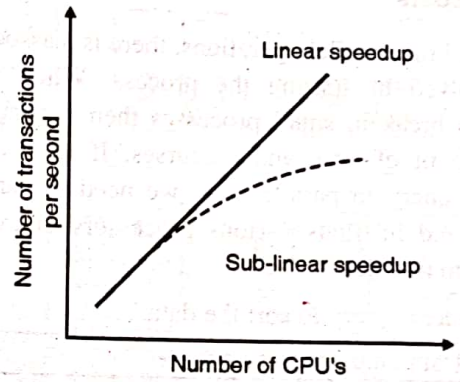


Fig. 5.4.1 : Speedup

2. Scaleup

- The ability to keep the same performance level when both workload and resources increase proportionally is known as **Scaleup.** It is the process of handling large task in same amount of time by increasing degree of parallelism.

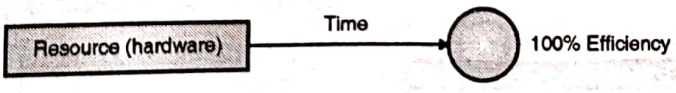
We can measure the ScaleUp is as follows:

$$\text{Speedup} = \frac{\text{Volume\_parallel}}{\text{Volume\_original}}$$

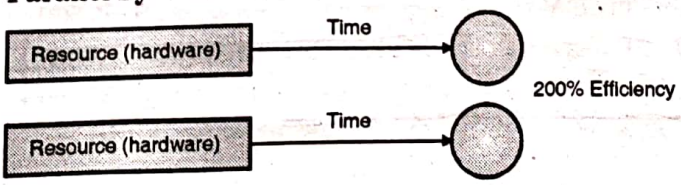
Where Volume_Parallel is the transaction volume processed in a given amount of time on parallel system.

- In case of good Scaleup if there is increase in transaction volume, then to keep response time constant, we can add hardware resources like CPU.

Original System



Parallel System



5.4.1.1 Different Factors Affecting the Speedup and Scaleup Attributes

SPPU - Dec. 16

University Question

Q. Explain the different factors affecting the speedup and scale-up attributes. **(Dec. 2016, 4 Marks)**

Startup costs

For all the parallel operations, there is a associated cost involved in starting the process. When a big process is break in small processes then it consumes some amount of time and recourses. If we want to execute a query in parallel then we need to partition the table and instructs various processors to execute the query in parallel.

Consider a query to sort the data.

```
Select * from emp order by ename
```

Now to execute this query in parallel we need to partition the table as per sorting criteria and instructs various processors to execute the query in parallel. Both of these operations need some amount of time before the parallel execution.

- **Interference :** The various resources are shared by all he processes which executes in parallel. Whenever interference of a new process happens, it leads to slow down the overall access of all the processes. This affects both speed-up and scale-up.
- **Skew :** It is difficult to break a big tasks in equal size small tasks. In such case the performance of the system depends upon the slowest CPU which processes the largest sub task. This type of uneven division of big tasks into smaller ones is called as skew. This also affects the speed-up and scale-up.

Syllabus Topic : Architecture of Parallel Databases

5.4.2 Architecture of Parallel Database

SPPU - Dec. 14, May 16

University Questions

Q. Explain any two parallel database architectures in details. **(Dec. 2014, 5 Marks)**

Q. Explain parallel database architectures. **(May 2016, 4 Marks)**

There are four different architectural models of parallel database:

1. Shared memory
2. Shared disk
3. Shared nothing
4. Hierarchical

5.4.2.1 Shared Memory

SPPU - Dec. 15

University Question

Q. Explain Shared Memory Parallel Database System architecture. **(Dec. 2015, 3 Marks)**

In this architecture of parallel database common memory is shared among the multiple processors. These processors are connected through the interconnection network to the main memory and disk. The connection used in this architecture is usually high speed network connection which makes data sharing easy. Shared memory architecture have large amount of cache memory at each processors.

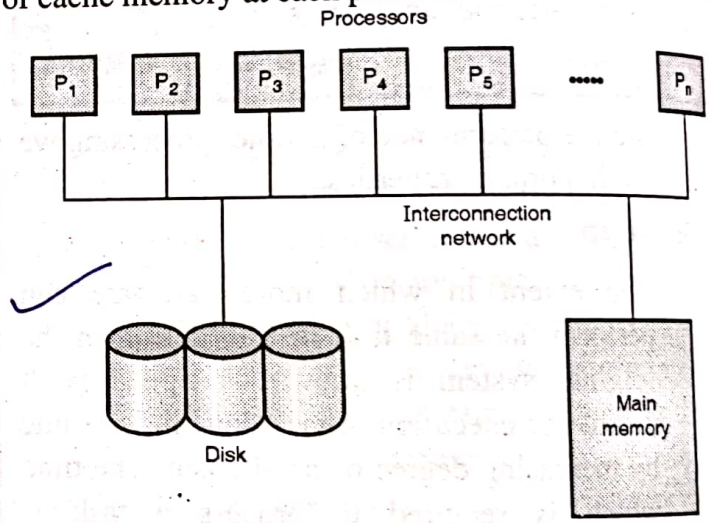


Fig. 5.4.2 : Shared memory architecture

Advantages of shared memory architecture

1. Any processor can access data easily.
2. Effective communication between processors through common memory address space.
3. Communication overheads are less.

Disadvantages of shared memory architecture

1. Waiting time of processors is increased due to more number of processors
2. Degree of parallelism is limited.
3. Addition of processor slows down the existing processors.
4. When a processor tries to access the data updated by other processors, then we have to take care that the data is of latest updated version.

