MANAGEMENT INFORMATION SYSTEM

SYLLABUS

Unit-1 Information System: Fundamental Concept of System, Role, Components, Types, Definition of MIS, MIS Model, Characteristics, Subsystem and Upgrowth in Organization

Unit-2 Information System Development: System Development Life Cycle, Phases of SDLC, Fact Finding Technique, DFD, Flow Chart , Security and Control Issues in Information System

Unit-3 Information System in Business: Marketing, HR, FM, Production and its Importance in Decision-Making

Unit-4 Data Communications: Introduction , Communication Devices, LAN, MAN,WAN, Internet Concepts, Protocols of Internet - TCP/IP Suite, Internet Services, Internet Applications

Unit-5 Database Management System: Levels of Data Abstraction, Types of Database, Data Models, DBMS, Functions, Benefits, Designing of Database, Data Mapping, Security Issues of DBMS

CONTENTS

INTRODUCTION

NOTES

Rapid globalization coupled with the growth of the Internet and information technology has led to a complete transformation in the way businesses or organizations function today. It has not only affected the management culture, but has also led to an increase in competition in terms of market and resources. Businesses have become more customer-driven and e-commerce is gaining popularity. Traditional means of correspondence have given way to online dealings, e-mails and chats.

With such a radical shift in the approach to doing business, came the need for a specialized system to handle the various departments and functions in an organization.

Management Information System or MIS can be called an organized and well-structured system put in place in an organization for the collection, storage, processing and dissemination of data in the form of information that helps the management in the smooth functioning of the organization.

This book, *Management Information System*, explains the concepts of MIS, its meaning, scope and role in modern management. It also deals with system analysis, input–output designs, the Internet and emerging technologies and how these have affected MIS; several data processing techniques, classification and implementation procedure of MIS and the organizational changes that have been brought about by the changing technologies associated with information system.

The book has been written in a self-learning manner. Every unit starts with the 'Unit Objectives' that lays bare what the students would learn in that unit. This is followed by the 'Introduction' that gives a brief outline of the concept to be dealt with. 'Summary' and 'Key Terms' are given after every unit to help students recapitulate the concepts. The 'Check Your Progress' and 'Questions and Exercises' sections in each unit help in better understanding the subject. The 'Further Reading' section creates a research interest in students for further exploration of the topics covered.

UNIT-1 INFORMATION SYSTEM

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Structure

INTRODUCTION

Information is defined as the processed form of data that is used for decision-making. There are various types of information such as strategic and tactical. The quality of information is determined on the basis of several factors such as completeness and accuracy. Information helps create a system which is defined as a collection of elements such as manpower and production. You need to integrate all the elements of the system to achieve the organizational goals. There are various types of systems such as physical and abstract and open and closed.

In this unit, you will be able to define the fundamental concept of system, its components and types. This unit will also define MIS, MIS model, its characteristics, subsystem and upgrowth in organization.

UNIT OBJECTIVES

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

- Explain how information helps in decision-making and planning process
- Describe the concept of MIS and its importance in an organization
- Identify how information is processed in various MIS

FUNDAMENTAL CONCEPT OF INFORMATION SYSTEM

Information is a processed form of data. According to Davis and Olson, 'Information is data that has been processed into a form that is meaningful to the recipient and is of real or perceived value in current or prospective actions or decisions.' An organization uses various types of information to control different elements such as employees, resources, operations and environment of the organization. Information is also required in the decision-making process so that right decisions can be taken at the right time.

A system which processes information to control the environment and activities of a business organization is generally known as information system. In other words,

an information system is a set of interrelated elements which help the management of an organization in maintaining information of the entire organization in a proper way. Maintenance of information includes handling of activities related to data collection, processing, retrieval and distribution in a well-mannered way.

The information system is also responsible for storing all the information related to employees, products, and external environment of the organization. Information provided by the information system is useful in decision-making and control process of the organization. It also helps managers and workers in analysing problems by providing necessary information to them.

The information system is a type of data processing systems which collects the data from different sources, processes that data and generates information from the data to use them for different applications within the organization. For example, in business context, the information system collects data from various systems such as finance and sales systems at the supplier side. The information system processes the data and generates information for the customer. Customers provide feedback to the supplier depending on the information processed by the information system. Figure shows the information system in business context.

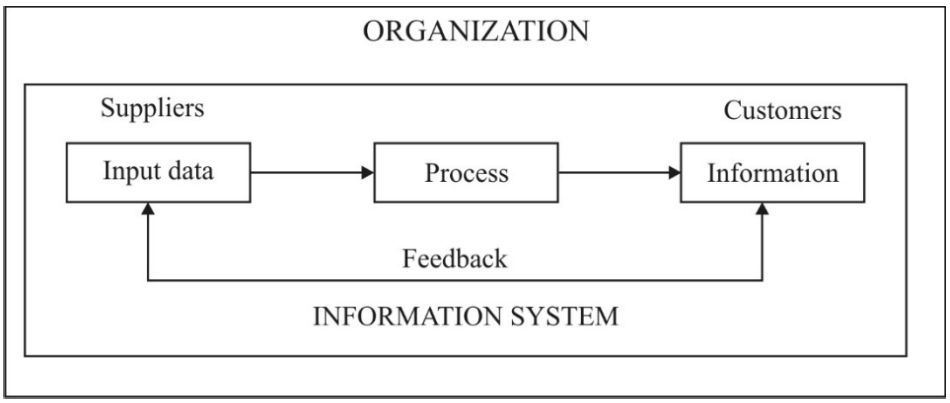

Fig. 1.1 *The Information System in Business Context*

The information system helps to manage and store information to perform various functions such as decision-making, documentation of business activities and generation of reports for the analysis of organizational operations. There are various terms that are used in the information system. They are as follows:

- **Data:** These are the raw material that can be a number, a fact, a sound, a picture or a statement gathered from different sources. Data represent something that exists in the real world such as business processes and employee details.
- **Information:** It is a meaningful data or a processed data. It defines the relation between different types of data.
- **System:** It is a collection of components that help in achieving a common objective. For example, in a human-machine system, the machine element consists of hardware and software to perform computation and human makes decisions based on this computation.

Role of Information System

Nowadays, every organization needs an effective information system because it helps the organization in dealing with various changes that occur in global economies and business enterprises. The information system makes communication possible with

inside as well as outside members of an organization. This means that the information system makes communication possible within an organization and ensures that all relevant information is conveyed to all the members in the organization.

An information system provides flexibility to the organization in adopting new methods and technologies by making flow of information more fluent and effective. It also conducts trade and business management of the organization on a global scale.

Components of Information System

An information system consists of two types of components—abstract system components and physical system components. Abstract system components perform the operations such as collecting input data, processing the data and generating information from that data. Physical system components consist of various elements such as hardware, software and human resources. There are a few more components of the information system which are as follows:

- **Data**: These are the input that the system takes to produce information.
- **Hardware**: A computer and its peripheral equipment such as input, output and storage devices are called hardware.
- **Software**: Software are application programmes or set of instructions that process the input data using computers, generate information and store information for future use.
- **Network**: It is a collection of computer systems connecting to each other for communication to share the information.
- **Manpower**: Information system professionals and users who perform various organizational operations such as analysis of information, designing and constructing information system and maintenance of information system. They may be IT experts, managers and workers.
- **Graphical User Interface (GUI)**: This is an interface for the users of information system to work with information on the computer system. A user can operate, process and retrieve information from the computer storage using GUI.

