UNIT 5 INTRODUCTION TO ONLINE ANALYTICAL PROCESSING

Structure

5.0 INTRODUCTION

In the earlier unit you had studied about Extract, Transform and Loading (ETL) of a Data Warehouse. Within the data science field, there are two types of data processing systems: online analytical processing (OLAP) and online transaction processing (OLTP). The main difference is that one uses data to gain valuable insights, while the other is purely operational. However, there are meaningful ways to use both systems to solve data problems. OLAP is a system for performing multi-dimensional analysis at high speeds on large volumes of data. Typically, this data is from a data warehouse, data mart or some other centralized data store. OLAP is ideal for data mining, business intelligence and complex analytical calculations, as well as business reporting functions like financial analysis, budgeting and sales forecasting.

In this unit we will focus on Online Analytical Processing (OLAP).

5.1 OBJECTIVES

After going through this unit, you should be able to:

- understand the purpose of a OLAP;
- describe the motivation and benefits of OLAP;
- discuss Multidimensional Modeling;
- describe various OLAP operations;

- list multi cube Applications and steps to create OLAP server, and
- discuss between various types of OLAP like MOLAP, ROLAP, DOLAP and HOLAP.

5.2 OLAP AND ITS NEED

Online Analytical Processing (OLAP) is the technology to analyze and process data from multiple sources at the same time. It accesses the multiple databases at the same time. It is a software which helps the data analysts to collect data from different perspective for developing effective business strategies. The query operations like group, join or aggregation can be easily done with OLAP using pre-calculated or pre-aggregated data hence making it much faster than simple relational databases. You can understand OLAP as a multi cubic structure, which has many cubes, each cube is pertaining to some database. The cubes are designed in such a way that generates reports effectively and efficiently.

OLAP is the core component of the data warehouse implementation, providing fast and flexible multi-dimensional data analysis for business intelligence (BI) and decision support applications. OLAP (for online analytical processing) is a software used to perform high-speed, multivariate analysis of large amounts of data in data warehouses, data markets, or other unified and centralized data warehouses. The data is broken down for display, monitoring or analysis. For example, sales figures can be related to location (region, country, state/province, company), time (year, month, week, day), product (clothing, male/female/child, brand, type), etc., but In a data warehouse, records are stored in tables, and each table can only sort data on two of the dimensions at a time. Recording and reorganizing them into a multi-dimensional format allows very fast processing and very in-depth analysis

The primary objective of OLAP or data analysis is not just data processing .For instance, If a company might compare their sales in the month of January with the month of February then compare those results with another location which may be stored in a separate database. In this case, it needs a multi-view of database design storing all the data categories. Another example of Amazon, it analyzes purchases made by its customers to recommend the customers with a personalized home page of products which are likely to be interested by them. So, this is one of the good examples of OLAP systems. It creates a single platform for all type of business analytical means which includes planning budgeting forecasting and analysis the main benefit of OLAP is the consistency of information and calculations using OLAP systems we can easily apply security restrictions on users and objects to comply with regulations and protect sensitive data.

OLAP assists managers in making decisions by giving multidimensional record views that are efficient to provide, hence enhancing their productivity. Due to the inherent flexibility support provided by organized databases, OLAP functions are self-contained. Through extensive control of analysis-capabilities, it permits simulation of business models and challenges.

Let's see the need to use OLAP to have better understanding of OLAP over relational databases:

1) Efficient and Effective methods to improve the sales of an Organization: In retail, having multiple products with different number of channels for selling the product across the globe. OLAP makes it effective and efficient

to search for a product in s different of a different region within a specified time period(like, excluding weekdays sales or just weekend sales or festival duration sales very specific from a very large data distributed.)

2) It improves the sales of a business. The data analysis power of OLAP brings effective results in sales. It helps in identifying expenditures which produce a high return of investments (ROI).

Usually, data operations and analysis are performed using the simple spreadsheet, where data values are arranged in row and column format. This is ideal for two-dimensional data. However, OLAP contains multidimensional data, with data usually obtained from a different and unrelated source. Using a spreadsheet is not an optimal option. The cube can store and analyze multidimensional data in a logical and orderly manner.

5.3 CHARACTERISITCS OF OLAP

The main characteristics of OLAP are as follows:

- **Fast:** OLAP act as bridge between Data Warehouse and front-end. Hence helps in the better accessibility of data yielding faster results.
- **Analysis:** OLAP data analysis and computational measure and their results are stored in separate data files. OLAP distinguishes better zero and missing values. It should ignore missing value and performs the correct aggregate values. OLAP facilitates interactive query handling and complex analysis for the users.
- **Shared:** OLAP operations drill-down or roll-up, it navigates between various dimensions in multidimensional cube making it effective and efficient reporting system.
- **Multidimensional:** OLAP has Multidimensional conceptual view and access of data to different users at different levels. The increasing number of dimensions and report generation performance of the OLAP system does not significantly degrade.
- **Data and Information:** OLAP has calculation power for complex queries and data. It does data visualization using graphs and charts.

5.4 OLAP AND MULTIDIMENSIONAL ANALYSIS

The multi-dimensional data model stores data in the form of data cube. In a data warehouse. Generally, it supports two- or three-dimension cubes. It gives the data different views and perspectives. Practically in retail store the data is maintained month wise, item wise, region wise thus involving many different dimensions.