5.4.2.2 Shared Disk Architecture

In the shared disk architecture of parallel database system single disk is shared among all the processors. These all processors also have their own private memory which makes data sharing efficient.

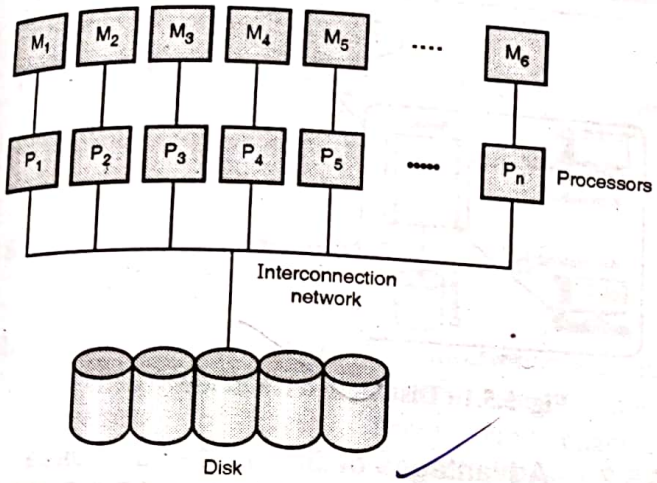


Fig. 5.4.3 : Shared disk architecture

Advantages of shared disk architecture

1. It has fault tolerance means failure of any processor does not lead to execution stop; rather any other processor completes the task.
2. As compared to shared memory architecture it supports large number of processors.
3. This architecture permits high availability.
4. Interconnection to the memory is more smooth and free.

Disadvantages of shared disk architecture

1. The scalability of Shared disc system is limited as large amount of data travels through the interconnection channel.
2. The speed of existing processors may slow down if more processors get added.

5.4.2.3 Shared Nothing Architecture

SPPU - Dec. 15

University Question

Q. Explain Shared Nothing Parallel Database System architecture. **(Dec. 2015, 7 Marks)**

- The shared nothing architecture is a distributed computing architecture in which each node is independent. More specifically, none of the nodes share memory or disk storage.
- In this architecture each processor has its own local memory and local disk.
- Intercommunication channel is used by the processors to communicate.
- The processors can independently act as a server to serve the data of local disk.

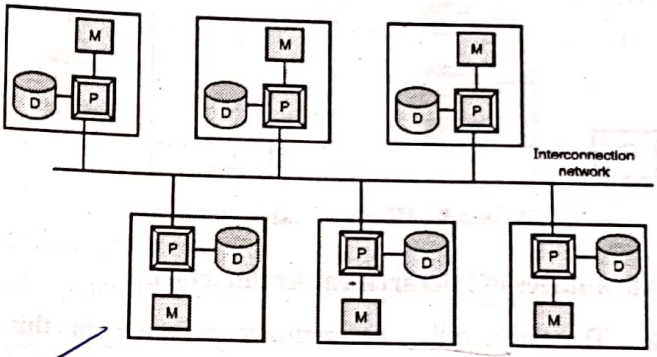


Fig. 5.4.4 : Shared nothing architecture

Advantages of shared nothing architecture

1. This architecture is scalable regarding the number of processors. Increase in their number is easy and flexible.
2. When nodes get added transmission capacity increases.
3. It is a read only database and decision support application.
4. In this architecture failure is local. It means that failure of one node can not affect to other nodes.

Disadvantages of shared nothing architecture

1. The cost of communication is higher than shared memory and shared disk architecture.
2. The data sending involves the software interaction.
3. In this technique more coordination is required.

5.4.2.4 Hierarchical Architecture

Hierarchical model architecture is also known as Non Uniform Memory Architecture. This is nothing but the combination of shared disk, shared memory and shared nothing architecture.

Consider there are two groups of processors say A and B. All processors from both the groups have local

memory. But processors from other groups can access memory which is associated with the other group in coherent.

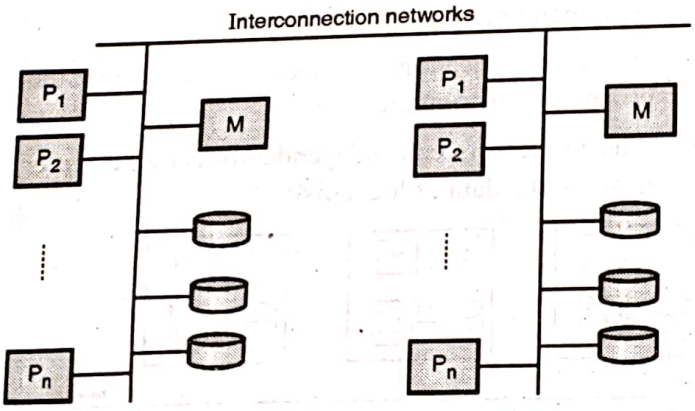


Fig. 5.4.5 : Hierarchical architecture

Advantages of Hierarchical Architecture

1. The availability of memory is more in this architecture.
2. The scalability of system is also more.

Disadvantages of Hierarchical Architecture

1. This architecture is costly as compared to other architectures.

Syllabus Topic : Distributed Database

5.5 Distributed Database

SPPU - Dec. 13, Dec. 15, May 16

University Questions

Q. Write a short note on : Distributed Database System. **(Dec. 2013, 3 Marks)**

Q. Define Distributed Database. **(Dec. 2015, May 2016, 2 Marks)**

5.5.1 Distributed Database Introduction

Distributed database is the type of database management system in which number of databases are stored at various locations and interconnected through the computer networks. Means we can say that, "Distributed database is a collection of various interconnected databases which are physically spread at various locations and communicate via a computer network. In distributed database system each site may have its own memory and its own Database Server.