The components of information system describe the functioning of the system. An information system takes the input data from the users of the information system to perform the business operations. The users interact with the computer to process the data using GUI. After processing of data, the information is retrieved at the user's end. Figure 1.2 shows the basic information system to perform the business operations.

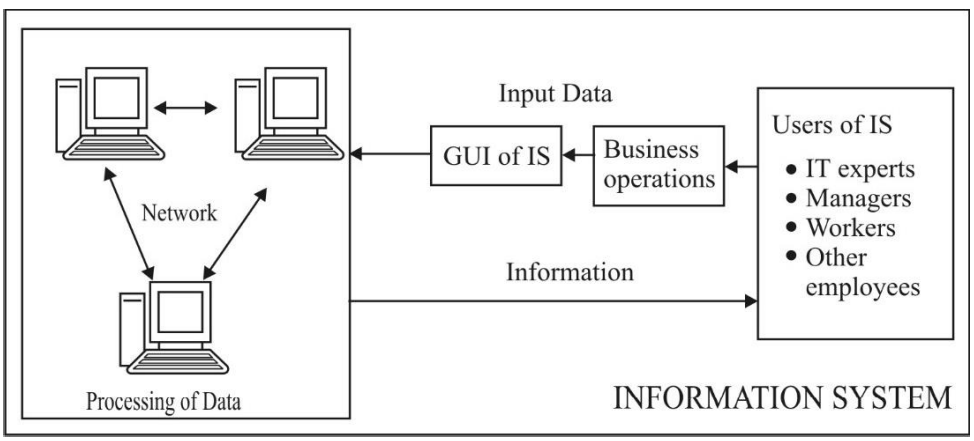

Fig. 1.2 *The Basic Information System*

Types of Information System

Different types of information are used in performing different functions of an organization. Based on the use and purpose of information, information can be broadly categorized into the following types:

- Strategic information
- Tactical information
- Operational information

Different levels of management such as top, middle and lower use different types of information. For example, top management uses strategic information, whereas lower management uses operational information. Figure 1.3 shows the various types of information.

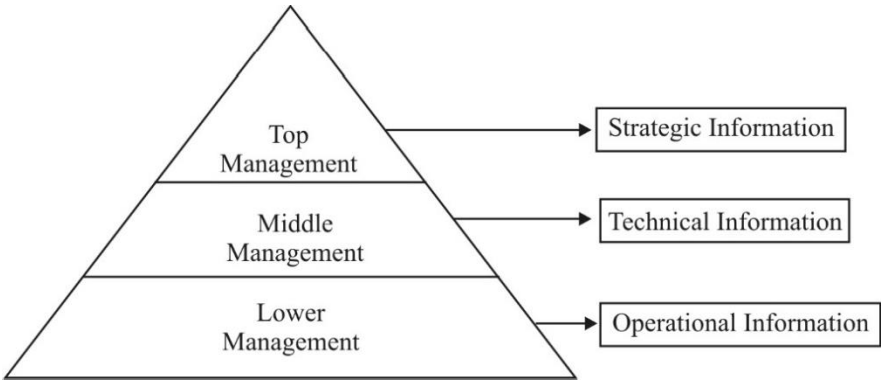

Fig. 1.3 *Types of Information*

Strategic Information

Strategic information helps the top management to devise the strategies that need to be implemented in an organization. The strategic information is vital for decision-making in an organization and generally used for long-term planning. For example, the top management of an organization needs strategic information to plan for adopting new technologies for increasing the production in an organization.

Tactical Information

Tactical information helps the middle-level management to devise the strategies that need to be implemented in an organization. Tactical information is vital for making control-related decisions in an organization. This information is generally obtained from the records of the day-to-day activities in an organization.

For example, the regional sales manager of an enterprise needs to forecast the future sales of the products on the basis of sales records of past three-four years. In such cases, the daily records maintained by an organization are the basis of collecting tactical information. Information obtained from external sources such as competitor records also has a deep impact on tactical information.

Operational Information

Operational information helps the lower-level management to devise the strategies that need to be implemented in an organization. Operational information is vital for making decisions required on a day-to-day basis and used for short-term planning. Operational information generally consists of work status, customer orders and stocks in hand related information.

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Quality of Information System

Information should contain various attributes to ensure that information worth the cost of its generation. Quality of information is measured in terms of its various attributes which are as follows:

- Timeliness
- Accuracy
- Relevance
- Adequacy
- Completeness
- Explicitness
- Exception-based

Timeliness

Timeliness is one of the major attributes of information which refers to the pre-specified period of time it takes to reach the intended recipients. Timeliness plays a vital role in the decision-making process of the management in an organization. According to B.K. Chatterjee, 1974, 'Information delayed is information denied.'

Consider an example where the accounts officer requires financial report on 1st of every month. Any delay in providing information results in delay in the decision-making process by the accounts officer. Timeliness ensures that information intended for a recipient should be accurate, timely and contemporary to the most current readings.

Accuracy

According to John G. Burch and Gary Grudnitski, 'The information that is free from mistakes and errors is clear, and accurately reflects the meaning of data on which it is based.' Information is said to be accurate if it provides required facts and figures to the intended recipient. Information can be presented to the intended recipient in different formats such as tabular form or graphical form. In 1975, H.C. Advani accepted the importance of accuracy by stating that the 'wrong information given to management would result in wrong decisions.' At the same time, he advocated that the accuracy should be within limits or as desired and should not be achieved by delay in time limits.

Delivery of accurate information helps the management to gain the confidence of the employees. Representation of accurate information also helps the management to take right decisions at the right time which leads to the success of an organization.

Relevance

Relevance is another key attribute of management information systems that determines the need and requirement of the information. A piece of information is said to be relevant, if it is able to solve the problems of what, when and why for the intended recipient.

Relevance of information depends on the requirement of intended recipient of the information. For example, the sales report information is relevant only to the sales engineer and the work status of the employees is useful only to the production manager.

Adequacy

Adequacy of information helps determine whether or not the information presented in the information system is adequate for making the organizational decisions. Lack of

required information can lead to incorrect decisions, whereas, overload of information create chaos in the information system. Therefore, the information required by an organization for taking managerial decisions should be enough and to the point. Adequacy of information also helps ensure that the report generated using the information represents the complete picture of operational processes in an organization.

Completeness

Completeness and accuracy go hand in hand, that is, the information which is adequate may or may not be complete in all respects. The completeness of the information means that the information covers all the details required by the management of an organization in order to take the managerial decisions.

Explicitness

Explicitness of information helps ensure that the information presented to the management does not require further analysis of the information on the part of the management. The explicit information is able to clearly depict the meaning and purpose of the report without any further scrutiny of the information.

Exception-Based

The most contemporary concept of representing the information is the one that is based on exceptions. Exception-based information ensures that only the information that is required by the management is delivered to the client. Exception-based information helps the management in saving time, cost and efforts which are required to evaluate the information. Whenever an exception-based report is sent to the management, it directly focuses on the target piece of information.

Dimensions of Information System

Information presented to the management has its dimension in terms of cost, business and technical issues involved. The various dimensions of information are as follows:

- Economic
- Business
- Technical

Economic Dimension

The economic dimension of information determines the cost involved in obtaining the information and the benefits that are derived from the information. Based on the cost and benefits analysis of the information, economic dimensions of the information are evaluated. Following are the factors that are determined during the cost and benefit analysis:

- **Cost of information**: It determines the total cost involved in obtaining the information. The cost of information includes:
  - Cost of acquiring the data from different data sources
  - Cost of maintaining the data in the database
  - Cost of generating the accurate information from the data stored in the database
  - Cost of communicating the information to the intended receiver
- **Value of information**: The value of information is determined on the basis of the benefits that can be derived from the information. For example, a company

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develops two products, A and B, and the benefits derived from product A equals to 20 and the benefits derived from product B equals to 30. The difference between the benefits of the two products is 10 units. If you add some information, the benefits derived from product increases from 20 to 40 and the cost of information increases by 20 units. Now, the difference between the benefits of the product A and B is again 10 units with the additional cost of 20 units for cost of information.