5.4.1 Multidimensional Logical Data Modeling and its Users

The multidimensional data modeling provides:

- Different views and perspectives to the data from different angles. The business users have a dimensional and logical view of the data in the data warehouse.
- Multidimensional conceptual view: It allows users to have a dimensional and logical view of the data.

- Multidimensional modeling creates environment for multiuser. Since the OLAP techniques are shared, the OLAP and database operations, containing retrieval, update, adequacy control, integrity, and security can be easily performed.

For example, in the Figure 1, it is shown that the dimensions Time, Regions and Products of a company can be logically saved in a cube. In Figure 2, in the cross tabular form in every quarter, products quantity are shown. In Figure 1, Products, Time and Regions these dimensions can be combined into cubes you can imagine what two dimensions would look like by using a spreadsheet metaphor with the time dimension as the columns and the products dimension as the rows if we add data to this view such as units sold that would be a measure. Measures can be any quantity such as revenue / expenses / unit's / statistics or any text or numerical value if we consider adding the third dimension regions then you can imagine each region being represented as an additional spreadsheet this is how it works when you're limited to a two-dimensional spreadsheet. however, an OLAP cube can represent all three dimensions as a single data set which allows users to fluidly explore all the data from any perspective and despite its name a cube can hold many more than three dimensions so what's the value of using all that to illustrate this.

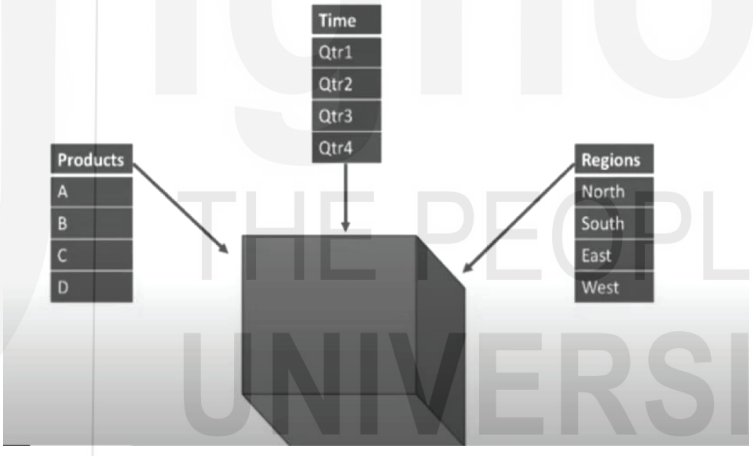

Figure 1: Cube Representation

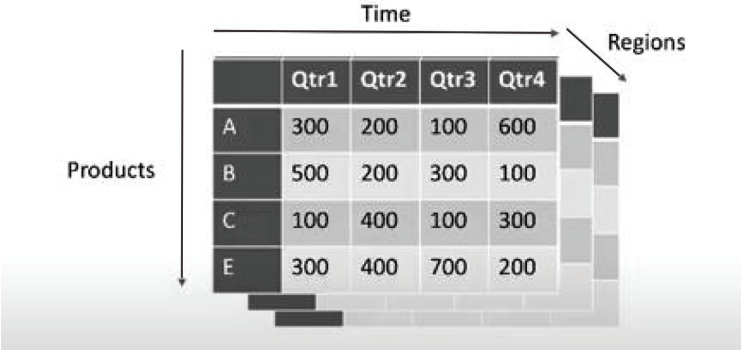

Figure 2: Measurable Data Shown

Let's say that a manager is tracking sales units with three different spreadsheets with three different dimensions products quarters and regions from looking at these spreadsheets. it appears that everything is equal as the manager of these stores would

probably stock them with the same number of items for each product quarter and region. The manager of a store house makes very different decisions to generate a report with just one or two dimensions or by adding more dimensions and reveal more detail which would allow to make better decisions on managing the inventory of the stores. Hence, you can view OLAP facilitates Business Oriented multidimensional data having lot of calculations. The data saved in multidimensional structure is very significant in speed thought analysis to companies to take better decisions. OLAP provides the flexibility of data retrieval to generate reports.

5.4.2 Multidimensional Structure

In the multidimensional model, data are organized into multiple dimensions, and each dimension contains multiple levels of abstraction defined by concept hierarchies. This organization provides users with the flexibility to view data from different perspectives. The data has been organized into multiple dimensions and at each level of dimension, contains multiple levels of abstraction defining the concept hierarchy. It provides flexibility to view data from different angles. Likewise, as explained earlier the conceptual hierarchy of a product is:

Department → Category → Subcategory→ Brand→ Product

It is important to identify the hierarchy from multi-dimensional cube in terms of query. Then we must look at the performance measure or on which attribute or dimension the query is focused on.

5.4.3 Multidimensional Operations

OLAP provides a user-friendly environment for interactive data analysis. A number of OLAP data cube operations exist to materialize different views of data, allowing interactive querying and analysis of the data.

The most popular end user operations on dimensional data are:

1) Roll-up
2) Drill-down
3) Slice and Dice
4) Pivot (rotate)

In daily life we come across operations where the manager is interested in knowing the aggregate of data from the concept hierarchy. It can use the concept hierarchy to roll the data up so for instance instead of a daily aggregated data we have monthly aggregate data and quarterly and then annual year. The concept hierarchy of Time dimension be:

Concept hierarchy of Time dimension

So, to perform this operation, we can roll-up and store the result. Also, it can subtotal those aggregated data. So, if the manager is interested in going down the

concept hierarchy or interested in the minute details to find out the driving attribute responsible for the increase or decrease of sales. For this OLAP operation drill down can be performed.