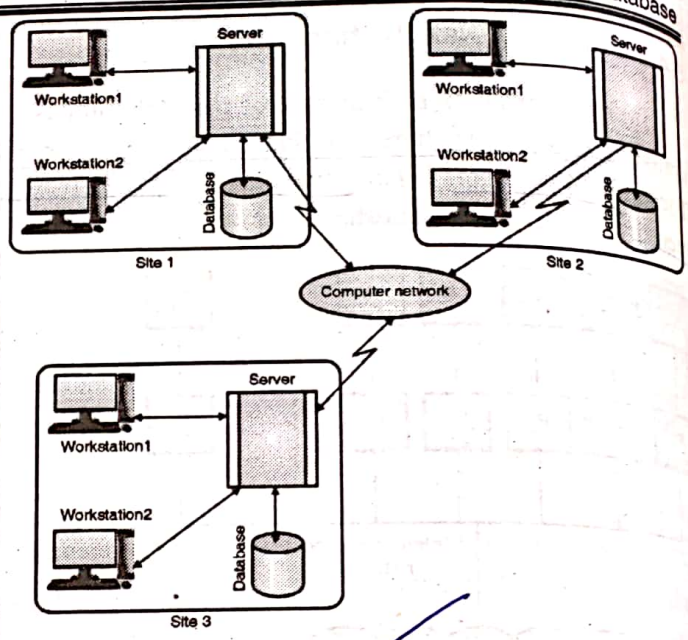


Fig. 5.5.1 : Distributed Database System

5.5.2 Advantages of Distributed Database

SPPU - May 14, Dec. 15

University Question

Q. What are advantages and disadvantages of Distributed Database system architecture? **(May 2014, Dec. 2015, 6 Marks)**

1. **Modular Development :** If we need to expand the same system at new locations, we can use distributed databases, we simply requires to add new computers and local data to the new site and have to connect them to the communication network. It does not interrupt the current functionality.
2. **Increases reliability :** The possibility of the system running at any point is known as reliability. In distributed database system if one component fails to work, other component can take over its function. Due to this the whole system does not affected.
3. **Improve performance :** In distributed database system, large database is distributed among the multiple sites. Due to this distribution a small database is exist at each site. The small database is easy to handle which increases the performance.
4. **Increase availability :** In distributed database system data is scattered at various nodes. Therefore if one node fails then data can be easily available from another node. It means that it have

higher availability.

5. **Faster response :** In this system most of the data is local. Due to this user request can be answered quickly.

6. **Local control :** The sites which contain the data are the owner of the data. These sites can locally control the data.

7. Even though the data is distributed, the system presents the data to the user as if it were located locally. User doesn't know where the data is located physically.

5.5.3 Disadvantages of Distributed Database

1. **Cost :** The requirement of additional hardware to establish a network between sites causes increment of cost. There are ongoing communication costs incurred with the use of this network. There are also additional manpower costs to manage and maintain the local DBMSs and the underlying network.

2. **Security :** In distributed database system database has access from all the sites therefore security becomes an issue for the distributed database system.

3. **Database design more complex :** In distributed database system we have to distribute the large database on various sites in the form of small databases. Due to this, designing of database become more complex.

4. **Increased processing overhead :** It required many messages to share within the sites to complete a distributed transaction.

5. **Complex data integrity :** In distributed database data integrity becomes complex. It requires too many resources to integrate the data.

5.5.4 Types of Distributed Database System

SPPU - Dec. 14, May 16

University Questions

Q. Compare homogeneous and heterogeneous distributed database. **(Dec. 2014, 5 Marks)**

Q. Explain homogeneous and heterogeneous Distributed Databases? **(May 2016, 6 Marks)**

There are two different types of distributed database.

1. Homogenous Distributed Database Systems
2. Heterogeneous Distributed Database Systems

5.5.4.1 Homogeneous Distributed Database Systems

In homogeneous DDBMS, all sites use the same database management system product. In homogeneous distributed database, as all sites have identical software, they are aware of each other and agree to cooperate in processing user requests. A homogeneous DBMS appears to the user as a single system.

It is much easier to design and manage. This design provides incremental growth by making additional new sites to DDBMS easily. It allows increased performance by exploiting the parallel processing capability of multiple sites.

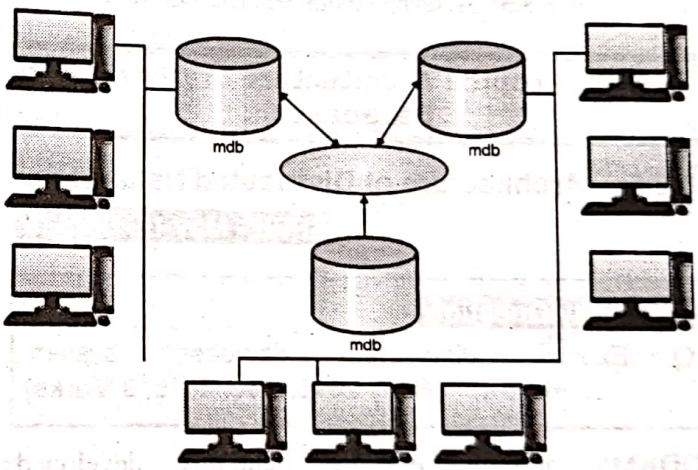


Fig. 5.5.2 : Homogeneous DDBMS

The following conditions must be satisfied for homogeneous database:

- The operating systems used at each location must be same or compatible.
- The database applications used at each location must be same or compatible
- The data structures used at each location must be same or compatible.