The actual value of information needs to be calculated through simple mathematics. You need to subtract the cost involved in obtaining the information to determine the actual value of the information.

Business Dimension

The business dimension of information helps determine the relevance of information at the various levels of the management. The business dimension of information at the top-level management is totally different from the business dimension of information at the lower-level management. The difference in business dimension arises from the difference in the level and nature of work performed at the various levels of the management.

Technical Dimension

The technical dimension of information covers the technical aspects of information such as the volume of information to be stored in the database and type of database. The type of database helps store the information in the database. The technical dimension covers the storing capacity of the database and the time required to retrieve information from the database.

Effects of Information System

When an organization wants to grow in the global market, then it must concentrate on the effectiveness of its information system. The information system affects the finances and working environment of organizations. Following are the impacts of information system on an organization:

- Economic impacts
- Organizational and behavioural impacts

Economic Impacts

Implementation of the information system in an organization has resulted in decreasing the number of employees. Information system is slowly substituting other capital forms such as, buildings and machinery and thus, reducing the cost of the organization. No organization can produce everything it needs, so when an organization takes over some other organization to take care of their mutual needs, the cost that is required for transaction is called transaction cost and each firm tries to reduce the transaction cost. Traditional market system is high-priced as it has to deal with distant supplier, take care of insurance and travel to obtain information about required products. The information system can reduce their transaction cost by getting into contracts with suppliers for getting their supply of products.

Reduction in management costs enables the firms to increase the revenues. The information system reduces the cost and shifts the transaction cost curve inwards, thus opening up the possibility of revenue growth without increasing the size of an organization as shown in Figure 1.4, which explains the phenomenon of revenue growth.

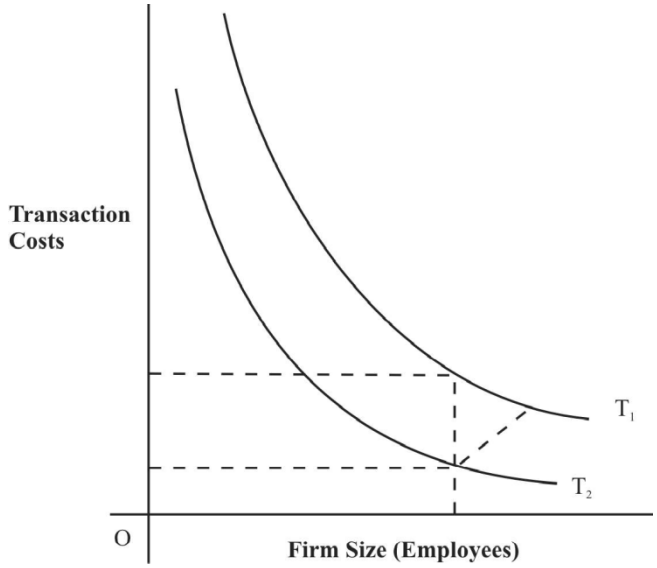


Fig. 1.4 *Transaction Cost Theory of the Impact of Information System on the Organization*

The information system also helps in reducing the cost incurred while communicating within an organization. With the growth of firm, several costs such as agency costs and coordination cost rise because the owner has to spend more money to supervise and manage the employees.

According to Agency Cost Theory, the firm is viewed as a 'nexus of contract' among self-interested individuals rather than as a unified, profit maximizing entity (Jensen and Meckling 1976). As firms grow in size and complexity, the agency cost rises because the owner must apply more efforts to supervise and manage the employees. This phenomenon is shown in Figure 1.5, where the information system has shifted the agency curve down and to the right, which enables the firms to expand while lowering agency costs. Figure 1.5 explains Agency Cost Theory.

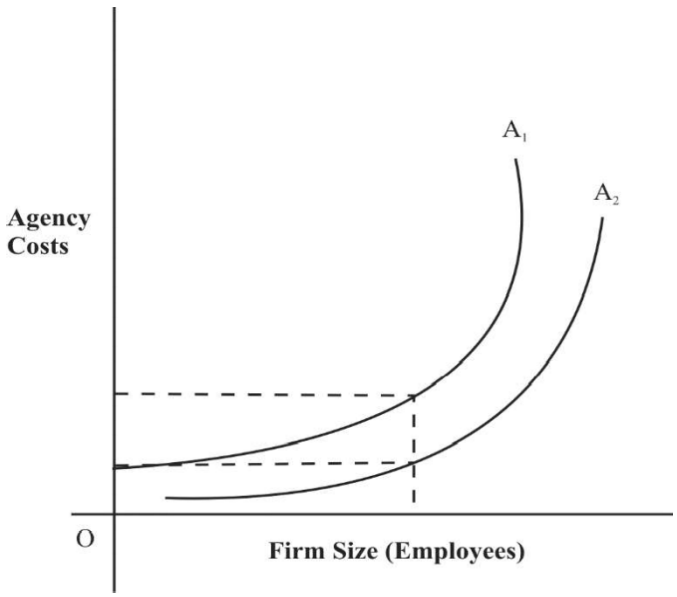
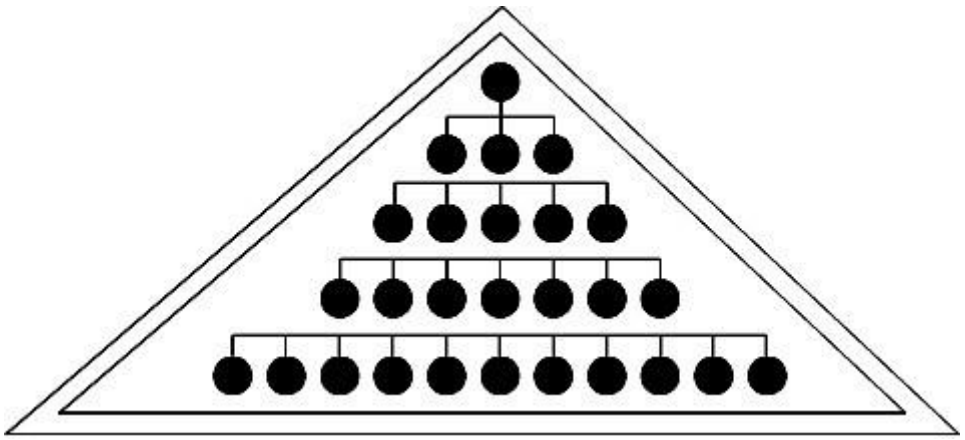


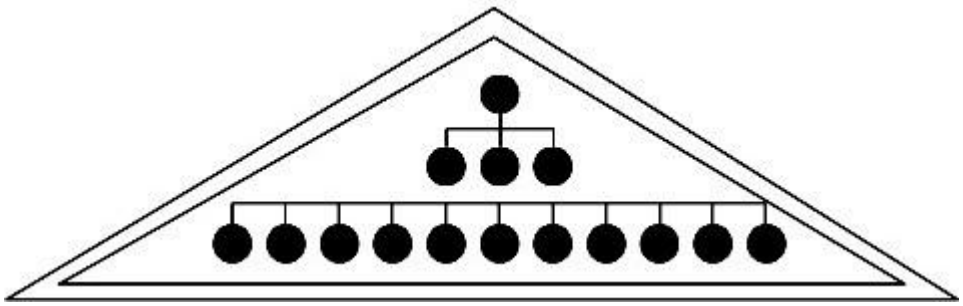
Fig. 1.5 *The Agency Cost Theory of the Impact of Information System on the Organization*