1) Roll-up:

The roll-up operation (also called drill-up or aggregation operation) performs aggregation on a data cube, either by climbing up a concept hierarchy for a dimension or by climbing down a concept hierarchy, i.e. dimension reduction. In the following example given at figure 3, it is shown a multidimensional cube containing the products of a Home appliances home appliances like laptop, furniture, mobile and kitchen appliances. If the manager wants to view the sales of all the products quarterly, the Roll-up operation can be performed on the categories. In this aggregation process, data is category hierarchy moves up from mobile to the Kitchen store. In the roll-up process at least one or more dimensions get reduced like category here.

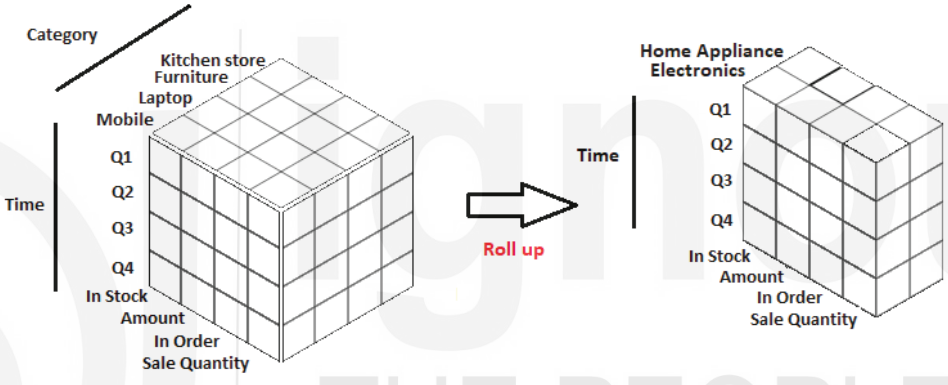

Figure 3: Roll-up on (Category from Home Appliances and Electronics)

It is also known as consolidation. This operation summarizes the data along the dimension.

2) Drill-down:

The drill down operation (also called roll-down) is the reverse of roll up. It navigates from less detailed data to more detailed data. It can be realized by either stepping down a concept hierarchy for a dimension or introducing additional dimensions.

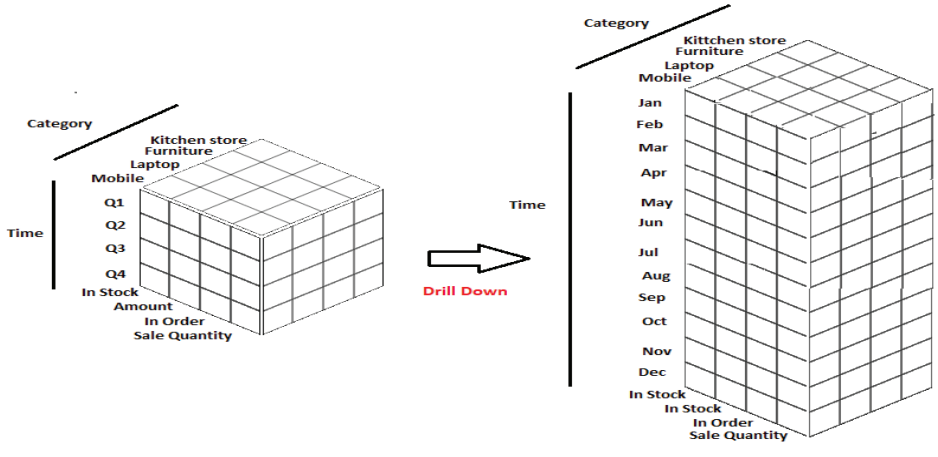

Figure 4: Drill down from Time to Months

You will observe in the above example given at figure 4 a multidimensional cube containing products and time. The Time dimension has been expanded from

Quarter →Months to observe the sales month-wise. This is called in Drill down.

3) Slice:

This enables an analyst to take one level of information for display. It is another OLAP operation to fetch the data. In this the query on one dimension is triggered in the database and a new sub cube is created.

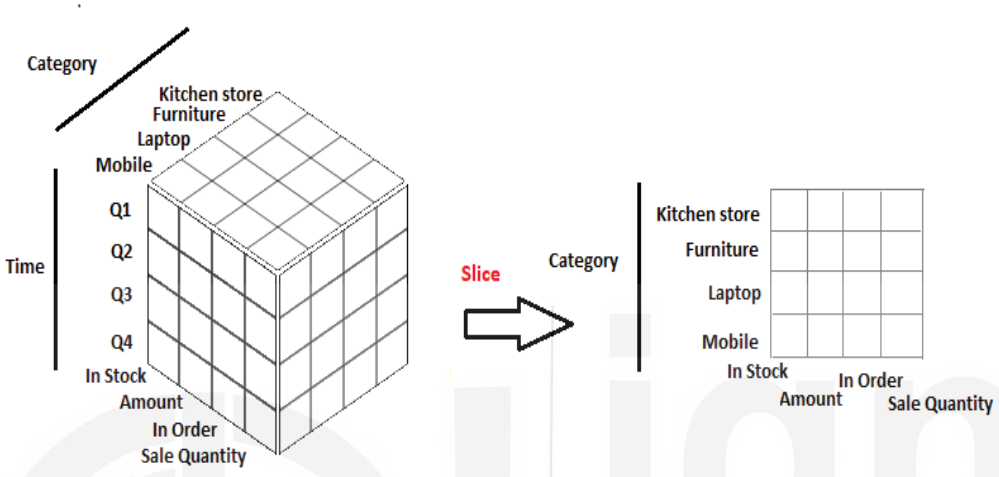

Figure 5: Slice OLAP Operation

In the above figure 5 it can be observed that slice operation is performed on "Time" dimension and a new sub cube is created to retrieve the results.