5.5.4.2 Heterogeneous Distributed Database System

The word heterogeneous state that the ability to

accept different forms of databases. In heterogeneous database we can use different types of databases. In this type we can use different schemas. In a heterogeneous system, sites may run different DBMS products, which need not based on the same underlying data model, and so the system may be composed of relational, networked, hierarchical and object-oriented DBMSs. In this system, different computers and different operating systems or data models can be used at the each of the location.

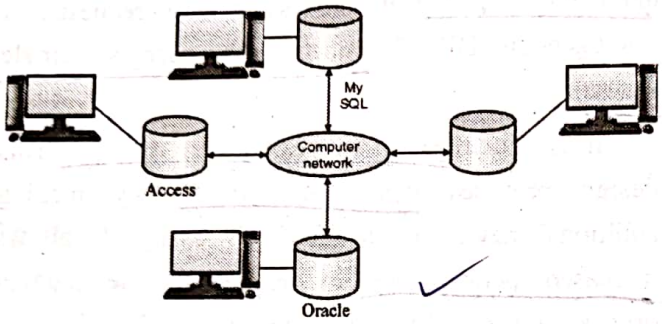


Fig. 5.5.3 : Heterogeneous Database System

Syllabus Topic : Architecture of Distributed Databases

5.5.5 Architecture of Distributed Database

SPPU - May 16, Dec. 16

University Question

Q. Explain distributed database system architecture. **(May 2016, Dec. 2016, 8 Marks)**

DDBMS architectures are generally developed depending on three parameters:

- **Distribution :** It states the physical distribution of data across the different sites.
- **Autonomy :** It indicates the distribution control of the database system and the degree to which each constituent DBMS can operate independently.
- **Heterogeneity :** It refers to the uniformity or dissimilarity of the data models, system components and databases.

Architectural Models

Some of the common architectural models are :

1. Client-Server Architecture for DDBMS
2. Peer-to-Peer Architecture for DDBMS
3. Multi-DBMS Architecture

5.5.5.1 Client-Server Architecture for DDBMS

Client-server architecture is a two-level architecture where the functionality of architecture is divided into servers and clients. Data management, query processing, optimization and transaction management are the functions of server. Client functions include mainly user interface, consistency checking and transaction management.

The two different client-server architectures are :

1. Single Server Multiple Client
2. Multiple Server Multiple Client

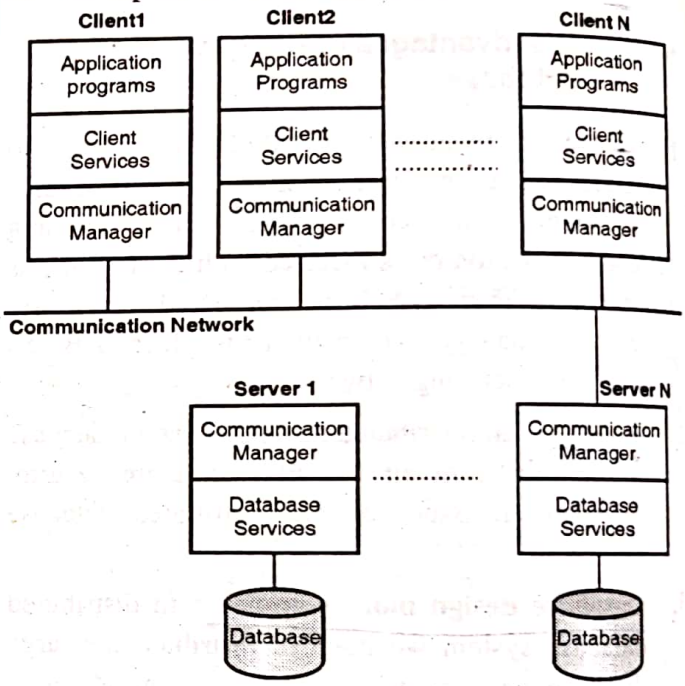


Fig. 5.5.4 : Client-server architecture

5.5.5.2 Peer-to-Peer Architecture for DDBMS

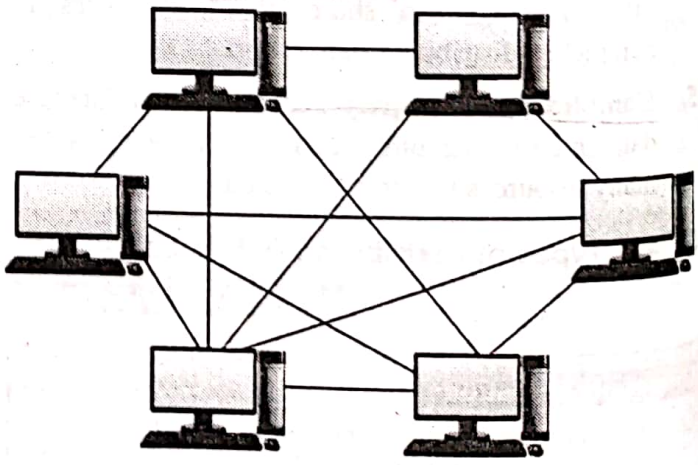


Fig. 5.5.5 : Peer-to-peer architecture for DDBMS

- The network architecture in which each workstation or node has same capabilities and

responsibilities is known as peer-to-peer architecture. Peer-to-peer may also be used to refer single software design. Due to this each peer may act as both client and server.

- The peers share their resources with other peers and co-ordinate their activities.