Organizational and Behavioural Impacts

You can understand complex organization using sociology-based theories. These theories explain how and why organizations are changing with the implementation of information system application. Following are the impacts of information system on an organization:



A traditional hierarchical organizations with many levels of management



An organization that has been 'flattened' by removing layers of management

***Fig. 1.6** Flattened Organizations*

- **Flattened organization**: Information system has changed the organizational structure to flattened organization. Flattened organization provides lower-level employees with more knowledge. Managers take less time to reach a decision as they get required information correctly on time so a flattened organization needs less number of managers. Traditional organizations were not efficient and inert to changes. To meet present day needs traditional organizations have reduced the number of employees and the number of levels in organizational hierarchies. Figure 1.6 explains the difference between traditional and flattened organization.
- **Emergence of virtual firms**: These firms are not restricted to any geographical boundary and are connected to its employees, managers, customers, suppliers and assets by telecommunication networks. For example, ABC Florist Ltd can sell fresh flowers directly to customers. This organization receives orders from telephone calls or through their Web site. The information system has changed the way of handling, evaluating and analysing data about organization.
- **Increasing flexibility of organization**: The information system has made firms more flexible, as they can react quickly to the changing needs of market and customers.

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DEFINITION OF MANAGEMENT INFORMATION SYSTEM (MIS)

Management Information System or MIS is a well-structured method which combines the principles, theories and practices of management using an information system. MIS plays an important role in business organization for planning and decision-making process. It provides managers with different tools which help organize, evaluate and run their departments efficiently. MIS also provides information to the employees at various levels of management for performing their respective jobs. In other words, MIS is an integrated computer-based user-machine system that provides information to support the operations, management analysis and decision-making functions in an organization. Various terminologies used in the definition are as follows:

- System consists of computer hardware and software, manual procedures, models of analysis, planning, control, decision-making information and a database.
- Integration helps to eliminate redundancy in the information and incompatibility of hardware and software. It can be achieved by following standards, guidelines and procedures.
- Computer-based means that the designers of MIS must have knowledge of computers and their use in data processing.
- User-machine means that the systems designer should understand the capabilities of an individual as a decision-maker and machine as a data-processor.
- Database is the collection of interrelated information stored in the form of fields, records and files. Databases are designed to offer an organized mechanism for storing, managing and retrieving information.

Definition of MIS

After understanding the overview of MIS by studying the concept of management, information and system, now you need to define and understand the term MIS as a whole. MIS is an integrated system which collects, maintains, correlates and selectively displays information to meet the specific needs of the various levels of management. It helps in making decisions and taking actions for fulfilling the objectives of an organization. The definition of the term 'Management Information System' varies from person to person. There are various definitions of MIS given by different authors which are as follows:

According to Schwartz, 'MIS is a system of people, equipment, procedures, documents and communication that collects, validates, operates on transformers, stores, retrieves, and present data for use in planning, budgeting, accounting, controlling and other management process.'

According to Coleman and Riley, 'An MIS (a) applies to all management levels; (b) is linked to an organizational subsystem; (c) functions to measure performance, monitor progress, evaluate alternatives or provide knowledge for change or collective action, and (d) is flexible both internally and externally.'

According to Davis and Olson, '[MIS is] an integrated user-machine system designed for providing information to support operational control, management control and decision-making functions in an organization. The information systems make use of resources such as hardware, software, men, procedures as well as supplies.'

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Goals of MIS

MIS is the most common type of management support systems. Various goals of MIS in an organization are as follows:

- To provide information to managerial end-users to support their day-to-day decision-making needs
- To produce reports for specific time periods designed for managers responsible for specific functions in an organization. For example, departmental expense reports and performance reports
- To provide correct information to the concerned manager at the right time
- To help in carrying out regular and routine operations
- To control, organize and plan better business operations

Limitations of MIS

There are fundamental weaknesses in an organization, such as improper management and unclear organizational functions. When the organization decides to implement an MIS, the following problems directly affect and limit an MIS:

- **Organizational framework**: Some managers think that they can solve a company's shortcomings using MIS. MIS does not help to achieve this goal without a good planning and control within the framework of an organizational structure. MIS must be built on top of a management system that includes the organizational arrangements, structure and procedures for adequate planning and control.
- **Generation of information**: The lack of managerial and operational applications to the MIS makes a great impact because it implies that the process of management is not being performed well to generate the information. The information is the raw material of decision-making for MIS and if information is not being generated, disseminated and used for management, then no system manual or computer is going to solve the organizational problems.
- **Managerial participation**: The most striking characteristic of the successful company is that the development of MIS has been viewed as a responsibility of the management. Their success is attributed directly to the fact that managers are required to become involved in the design of their own systems. This includes both top management and operating line management. Moreover, the president of the organization needs to take a personal interest and participate directly in defining what work the computer should do for the company.

Significance of MIS

The primary goal of MIS is to improve the management of an organization and for achieving this, timely and reliable information on various fields such as marketing, finance, and human resource of the organization play a significant management role. This information is obtained through a logical and well-structured method of collecting information and processing of the collected information. MIS helps the decision makers to carry out the decisions in their organizations. In today's business environment, MIS is of great significance and it is considered as important as the five M's related to the business industry which are money, minutes, materials, men and machines.

The significance of a planned, analysed, designed and maintained MIS is as follows:

- Provides timely, useful and reliable information that helps in the progress and growth of the business and management infrastructure in a situation of increased business complexities. This information can significantly help the management in taking quick, rational and speedy decisions.
- Supports the business processes and operations of the organization that help in globalization and liberalization of the organizations and enables the organization to compete both locally and globally.
- Provides Management Information (MI) at various stages of decision-making in an organization that helps assist the decision makers to take decision in an organization.

Elements of MIS

MIS, due to its significant contributions in the management field, has gradually become a part of most of the organizations and the organizations must have a good understanding of MIS. To understand MIS, you need to understand the elements such as management, information and system of MIS in detail. Figure 1.7 shows the elements of MIS.

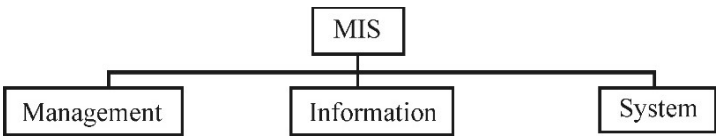

Fig. 1.7 *The Elements of MIS*

Management

The term management is defined as the art of getting things done through people by dividing them into organized groups and assigning each group a different activity. Later, the outcomes of all the activities performed by each group are appended together to accomplish the final goal. In other words, you can define management as the process of achieving the business objectives of an organization by making the best decisions that involve optimized combination of manpower, resources and working environment of the organization. The key person involved in the management of an organization is the manager who needs to perform different activities in a systematic way to carry out the process of management. The manager plans about a project by setting goals and objectives and implement procedures, rules, programmes, budgets, strategies and schedules to achieve the plan. The various activities performed by a manager are as follows:

- **Planning**: Planning is the process of determining the goals and objectives of a project before starting the implementation of the project. Planning helps bridge the gap between the current and the final position of the project. While planning for a project, the manager needs to find out the answer of the following questions:
  - What to do?
  - When to do?
  - Who is to do?
  - How is it to be done?
  - Why is it to be done?
  - Where is it to be done?