Slice for Time = "Q1"

4) Dice:

This allows an analyst to select data from multiple dimensions to analyze. This OLAP operation is just like the Projection relational query you have read in RDBMS. In this technique you select two or more dimensions that results in the creation of a sub cube as shown in figure 6:

Dice for (Category= "Laptop" or "Mobile") and (Time = "Q1" or "Q2") and (Stock = "Amount" or "Sale Quantity")

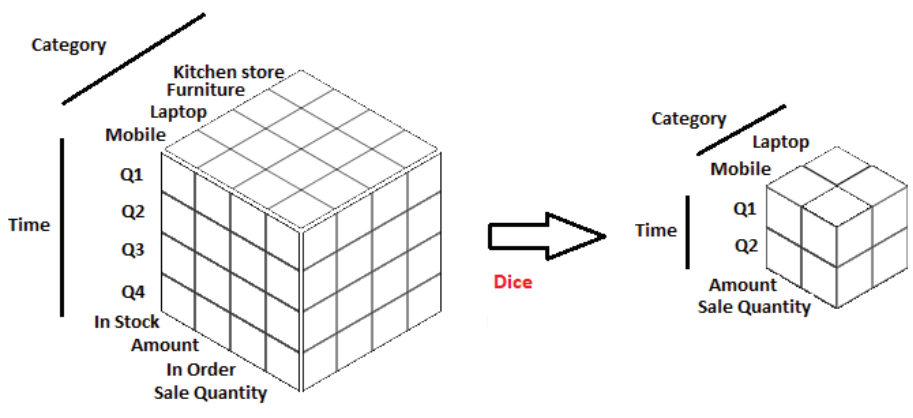

Figure 6: Dice OLAP Operation

4) Pivot:

Analysts can gain a new view of data by rotating the data axes of the cube. This OLAP operation fixes one attribute as a Pivot and rotate the cube to fetch the results. Like inverting the spreadsheet it gives a different perspective. You can observe in the figure 7 that the presentation of the dimensions has been changed to impart a different perspective of the data cube for data analysis.

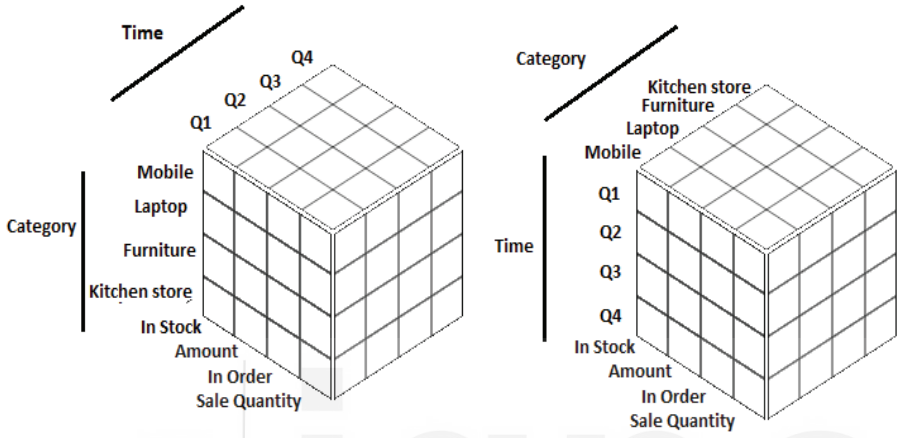

Figure 7: Pivot OLAP Operation

☞ Check Your Progress 1

1) Who are the users of the Multidimensional Data Modeling?

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2) What are the five categories of decision support tool?

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5.5 OLAP Functions

Online Analytical Processing (OLAP) functions can return the ranking and row numbering. It is very similar to the SQL aggregate functions, however, an aggregate function return an atomic value.

- The OLAP function returns a scalar value of a query. OLAP functions can be performed at the individual row levels too.
- OLAP functions provide data mining functionalities and data analysis. The detailed data analysis and values are supported with OLAP functions.
- The exhaustive and comprehensive data analysis can be achieved row wise unlike simple SQL functions produces results in the form of reports like WITH. OLAP runs on rows of the data warehouse.
- OLAP functions uses SQL commands like INSERT/SELECT/ POPULATE on tables or Views.