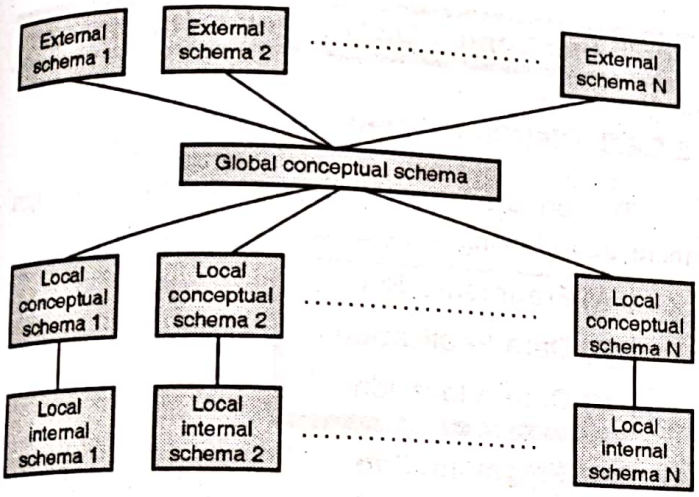


Fig. 5.5.6

- This architecture generally has four levels of schemas

1. **Global Conceptual Schema :** As the name suggest, it shows only the global logical view of data.
2. **Local Conceptual Schema :** It only shows logical data organization at each site. The data on every site is local for that particular site.
3. **Local Internal Schema :** Local internal schema shows the physical data organization at each and every site.
4. **External Schema :** External schema shows the external user view.

5.5.5.3 Multi - DBMS Architectures

Multi-database management system architecture is an integrated database system formed by collection of two or more autonomous database systems. Multi-DBMS can be expressed through six levels of schemas.

- **Multi-database View Level :** It shows multiple user views which consists of subsets of the integrated distributed database.
- **Multi-database Conceptual Level :** It shows the integrated multi-database that consists of global logical multi-database structure definitions.
- **Multi-database Internal Level :** It shows the data distribution across different sites and multi-database to local data mapping.
- **Local database View Level :** It shows the public view of local data.
- **Local database Conceptual Level :** It shows the local data organization at each site.
- **Local database Internal Level :** It shows the physical data organization at each site.

There are two design alternatives for multi-DBMS

- Model with multi-database conceptual level.

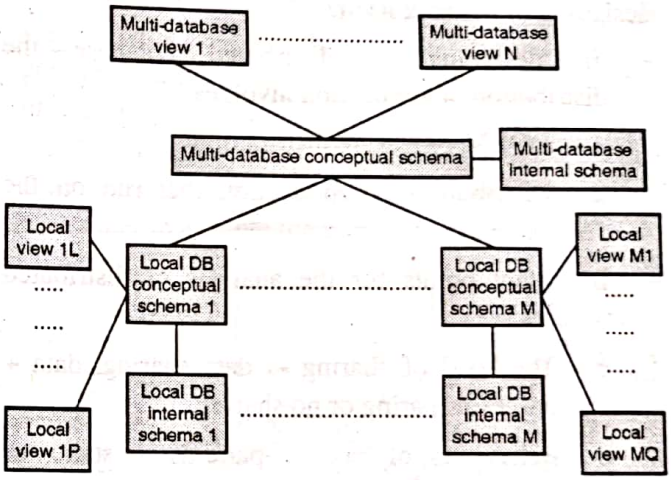


Fig. 5.5.7

- Model without multi-database conceptual level.

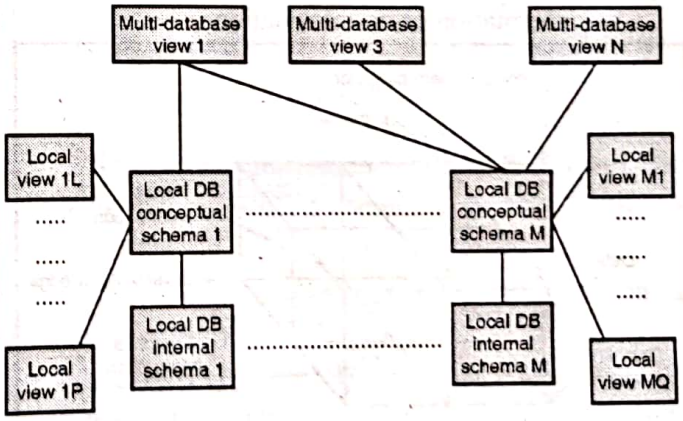


Fig. 5.5.8

Syllabus Topic : Distributed Database Design

5.5.6 Distributed Database Design

The design of distributed database includes

A) Design problem
B) Design strategies(top-down, bottom-up)
C) Distributed Database Storage
- Fragmentation
- Data replication
- Data Allocation

5.5.6.1 Design Problem

In **designing a distributed database**, you must decide which portion of the database and programs are to be stored at which location. It also includes the designing of network itself.

- In designing of distributed database the distribution of application involves
  1. DDBMS software distribution
  2. Distribution of application that run on the database
- Important points for the analysis of distributed systems are -
  - The level of sharing - data sharing, data + program sharing or no sharing
  - Behaviour of access patterns - static or dynamic
  - Level of knowledge on access pattern behavior - partial information, complete information or no information.