- **Organizing**: Organizing is the process of arranging the activities which are required to meet the objectives determined in the planning for a project. In an organization, the manager organizes the various activities by performing the following steps:
  - Divides the activities as per the planning of the project
  - Allocates the activities to individual employee or a group in the organization
  - Provides authority to the employee or the group for performing the activities
- **Staffing**: Staffing is the process of assigning the right person for the right job. It means allocating a job to a person as per his/her skills or identifying the persons in the organization that are suitable for accomplishing a particular job.
- **Directing**: Directing helps the manager to achieve the pre-determined goals and objectives by guiding and motivating the people involved in the project. The directing process includes:
  - Enabling communication among the employees of the organization
  - Providing motivation to the employees to work properly
  - Providing leadership quality that helps lead the employees of the organization to perform their respective activities
- **Controlling**: Controlling is a process which helps ensure that the organizational activities are performed as per planning. The controlling process involves the following actions:
  - Setting standards for measuring the performance of the organizational activities
  - Measuring the actual performance of the employees
  - Comparing the final project with the planned project and determining the deviations, if any
  - Taking corrective actions for resolving the deviations found in the final project

The manager controls the work performance by setting the performance standards and avoiding deviations from the standards. The manager performs all these functions through decision-making which is the fundamental pre-requisite for each of the preceding processes.

Information

Information is a very valuable resource that is required by the management of an organization to run the business. Information is the processed data that are provided to the decision makers or managers to aid them in their project. Figure 1.8 shows the relation of data with the information.

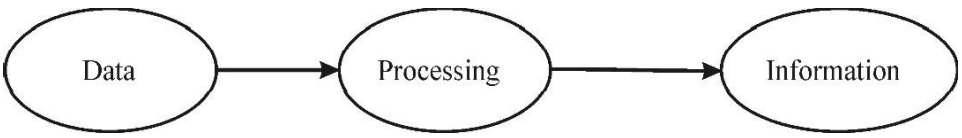

Fig. 1.8 *Relations of Data with Information*

In an organization, the concept of data and information is relative to each other. The information for one person may be the data for another person. The type of information utilized in the different management levels of an organization depends on the nature of

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the jobs performed by the managers at those levels. The various types of information in an organization can be:

- **Structured**: Structured information is well defined and thus, its processing is not difficult. For example, the proper monthly production schedule for a particular product is a structured information.
- **Unstructured**: Unstructured information is not well defined and thus, processing the information becomes difficult. For example, prediction on the future of an organization is an unstructured information.
- **External**: External information is the information which is achieved from a source located outside the operations of the organization. The external information helps the top management to carry out their future plans and policies. For example, population growth in the market, in which an organization serves, is external information.
- **Internal**: Internal information is the by-product of the various internal operations performed in the organization. This information helps operation management of the organization to carry out their plans. For example, the total purchase conducted by the organization in a particular week is internal information.

System

The system in MIS is defined as a set of elements that are joined together to achieve a common objective. These elements are interrelated and interdependent. A system is made up of various subsystems which in turn are composed of other subsystems.

A system has three elements, namely, inputs, process and output. Inputs are outputs into a system that are processed by using a transformation process which help convert the input into the desired output or result of the system. For example, in an information system, data are inputs which are processed to convert into information as the output of the system. Similarly, in a manufacturing plant, raw materials are the inputs which are processed for converting them into the desired end products.

MIS Model

The information system is considered to be evolved through three different levels of systems which are as follows:

- **Conceptual Model**: At the start of adopting of MIS, conceptual model is used to specify the functionality of MIS in the organization. It is the first level of development of information system in an organization. At this level, experts think about such a system in which entire information of organization flows from one place to another place without the intervention of any person. At this level, all objectives of MIS are set by the management of the organization.
- **Logical Model**: It is the middle level of development of information system in an organization. In this model, all objectives which are decided at the middle level are logically implemented. In other words, logical model of MIS provides a logical system design which involves understanding about the flow of data and information among various subsystems of MIS. Logical model of MIS includes large number of Data Flow Diagrams (DFD) and Flow charts.
- **Physical Model**: It is the last level of development of information system in an organization, i.e., it is the actual implementation of MIS in an organization. Testing and evaluation processes related to MIS are also implemented at this

level of development of information system in an organization. Physical model of MIS contains software, programmes, data files and documentation related to MIS.

Characteristics of MIS

MIS exhibits different characteristics which help specify the approach, design and development of MIS. The various characteristics of MIS include the following:

- **System approach**: MIS follows the system approach which implies a step by step approach to the study of complete system of an organization and its performance in the light of the objectives of the system. In doing so, MIS takes a comprehensive view of the subsystems that operate within the organization.
- **Management-oriented**: The management-oriented characteristic of MIS implies that top-down approach needs to be followed for designing MIS. The top-down approach suggests that the system development starts with determining management requirements and overall business objectives. In addition, the development plan of MIS should be derived from the overall business plan. MIS, being management-oriented, also implies that the management is actively involved in directing the system development efforts.
- **Need-based**: The design and development of MIS should meet the information required by the managers at different levels of management such as strategic planning, management control and operational control. This implies that MIS needs to provide the requirements for the managers throughout the management hierarchy of the organization.
- **Future-oriented**: The design and development of MIS should not be restricted to the past information. It should also look into the future aspects on the basis of the predictions made for the system.
- **Integrated**: MIS has the ability to produce meaningful information because of the integration concept. It means taking a comprehensive view of the subsystems that operate within the organization. An integrated system which blends information from several operational areas is a necessary characteristic of MIS. For example, to develop an effective production scheduling system, it is necessary to balance the integration of the following factors:
  - Set-up costs
  - Work force
  - Overtime rates
  - Production capacity
  - Inventory level
  - Capital requirements
  - Customer services

  Thus, integrated approach blends information from several operational areas.
- **Common data flows**: The common data flow is an economically sound and logical concept that supports several basic principles of system analysis that include avoiding duplication, combining similar functions and simplifying operations. The integration concept of MIS helps maintain the common data flow by avoiding duplication and redundancy in data collection, storage and dissemination.

- **Long-term planning**: The development of MIS is a long process. This involves detailed planning of the system and analysis of the future objectives and requirements of the organization. While planning the MIS, the designer needs to be cautious that the system should not be an outdated one.
- **Subsystem concept**: The development of MIS allows you to understand the subsystem concept which helps view the system as a combination of various subsystems. These subsystems are more meaningful and easy to plan.
- **Central database**: The development of MIS allows an organization to collect data at a central location. Each information of an organization regarding inventory, personnel and customers is stored in the central database. MIS is responsible for collecting, validating and placing the information in the central database for the use of the management.

Functions of MIS

The prime objective of MIS in an organization is to obtain management information which can be used by the managers of the organization for decision-making. To meet this object, MIS needs to perform the following functions:

- **Collecting data**: MIS helps collect data from different external and internal sources of an organization. MIS can perform this function using both manual and computerized techniques. The manual techniques include recording data on physical medium such as paper, while the computerized technique specifies collecting data directly using the computer terminals.
- **Processing data**: Processing the data includes converting the collected data into the required management information. To process the data, you need to perform various activities such as calculating, comparing, sorting, classifying and summarizing the data. These data processing activities organize, analyze and manipulate captured data by using various statistical, mathematical, operations research and other business models.
- **Storing information**: MIS allows you to store both processed and unprocessed data used in an organized manner for future use. The stored data in MIS is organized into fields, records, files and databases. MIS also allows you to store information as an organizational record that is not immediately required.
- **Retrieving information**: MIS helps retrieve information from its databases when users request for the information. MIS either allows to distribute the retrieved information or sends for further processing as per the requirements of the users.
- **Disseminating management information**: Disseminating MI involves dividing and distributing the retrieved information to the users of the information. Disseminating MI can be performed in two ways, periodic and online. Periodic dissemination is performed through reports and online dissemination is performed through computer terminals. Figure 1.9 shows the various functions performed by MIS.