5.6 Data Warehouse and OLAP: Hypercube and Multi Cubes

The OLAP cube is a data structure optimized for very quick data analysis. The OLAP Cube consists of numeric facts called measures which are categorized by dimensions. OLAP Cube is also called the hypercube. So, we can say that multidimensional Databases can we see hypercube and multi cube. Multidimensional cubes have smaller multiple cubes and in hypercube it seems there is one cube as logically all the data seems to be as one unit of cube. Hypercube have multiple same dimensions logically. The differences of Multi cube and Hyper cube are shown in Table 1 below:

Table 1: Differences between Multi cube and Hyper cube

	Multi Cube	**Hyper Cube**
Metadata	Each dimension can belong to many cubes	Each dimension belongs to one cube only
Dimension	Not necessary all the dimensions should belong to some cube	Every dimension owned by a hypercube
Measure Computation	Complex, data can be retrieved from the all the cubes	Simple, as all the numerical facts are available at one place
Multiple	multicube system, if there are two rows in the DIMENSIONS rowset for which the DIMENSION_NAME value is the same (and the CUBE_ NAME value is different), these two rows represent the same dimension. As, sub cubes are built from the same pool of available dimensions.	in a multiple hypercube scenario, it is possible for two hypercubes to have a dimension of the same name, each of which has different characteristics. In this case, the DIMENSION_ UNIQUE_NAME value is guaranteed to be different.

5.7 APPLICATIONS OF OLAP

OLAP reporting system is widely used in business applications like:

- Sales and Marketing
- Retail Industry
- Financial Organizations – Budgeting
- Agriculture
- People Management
- Process Management

Examples are Essbase from Hyperion Solution and Express Server from Oracle.

☞ **Check Your Progress 2**

1) Explain the OLAP application reporting system in Marketing?

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2) What is the purpose of hyper cube. Show slice and dice operation on the sub-cube/hypercube?

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3) List the features of an OLAP.

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5.8 STEPS IN THE OLAP CREATION

The basic unit of OLAP is an OLAP cube. It is a data structure designed for better and faster retrieval of results from the data analysis. OLAP cubes. It has dimensions with numeric facts. The data arrangement in rows and columns in multidimensional is the logical view not the physical view.

The steps involved in the creation of OLAP are as follows:

Steps to create an OLAP

Step 1: Extract data from variety of sources like text, excel sheets, multimedia files, Online Transaction Processing data in flat files.
Step 2: Transformation and Standardization of data: Since, the data is distributed and incompatible to each other. It involves the data preprocessing or cleaning part where the semantics of databases are changed into a standard form.
Step 3: Loading of data: After all the database nomenclature have been followed then the data is loaded onto the OLAP server or OLAP multidimensional cube.
Step 4: Building of a Cube for data analysis: • Select the dimensions means set of subsets of significant attributes. • Select the concept hierarchies. • Populate the cube with the relevant data • Select the numeric attribute to apply aggregate function.
Step 5: Report Generation

The steps to create OLAP shown in the below figure 8:

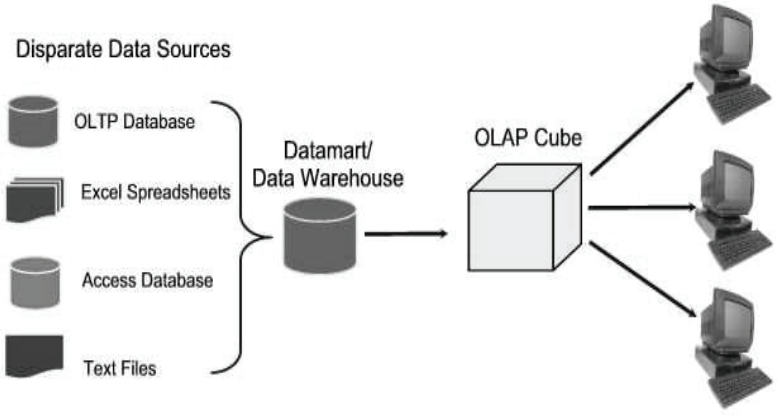

Figure 8 : Steps to create OLAP Cube

5.9 ADVANTAGES OF OLAP

The SQL functions like Group By, Aggregating functions are quite complex to operate in relational databases as compared to multidimensional databases. OLAP can pre-compute the queries can save in sub cubes. The hypercubes also make the computation task faster and saves time. OLAP has proved to an extremely scalable and user – friendly method which is able to perfectly cater to its entire customer needs ranging from small to large companies.

Some listed benefits of using OLAP are as follows:

- ***Data Processing at a faster speed***

The speed of query execution has been tremendous since the use of OLAP technology and is now counted as one of the primary benefits for it. This prevents the customers from spending a lot of time and money on heavy calculations and creating complex reports.

- ***Accessibility***

The cube enables the various kinds of data like – transactional data from various resources, information about every supplier and consumer, etc. all is saved in a concise one location which is easy to operate.

- ***Concise and Fine Data***

OLAP works on the principle of combining multiple and similar records together, which are saved in multiple tables forming a schema between them as a source of connection. Theses tables combine to form the cube to make the massive information concise and yet finely available to the user. Records can be elemental right down to a single element by "drill down" and back to the cube by "drill up" operations.

- ***Data Representation in Multi-Dimension***

OLAP cube is the center of all the data. Each element of the cube contains various attributes and the number of processes performed on it. The cube axes are outlined by the measure and dimension of the cube which is mostly three - dimensional system. This allows the user to take the information from various slices of the cube. A cube slice is a two – dimensional in nature which gives a clear image of the knowledge trying to be represented.

- ***Business Expressions commonly used***

The size of an OLAP cube consisting of data portrays the company's economic and financial conditions. The end user does not manipulate the database files; they deal with end processes like products, salesmen, employees, customers, etc. This gives a reason to even user with less to zero technical background to use LAP technology.