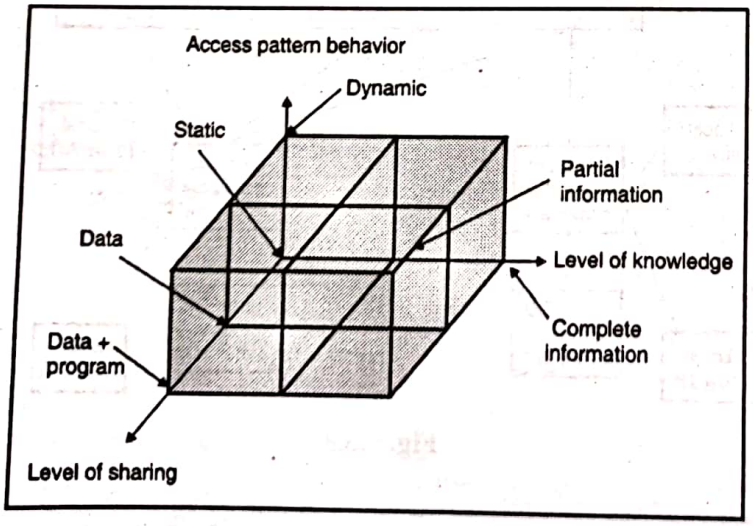


Fig. 5.5.9

5.5.6.2 Design Strategies

Top-down approach

- Designing systems from initial stage
- Homogeneous systems

Bottom-up approach

- The databases considered to be exist at a number of sites already
- To solve common tasks the databases should be connected

Syllabus Topic : Distributed Data Storage

5.5.6.3 Distributed Data Storage

To store a relation in distributed database design there are following approaches

A) Fragmentation
B) Data Replication
C) Data Allocation

A) Data Fragmentation

The data fragmentation is the technique used in distributed database design. This technique is used to break up the database into logical units called **fragments**. The information of fragmentation is stored into the catalogue of distributed database system which is used by the processing computer to process the user's request. There are three different types of fragmentation :

1. **Horizontal Fragmentation** : The fragmentation of relation is done horizontally, in the form of rows. Each fragment which contains unique rows is stored in different computer nodes. Each horizontal fragment may have a different number of rows, but each fragment must have the same number of attributes.
2. **Vertical Fragmentation** : The division of relation into fragments consist of collection of attributes. In the vertical fragments there can be same number of rows and can have different attributes which depends upon the key.
3. **Mixed Fragmentation** : Mixed Fragmentation is the combination of both horizontal and vertical fragmentation. It is the two-step process. The first step is to achieve the horizontal fragmentation to obtain the necessary rows. And second step is to achieve vertical fragmentation to divide attributes among the rows.

B) Data Replication

The data replication is the storage of copies of data at multiple sites on the network. Fragmented copies can be stored at various sites. The data replication enhances data availability and response time. All copies of fragmented data must be identical. The maintenance of replication may become complex. A database can be either **fully replicated, partially replicated** or **un-replicated**. We can use data replication while we have to handle large database. Due to replication it becomes possible to retrieve the lost data. We can retrieve lost data from the other sites.

1. **Fully replicated :** The fully replicated database stores multiple copies of entire database on all the sites. The availability of entire database on all the sites leads to fast processing of queries.
2. **Partially replicated :** Portion of tables(relations) is stores on different sites. The frequency of data access is considered while distributing the data on different sites.
3. **Non replicated or No replication :** Non replicated replication stores single copy of database fragment at a single site. There is no duplication occurs in this phase.

C) Data Allocation

The data allocation decides the locations of different data for storage purpose. Data allocation can be centralized, partitioned or replicated.

1. **Centralized :** The data can be stored on a single particular site. There is no distribution of database.
2. **Partitioned :** The database get divided into multiple fragments and stored on various sites.
3. **Replicated :** Copies of one or more database fragments are stored at several sites.

Syllabus Topic : Distributed Transaction Basics

5.6 Distributed Transaction

A **distributed transaction** contains one or more statements which make updations in the data of two or more distinct nodes of a distributed database.

5.6.1 Distributed Transaction Basics

There are two types of transaction we can consider :

1. **Local Transaction :** Local transactions are the transactions which perform operation only on the single local database. These transactions can access and update the data from local database only.
2. **Global Transaction :** Global transactions are the transactions which perform operation on the several local databases. It can access and update several local databases.

For distributed transaction, we will study the system structure of distributed database and its possible failure modes. Maintaining ACID properties of transaction is very important task which is done by a utility called as Transaction Manager. All sites have their own Transaction Managers which co-operate each other to execute the transactions successfully.

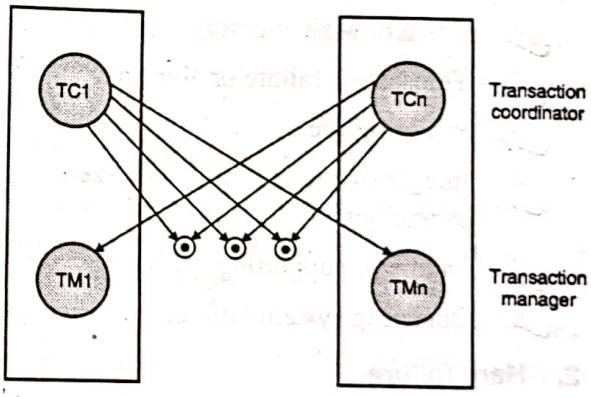


Fig. 5.6.1

Now to understand the working of Transaction Manager we will consider a system with two subsystems.

- **Transaction Manager :** The execution of transactions which access the local data is managed by the Transaction Manager. These transactions may be local or part of any global transaction. The Transaction Manager should participate in appropriate concurrency control scheme to coordinate the concurrent exeeution of transactions executing that site.
- **Transaction Coordinator :** At the site, the execution of all local and global transactions is coordinated by the Transaction Coordinator. The Transaction coordinator should start the execution of transaction.