NOTES

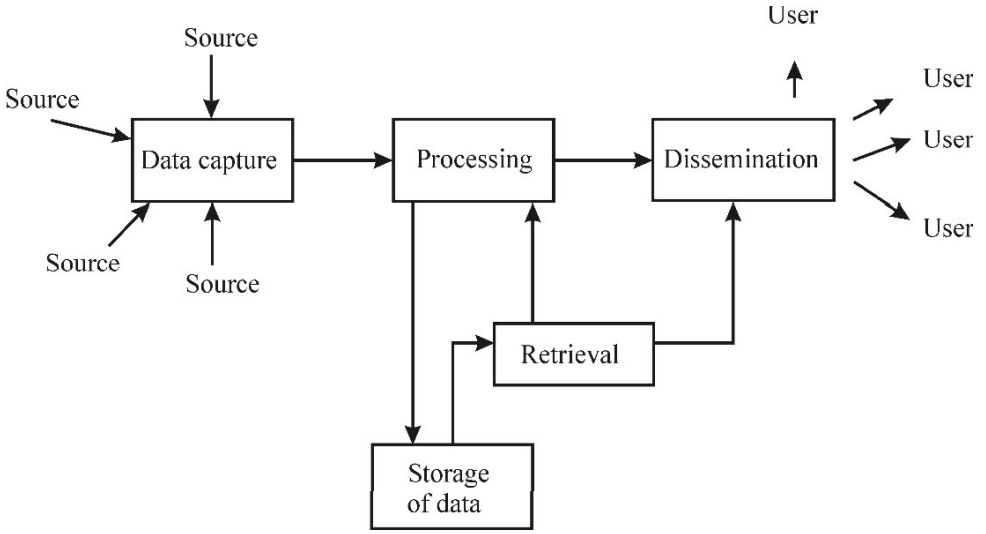


Fig. 1.9 *Functions of MIS*

Structure of MIS

The structure of MIS does not follow any universally accepted framework which makes it a difficult concept to understand. However, different management gurus have provided different approaches to describe the structure of MIS that depend on the constituent components and functions of MIS.

The structure of MIS can be described by using the following approaches:

- Physical components
- Information processing functions
- Levels of management activities
- Decision support

Physical Components

You can understand the structure of MIS by analysing the physical components used in the information system of an organization. The various physical components used in an information system are as follows:

- **Hardware**: Hardware refers to the components of an information system that includes the physical data processing equipment and the peripheral devices used in the information system. The examples of hardware are Central Processing Unit (CPU), monitor, keyboard, printer, disk drives, etc.
- **Software**: Software refers to the written instructions or programmes that are used to manage the operations of the hardware in an information system. The two major categories of software are: system software and application software. System software includes various operating systems such as Windows and Linux, while application software includes various application specific programmes such as Word, Excel and PowerPoint.
- **Database**: Database refers to an organized collection of data used by application software in an information system. Examples of databases include Access, MySQL, etc.

- **Procedures**: Procedures refer to a written set of steps which helps operate an information system.
- **Operating personnel**: Operating personnel refers to the manpower involved in operating an information system. Various operating personnel include system administrator, computer operator, database administrator, system analyst, system manager, etc.
- **Input and output**: Input refers to the data entered into an information system and output refers to the data which is received from the information system after the processing of the input data.

Information Processing Functions

You can also describe the structure of MIS with the help of its various information processing functions which explains the functionality of MIS. Figure 1.10 shows the information processing functions of MIS.

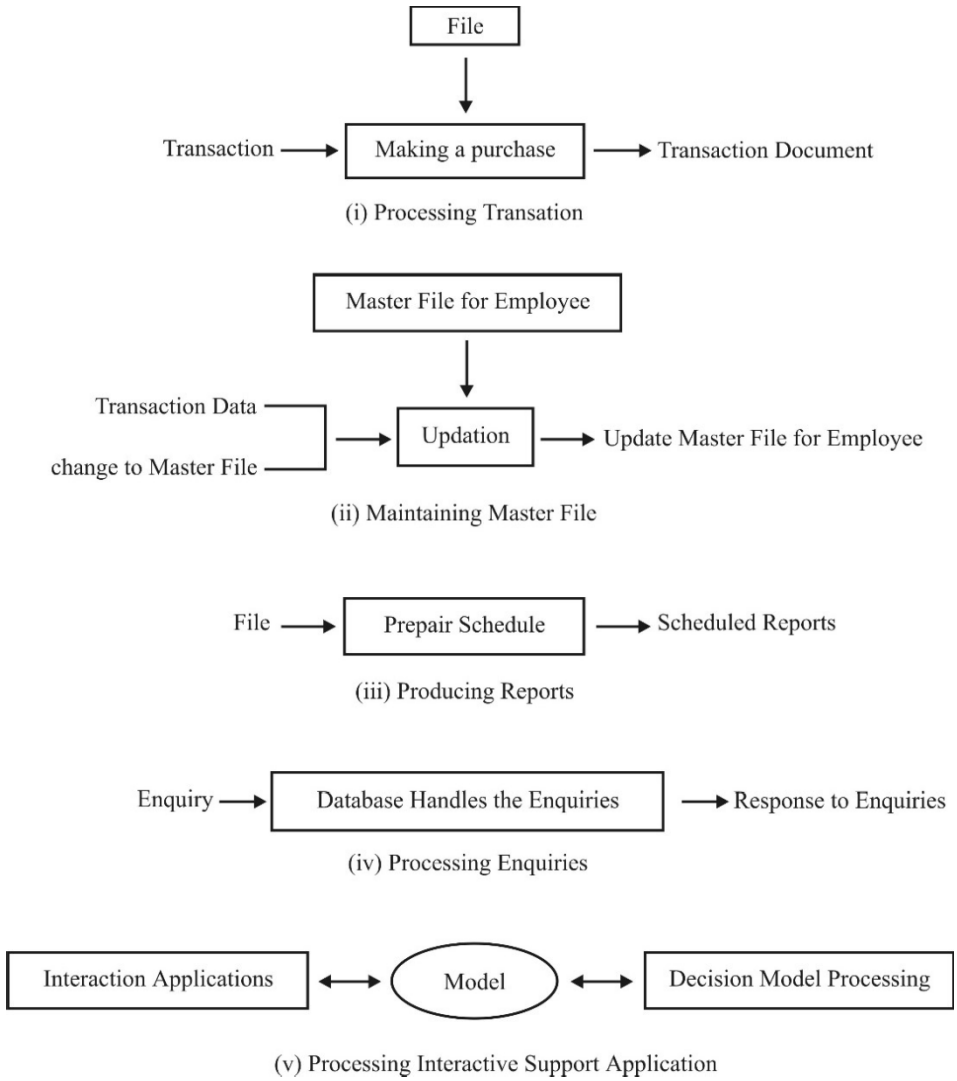


***Fig. 1.10** Information Processing Functions of MIS*

The following information processing functions of MIS help explain the functionality of MIS:

- **Processing transactions**: MIS helps process a transaction which you can define as an activity performed in an organization. The processing of the transaction can be internal or external to the organization. Examples of transaction include making a purchase, manufacturing a product, etc.
- **Maintaining master files**: MIS handles the creation and maintenance of the master file in an organization. Master files are those files that stores mainly permanent data and used as the primary source of information to perform an activity in the organization. For example, to prepare the salary of an employee, the primary requirements are the employee's basic pay, traveling allowances, deductions, etc., which is generally stored in the master files of the employees.
- **Producing reports**: MIS helps produce various reports in an organization. These reports may include the output generated by the MIS, the scheduled tasks for MIS or some ad hoc requests to MIS.
- **Processing enquiries**: MIS is also used to process enquiries that help you understand and maintain the data used in MIS. To process the enquiries, MIS generally uses its databases and follows some previously scheduled or ad hoc format for the enquiries.
- **Processing interactive support applications**: MIS contains various interactive applications which help support the planning, analysis and decision-making of the system.