- ***Situational Scenarios***

The way the cube can cover almost all parts of a data item is through creating various what – if situations; these what – if situations help in extraction of cube information without tampering the original information on the cube. This feature of OLAP technology is responsible for providing the customers the ability to update the values to look at the consequences brought in the cube's situation. Through this feature business intelligence can deeply examine the possible factors of driving a situation in a company and prevent them if necessary.

- ***Easily Understood Technology***

Most of the users or customers working on OLAP technology come from a background of less to minimum technology skills. They mostly do not need any unique training to use this technology, which in return helps the company save some money. Moreover, OLAP technology providers provide their end users with enough tutorial, documents and some start off technical assistance particularly in case of web – based OLAP operations. The end customers are given sessions to continuously work with a group of technical experts so that they do not have to solve all the OLAP issues by themselves.

5.10 OLAP ARCHITECTURE: MOLAP, ROLAP, HOLAP AND DOLAP

There are types of OLAP architecture: ROLAP, MOLAP, HOLAP and others as shown in the below figure 9.

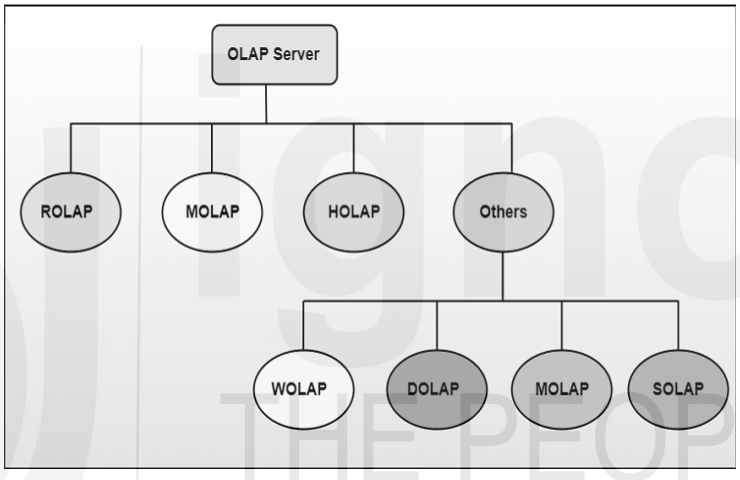

Figure 9: Types of OLAP Architecture

ROLAP Architecture

ROLAP implies Relational OLAP, an application based on relational DBMSs. It performs dynamic multidimensional analysis of data stored in a relational database. The architecture is like three-tiered. It has three components viz. front end (User Interface), ROLAP server (Metadata request processing engine) and the back end (Database Server) as shown in the Figure 10.

- Database server
- ROLAP server
- Front-end tool

In this three-tiered architecture the user submits the request and ROLAP engine converts the request into SQL and submits to the backend database. After the processing of request the engine, it presents the resulting data into multidimensional format to make the task easier for the client to view it.

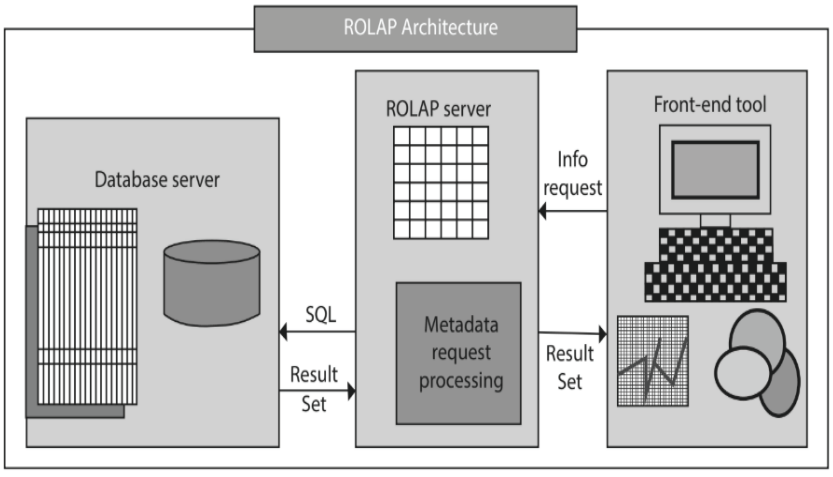

Figure 10 : ROLAP Architechture

The characteristics of ROLAP are:

- ROLAP utilizes the more processing time and disk space.
- ROLAP enables and supports larger user group in the distributed environment.
- ROLAP processes complex queries utilizing the greater amounts of data.

Popular ROLAP products include Metacube by Stanford Technology Group, Red Brick Warehouse by Red Brick Systems.

MOLAP Architecture

MOLAP it stands for Multidimensional Online Analytical Processing. It processes the data using the multidimensional cube using various combinations. Since, the data is stored in multidimensional structure the MOLAP engine uses the pre-computed or pre-stored and stored. The architecture has three components:

- Database server
- MOLAP server
- Front-end tool

MOLAP engine processes pre-compiled information. It has dynamic abilities to perform aggregation of concept hierarchy. MOLAP is very useful in time-series data analysis and economic evaluation. MOLAP in shown in Figure 11.