Break the transaction in sub-transactions and assign it to different sites. Coordinate the completion of transaction, in which the transaction either committed or aborted.

Syllabus Topic : Failure Modes

5.6.2 Failure Modes

In distributed transactions failure can be broadly categorized into three different groups. They are as follows:

1. Soft Failure

This type of failure can cause the loss of volatile memory of the computer. Due to this we lost the information stored in the non-persistent storage like main memory, buffers, caches or registers. It is also known as system crash. The various types of soft failures are as follows :

1. Crash of Main memory
2. Transaction failure or abortion.
3. Power failure.
4. Integer overflow or divide-by-zero exceptions.
5. Failure of supporting software.
6. Operating system failure.

2. Hard failure

Hard failure causes the loss of data which is stored in non-volatile storage such as Disk. It is also known as Disk Failure. Because of failure in disk, corruption of data in some disk blocks or failure of the total disk may occur. The causes of a hard failure are as follows :

1. Faults in media.
2. Malfunction in Read-write operations
3. Information Corruption on the disk.
4. Power failure.
5. Read/write head crash of disk.

If we have new, formatted and ready-to-use disk in backup then recovery from disk failure can be easy and short.

3. Network Failure

Network failures are widely spread in distributed or network databases. It consist of the errors induced in the database system due to the distributed format of the data in the network and transformation of data.

There are number of reason of network failure

1. Failure in communication link
2. Data corruption in transformation process.
3. Site failures.
4. Congestion in network

Syllabus Topic : Commit Protocols

5.7 Commit Protocols

Atomicity is an important ACID property. To maintain atomicity it is necessary that the final outcome of any transaction should be accepted by all the sites on which it is executing. That means the transaction must be either committed for all the sites or aborted for all the sites. For this purpose the commit protocols are used.

There are different commit protocols. They are as follows:

1. One-phase Commit Protocol (1 PC)
2. Two-phase Commit Protocol (2 PC)
3. Three-phase commit protocol (3 PC)

5.7.1 One-phase Commit Protocol (1 PC)

One phase commit protocol in distributed database is the simplest commit protocol. In distributed transaction there is a controlling site and a number of slave sites where the transaction is being executed. For the One phase commit protocol following steps takes place:

1. When each slave has completed its transaction locally, it sends a done message to the controlling sites. client to server
2. After sending the message the slave sites wait for 'Commit' or 'Abort' message from controlling sites. This waiting time is called as window of vulnerability.

3. When a controlling site receive 'Done' message from slave site, it takes a decision to commit or abort. This is called as Commit Point. Then the controlling site sends this decision to all the slave sites.
4. After receiving this message from controlling sites, the slave sites either commit or abort and then send an acknowledgement message to controlling sites.

5.7.2 Two-phase Commit Protocol (2 PC)

SPPU - Dec. 15

University Question

Q. Explain Two Phase Commit Protocol in Distributed Database **(Dec. 2015, 5 Marks)**

In distributed database **two phase commit protocols** reduces the waiting time means vulnerability of one phase commit protocol. Two steps are performed in two phase commit protocol as follows:

Step 1: Prepare Phase

- As we have seen in one phase protocol, after completing the transaction locally, each slave sends a 'done' message to the controlling sites. When the controlling sites received 'done' message from all slaves. It sends a prepare message to the slave sites.
- The slaves sites vote on whether they want to commit or not. If a slave wants to commit, it sends a "Ready" message.
- A slave site that does not want to commit, sends a "Not Ready" message to controlling sites. This may happen when the slave site has conflicting concurrent transactions or there is a timeout.

Step 2 : Commit/Abort Phase

- After the controlling site received "Ready" message from all the slave sites :
  - The controlling site sends a "Global Commit" message to the slave sites.
  - The slave sites apply the transaction and send a "Commit ACKNOLEDEGEMET" message to the controlling site.
  - When the controlling site receives "Commit Acknowledgement" message from all the slaves, it considers the transaction as committed.
- After the controlling site has received the first "Not Ready" message from any slave :
  - The controlling site sends a "Global Abort" message to the slaves.
  - The slaves abort the transaction and send "Abort Acknowledgment" message to the controlling site.
  - When the controlling site receives "Abort Acknowledgment" message from all the slaves, it considers the transaction as aborted.

5.7.3 Three-phase Commit Protocol (3 PC)

SPPU - Dec. 15

University Question

Q. How 3 PC is different than 2 PC? **(Dec. 2015, 3 Marks)**

This protocol contains one more phase '**Prepare to Commit Phase**' than the **2 PC**. We will see the **difference** between these two protocols in the three steps of **3 PC**.

Step 1 : Prepare Phase

- As we have seen in one phase protocol, after completing the transaction locally, each slave sends a 'done' message to the controlling sites. When the controlling sites receives 'done' message from all slaves. It sends a prepare message to the slave sites.
- The slaves sites vote on whether they still want to commit or not. If a slave wants to commit, it sends a "Ready" message.
- A slave site that does not want to commit, it sends a "Not Ready" message to controlling sites. This may happen when the slave site has conflicting concurrent transactions or there is a timeout.

Step 2 : Prepare to Commit Phase

- In this step controlling site issues an "Enter Prepared State" broadcast message.
- The slave sites vote "OK" in response.

Step 3 : Commit / Abort Phase

- After the controlling site receives "Ready" message from all the slave sites–
  - The controlling site sends a "Global Commit" message to the slave sites.

- The slave sites apply the transaction.