Levels of Management Activities

MIS structure can also be described by using the levels of various management activities performed within the organization. The levels that help describe the structure of MIS are as follows:

- **Strategic planning level**: The strategic planning level of management activities specifies the long-term plans which are based on the business objective of the organization. The various activities included in the strategic planning level are deciding the product mix, planning market strategy, identifying environmental factors for the plans, etc.
- **Management control level**: Management control level of activities specifies the internal activities performed by one or more managers. The various management control level activities include acquisition and organization of resources, structuring organizational works, recruiting and training personnel, etc.
- **Operational control level**: The operational control level of management activities specifies short-term plans and decisions for the currents operations in the organization. The various operational control level activities include determining production levels, defining inventory levels, etc.

Decision Support

You can also define the structure of MIS on the basis of how it supports in decision-making of an organization. A decision in an organization depends on the structure which is provided to make the decision. A structured decision is generally pre-planned, whereas a highly unstructured decision is not pre-planned. The structured decisions

are regular and well-defined and they can be processed with the software instructions related to MIS. Therefore, structured decisions are called programmable and many of the programmable decisions are also automated. An unstructured decision is called non-programmable and they are irregular. You can also find decisions in an organization that are more or less structured and contain both programmable and non-programmable elements. These decisions are called semi-structured decisions.

Classification of MIS

Over the years, though MIS has come across a significant change in its approach, from an elementary concept to an advanced discipline, MIS is still considered to be in its evolutionary stage. Therefore, it is difficult to classify the information systems under MIS distinctly. However, you can categorize these information systems on the basis of their roles in the operations and management of business as follows:

- Operations support systems
- Management support systems
- General support systems

1. Operations Support Systems

In an organization, when a transaction takes place, data are produced as a by-product of the transaction. These data are then processed to carry out operations for supporting the business of the organization. The information systems, which are used to support such data, are called operations support systems. The operations support systems allow you to perform various tasks such as efficient processing of business transactions, supporting organizational communications and updating databases of the organization. You can find the following different types of operating support systems in an organization:

- **Transaction Processing Systems**: A Transaction Processing System (TPS) allows you to process and record data and helps produce reports from the processed data. It also represents the automation of the general routine processes which are used to support business operations in an organization. TPS can process data using any two methods, batch processing and real-time processing. For example, many retail stores use TPS with the capability of real-time data processing which helps to capture and transmit sales data immediately. You can also use the batch processing method for the same TPS by providing the information after a fixed period of time such as weekly or monthly.
- **Process Control Systems**: A Process Control System (PCS) monitors and controls the physical processes in an organization. While monitoring the physical processes, PCS handles the architecture and mechanisms involved in the physical process. An example of a PCS is the electronic sensors linked to computers used in pharmaceutical industries that help in monitoring the chemical process and the adjustments need to be performed.
- **Office Automation Systems**: Office automation systems refers to those information systems in which computer and communication technology applications are used to process office transactions and office activities at all levels of an organization. The office automation systems provide secretarial assistance and enhanced communication facilities at different level of management that helps improve the productivity of the managers at different levels. The office automation system performs various activities such as typing,

mailing, scheduling of meetings, conferences, etc. To perform these activities, you can use the following office automation systems:

- **Word Processing**: Word processing enables you to create computer-assisted documents such as reports and memos using textual data which are entered via a keyboard.
- **Electronic Filing**: Electronic filing allows you to store incoming and outgoing documents on a magnetic disk that you can use for future reference.
- **Electronic Mail**: Electronic mail (e-mail) uses the telecommunication network and software applications to transfer different documents among several computers connected through a network.

2. Management Support Systems

Management support systems include those information systems which emphasize on providing information and support for effective decision-making by the managers of an organization. The various management support systems are as follows:

- Management information system
- Decision support system
- Executive support system

Management Information System

Management information system is the information system that takes data as input and processes the data to convert it into information as the output. Figure 1.11 shows the processing of management information systems:

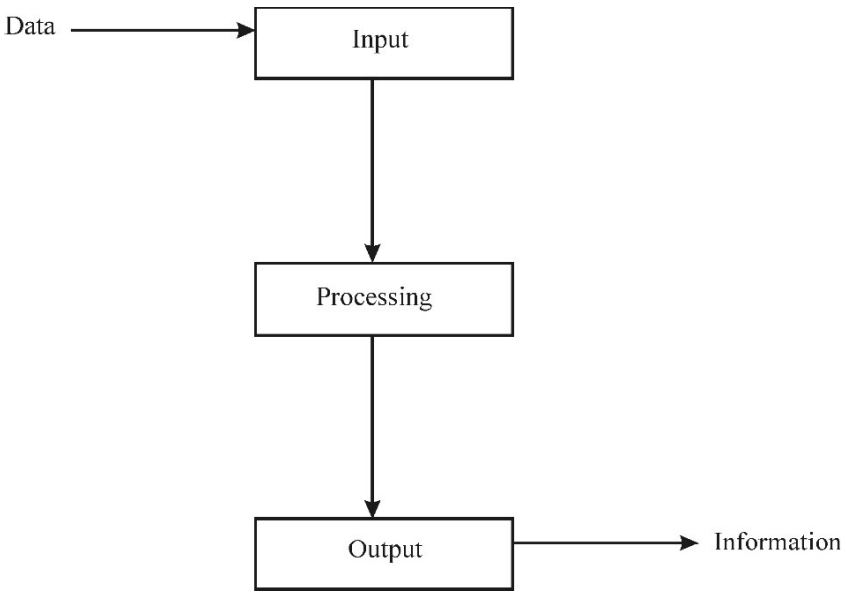


Fig. 1.11 *Processing of Management Information System*

A management information system uses TPS to get the input data for processing. It processes the data received from TPS to support a wide range of organizational functions and management processes. Therefore, the information generated from the management information system can be used for the control of operations and management along with various short-term and long-term planning. Management information system also helps provide analysis and planning of data and support decision-making.

Decision Support System

Decision Support Systems (DSS) are information systems that support decision-making in an organization. DSS is also used in planning and error handling in the organization. A DSS has three elements, namely database, model base and user interface. The database specifies the accumulation of data from the master files and external sources. The model base specifies a library of models which help in manipulating and analysing the data in the desired way. The user interface allows a user to communicate with DSS.

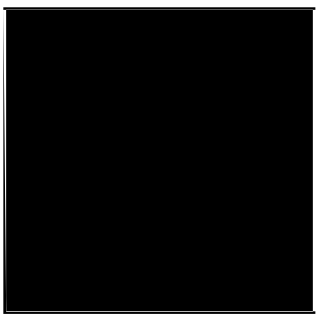
Executive Support System

Executive Support System (ESS) extends the management information system and includes the functionality of a DSS that helps support the decision-making of the chief executives in an organization. Therefore, ESS is an extensive and broad information system that includes different types of DSS and is more specific and person-oriented than other information systems. Apart from decision-making, an ESS also provides additional facilities such as data analysis and electronic mail.