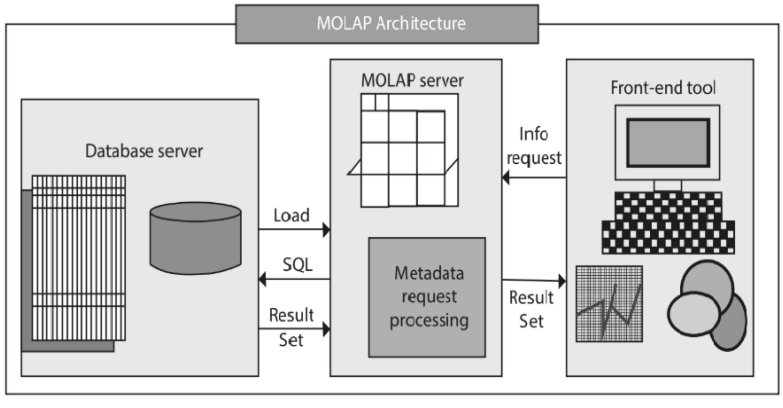

Figure 11 : MOLAP Architechture (Source : internet)

The characteristics of MOLAP are:

- It is a user-friendly architecture, easy to use.
- The OLAP operations slice and dice speeds up the data retrieval.
- It has small pre-computed hypercubes.

Tools that incorporate MOLAP include Oracle Essbase, IBM Cognos, and Apache Kylin.

HOLAP Architecture

It defines Hybrid Online Analytical Processing. It is the hybrid of ROLAP and MOLAP technologies. It connect both the dimensions together in one architecture. It stores the intermediate or part of the data in ROLAP and MOLAP. Depending on the query request it accesses the databases. It stores the relational tables in ROLAP structure, and the data requires multidimensional view are stored and processed using MOLAP architecture as shown in figure 12. It has the following components:

- Database server
- ROLAP and MOLAP server
- Front-end tool

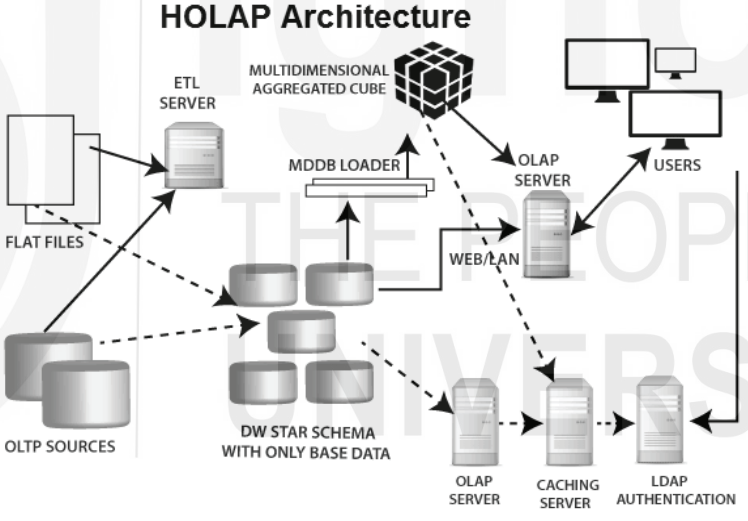

Figure 12 : HOLAP architecture(source: internet)

The characteristics of HOLAP are:

- Flexible handling of data.
- Faster aggregation of data.
- HOLAP can drill down the hierarchy of data and can access to relational database for any relevant and stored information in it.

Popular HOLAP products are Microsoft SQL Server 2000 presents a hybrid OLAP server.

DOLAP Architecture

Desktop Online Analytical Processing (DOLAP) architecture is most suitable for local multidimensional analysis. It is like a miniature of multidimensional database or it's like a sub cube or any business data cube. The components are:

- Database Server
- DOLAP server
- Front End

The characteristics of DOLAP are:

- The three-tiered architecture is designed for low-end, standalone user like a small shop owner in the locality.
- The data cube is locally stored in the system so, retrieval of results is faster.
- No load on the backend or at the server end.
- DOLAP is relatively cheaper to deploy.

☞ **Check Your Progress 3**

1) Compare ROLAP, MOLAP and HOLAP.

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2) Write limitations of OLAP cube.

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5.11 SUMMARY

OLAP has proven to be an asset in the field of Business Intelligence as it helps in relieving the large amount of data handling along adding the cost benefits of working with this very technique. Furthermore, OLAP providers normally offer their clients with significant documentation, tutorials, and spark off technical assistance in terms of web-primarily based totally OLAP clients. The customers are continuously loose to deal with the group of tech experts while not having to control all the troubles tied to the software program themselves. The concept hierarchies help to organize the dimensions into logical levels. The various OLAP operations help to extract information across sub cubes. The creation of cube and types of OLAPs helps to understand the architecture and usage of various applications of OLAP.

5.12 SOLUTIONS/ANSWERS

Check Your Progress 1

1) Knowledge workers such as data analysts, business analysts, and Executives are the users of OLAP.

2) Decision making Tool features are:

- Report Generation
- Query Handling
- EIS (Executive Information System)
- OLAP (Online Analytical Processing)
- Data Mining

Check Your Progress 2

1) In Marketing, OLAP can be used for various purposes as it helps like planning, budgeting, Financial marketing, sales data analysis and forecasting. The customer experience is very important to all the companies. So, OLAP works very efficiently in analyzing the data of customers, market research analysis, cost-benefit analysis of any project considering all the dimensions.

   There are various OLAP tools available. The OLAP tool should have the ability to analyze large amounts of data, data analysis, fast response to the queries and data visualization. For example, IBM Cognos is a very powerful OLAP marketing tool.