– After the controlling site has received the first "Not Ready" message from any slave –

- The controlling site sends a "Global Abort" message to the slaves.
- In this phase commit acknowledgement an abort acknowledgement is not required unlike two phase protocol.

Syllabus Topic : Concurrency Control in Distributed Database

5.8 Concurrency Control in Distributed Database

In distributed database systems, database is typically used by many users. These systems usually allow multiple transactions to run concurrently i.e. at the same time. The activity of coordinating concurrent access to a single database in a multiuser database management system (DBMS) is known as **Concurrency control**. It allows users to access a database in a multi-programmed fashion. In centralized database system, several locking protocols are used for concurrency control. The major difference between centralized and distributed database system is that how lock manager deal with replicated data.

There are some approaches for concurrency control in distributed database :

A) Single Lock Manager

- In distributed database system which have several sites, maintains a single lock manager at a particular chosen site this concept is known as single lock manager approach. Fig. 5.8.1 shows the single lock manager approach.
- Here the sites S1, S2, S3, S4, S5, and S6 are present among those the data D is replicated on S1 S6 and S4. And the site S3 acts as a Lock Manager.
- At the site S2 transaction T1 requests for data item D(step 1). These requests are forwarded by the site S2 to the lock manager's site S3 for granting purpose (step 2).

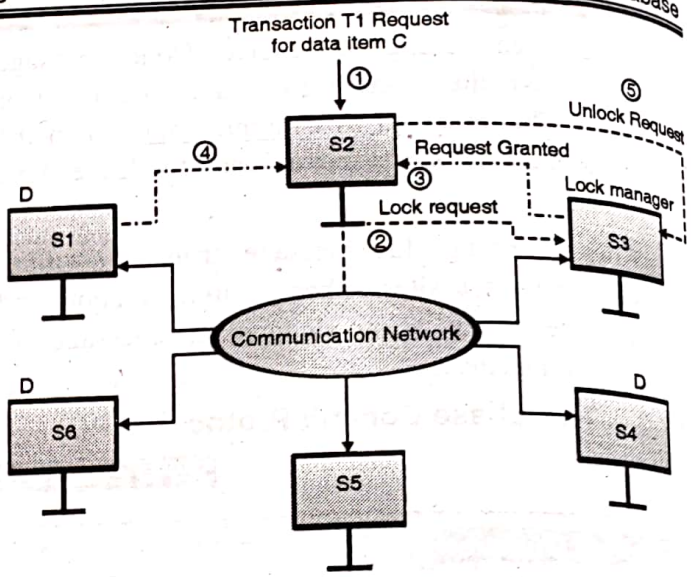


Fig. 5.8.1 : Single lock manager approach

- If the requested data item is free then the request for that data item is granted immediately by the lock manager(step 3).
- If the request is granted then the data item can be read from any site where the replica of required data item is present; here, the site S2 takes data item D from site S1(step 4).
- After the transaction T1 executed successfully the Transaction /manager at site S2 again send the request for unlock the data item so that other transactions can used the data item D now(step 5).

B) Distributed Lock Manager

- In distributed database system there are several sites and data is replicated or fragmented on those sites. The distributed lock manager approach is nothing but the distributing the functionality of lock manager over several sites.
- Fig. 5.8.2 shows the distributed lock manager approach using primary copy protocol.
- Here the sites S1, S2, S3, S4, S5, and S6 are present.
- Data A, B, C is replicated on multiple sites.
- Among the six sites S6 holds primary copy of data item B so the lock manager for granting data access on B is present at only site S6, similarly S5 site acts as a lock manger for data item A and S4 acts as a lock manager for data item C.

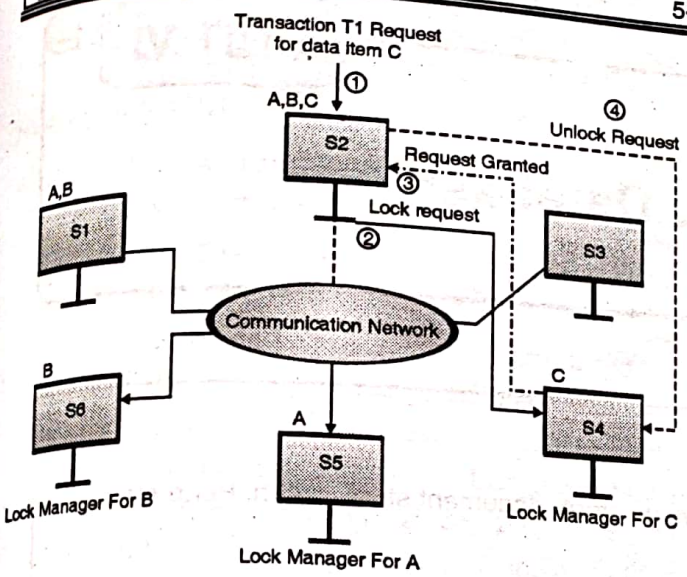


Fig. 5.8.2 : Distributed lock manager approach

- At the site S2 transaction T1 requests for data item C (step 1). Even if the replica of C is present at site S2 locally it is mandatory to first the request lock for accessing C from site S4 as it is acts as lock manager for C. So the transaction manager at site S2 sends lock request to site S4(step 2).
- If the requested data item is free then the request for that data item is granted immediately by the lock manager, hence site S4 grants lock request for C(step 3).
- Now the transaction T1 can access local copy of Data item C present at site S2(step 4).
- After the transaction T1 executed successfully the Transaction manager at site S2 again send the request for unlock the data item so that other transactions can used the data item C now(step 5).

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