2) **Purpose of Hypercube in OLAP**: The cube is basically used to represent data with some meaningful measure to compute. Hypercube logically has all the data at one place as a single unit or spreadsheet which makes the computation of queries faster. Each dimension logically belongs to one cube. For example, a multidimensional cube contains data of the cities of India, Product, Sales and Time with conceptual hierarchy (Delhi→2018→Sales). As, shown in below figures.

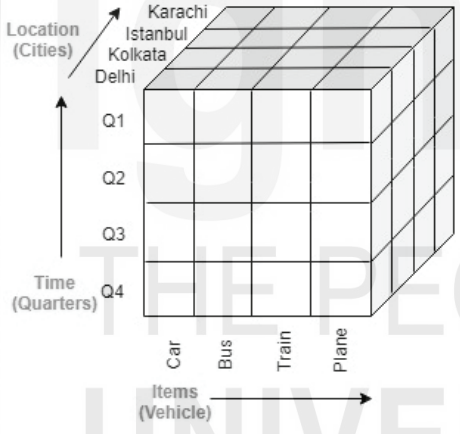

Figure 13: Multidimensional Cube

In the cube given in the overview section, a sub-cube(hypercube) is selected with the following conditions

Location = “Delhi” or “Kolkata” Time = “Q1” or “Q2” , Item = “Car” or “Bus”

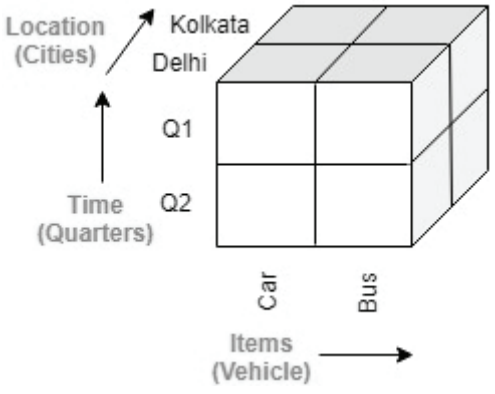

Figure 14 : Hypercube or sub-cube

Slice is performed on the dimension Time = "Q1".

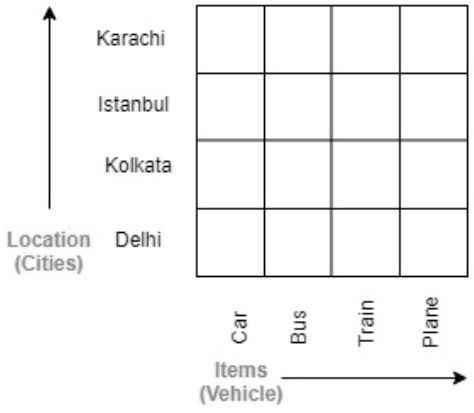

Figure 15 : Slice on Hyper cube

In the sub-cube ,pivot operation is performed.

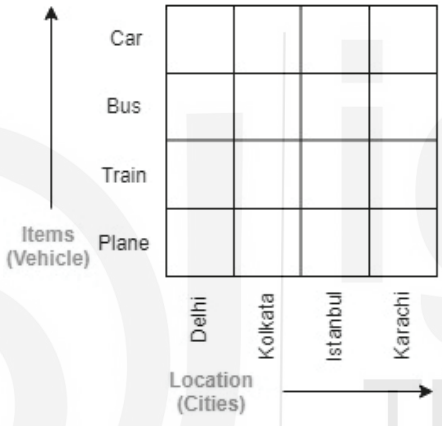

Figure 16: Pivot operation

3) Features of OLAP are:

- Conceptual multidimensional view
- Accessibility of data
- Efficient and flexible Reporting system
- Client/Server architecture
- Supports unrestricted dimensions and aggregation levels
- Uses dynamic sparse matrix handling for faster query results
- Multiuser support

Check Your Progress 3

1) Comparative analysis between ROLAP, MOLAP and HOLAP

Features	ROLAP	MOLAP	HOLAP
Accessibility of data an and Processing time	Very slow because of join operation between tables. The data is fetched from data warehouse.	Fast because of multidimensional storage. The data is fetched from multidimensional data cube.	Fast

Features	ROLAP	MOLAP	HOLAP
Storage space requirement	Data is stored in relational tables. Comparatively Large storage space requirement	Data is stored in multidimensional tables. Medium storage space requirements	It uses both ROLAP, MOLAP. Small storage space requirements. No duplicate of data
Latency	Low latency	High latency	Medium latency
Query response time	Slow query response time	Fast query response time.	Medium query response time
Volume of data	Used for large volumes of data	Limited volume of data	Can be used in both scenarios
Retreival of data	Complex SQL queries are used	Sparse Matrix is used	Both
Data View	Static view of data	Dynamic view of data	Both static and dynamic view of data

2) Limitations of OLAP cube are:

- OLAP requires a star/snowflake schema:
- There is a limited number of dimensions (fields) a single OLAP cube.
- It is nearly impossible to access transactional data in the OLAP cube.
- Changes to an OLAP cube requires a full update of the cube – a lengthy process.

5.13 FURTHER READINGS

- William H. Inmon, Building the Data Warehouse, Wiley, 4th Edition, 2005.
- Data Warehousing Fundamentals, Paulraj Ponnaiah, Wiley Student Edition
- Data Warehousing, Reema Thareja, Oxford University Press
- Data Warehousing, Data Mining & OLAP, Alex Berson and Stephen J.Smith, Tata McGraw – Hill Edition, 2016.