3. General Support Systems

The information systems under MIS that perform both the roles of operations and management are categorized as general support systems. The various general support systems are as follows:

- **Business Expert System**: A Business Expert Systems (BES) is an advanced and knowledge-based information system that acts as an expert to provide knowledge-specific solutions to application areas which include medical, business and engineering. The main elements of a BES are as follows:
  - **Knowledge base**: It contains information about the specific area for which the BES can provide expert information.
  - **Inference engine**: It specifies how you can deduce an inference from the stored data and rules.
  - **User interface**: It allows a user to communicate with BES.
- **Knowledge Management Systems**: A Knowledge Management System (KMS) is a knowledge-based information system that helps support in creation and distribution of business knowledge to the managers and other employees of an organization. KMS also helps in providing quick feedback to the employees and improving business performance of the organization.
- **Strategic Information Systems**: A Strategic Information System (SIS) is an information system that helps an organization in achieving strategic advantage over its competitor by applying Information Technology (IT) to the products and services of the organization. Therefore, any information system such as TPS, DSS, ESS, etc., which uses IT for leveraging an organization in the competition can be referred to as SIS.
- **Functional Business Systems**: A Functional Business System (FBS) helps support the various function areas such as production, marketing and accounting of an organization. Examples of FBS include Financial Information System, Production Information System, Marketing Information System, etc.



SUBSYSTEM AND UPGROWTH IN ORGANIZATIONS

NOTES

An information system consists of many subsystems. Subsystem refers to a part of information system that plays a specific role in the working of information system. An information system becomes effective only when all its component subsystems work properly. Subsystems have a great importance for the end-users of the information system since the subsystems are the integral part of any type of information system. These subsystems are as follows:

- Real-life business subsystem
- Production subsystem
- Marketing subsystem
- Personnel subsystem
- Material subsystem
- Financial subsystem

Real-Life Business Subsystem

Real-life business subsystem is responsible for collecting information about the organization and its business environment. This information is very important to implement an information system in the organization because the information system of the organization must be compatible with each and every business activities of the organization. It must answer the following questions:

- What is the relationship between the information and business system of the organization and the end-users of the information system?
- What are the objectives of the management behind the implementation of the information system in the organization?
- What is the importance of the information system for the organization?
- Why is understanding the business system important to analyst?

Answers to the above questions help the analyst of the information system to understand the scope and complexity of the information system.

Production Subsystem

Production subsystem is responsible for collecting all the information provided by the production department of the organization. The production department of the organization deals with the decision-making related to the production process so that the resulting goods and services are produced in accordance with the quantitative specifications and demand schedule with minimum cost.

Marketing Subsystem

Marketing subsystem is responsible for collecting information about acquisition, transportation, storage and delivering of the product of the organization. All the data, which are required for the marketing subsystem of the information system, are gathered from the records of the marketing department of the organization.

Personnel Subsystem

Personnel subsystem is responsible for maintaining information such as records of account, employees and finance of the organization. It also provides a way to record information in the storage medium of the information system from the terminal ends of the information system.

Material Subsystem

It is responsible for collecting information about materials used in different departments of an organization. It is also called material handling system of information system because it provides required material to different departments of the organization at the right time. All inventory- and stock-related information is handled by this subsystem of the organization. Financial Subsystem

Financial Subsystem

Financial subsystem is responsible for collecting all the information related to financial management of the organization. Financial management of the organization provides following information:

- Historical cost of the product produced by the organization
- Income sources of the organization
- Cost required to purchase materials and machines for the production
- Account status of selling products
- Funds and resources available from the outsiders such as banks and financial institutions
- Estimated and actual budget of the organization

Decomposition of System

Decomposition of system refers to the division of system into various subsystems. The decomposition of system into various subsystems allows you to perform complex tasks with greater ease. Moreover, the division of system into various subsystems leads to the hierarchical representation of the operations. A system is divided into smaller units until the smallest unit of the system becomes manageable at the system level. Figure 1.12 shows the decomposition of a system.

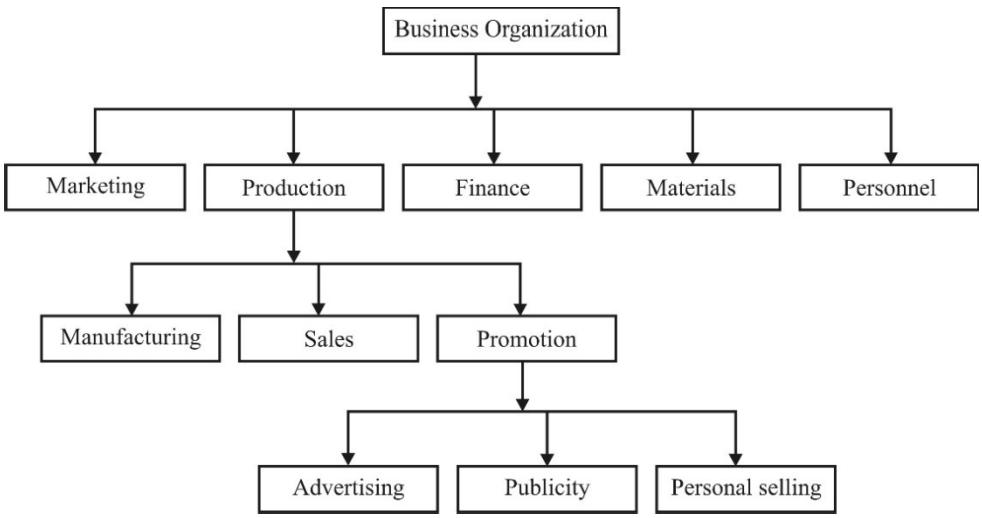


Fig. 1.12 *Decomposition of a Business Organization*

The decomposition of a system can be best exemplified by the hierarchical arrangement of various departments in an organization. Consider the example of an organization where multiple units integrate with each other to achieve a common objective. In such an organization, the system is decomposed into various departments such as marketing, production, finance, materials and personnel. The production department is further categorized into various departments such as manufacturing, sales and promotion. The task assigned to the promotion department can be further divided into different sub departments such as advertising, publicity and selling.

The decomposition process of a system into several smaller subsystems is used to analyse the structure and working of an existing system. It also helps in the design, development, and implementation of a new system.

The process of decomposition helps to identify and separate the subsystems that can work independently in a system and decouple them to achieve efficient results. Decoupling refers to the phenomenon in which the interaction between subsystems and other elements of the system disappears. It allows the subsystem to function independently. It minimizes the adverse effect of a subsystem on other subsystems. In some cases such as inventory management, decoupling allows the production processes to function efficiently instead of delaying all the processes due to the unavailability of a few resources.

1.4.1 Upgrowth in Organizations

In the following section, we will discuss Nolan stage model to understand the various features of information system correspond to the stages of growth.

The Nolan Stage Model: IS Planning Framework

Nolan stage model is developed by Richard Nolan in 1974 to provide framework for information system planning in which the various features of information system correspond to the stages of growth. This model very clearly explains the stage by stage development of an information system in an organization. Initially, the model consisted of four stages; initiation, expansion or contagion, formalism or control, and maturity or integration. The basic principle behind this model is that an organization must go through each stage of growth before progressing to the next stage. This model is named as contingency model because it states: 'if these features exist then the information system is in this stage.'

Nolan four stage model not only helps an analyst to diagnosis the stages of information system within an organization, but also helps him to understand the reasons for success or failure of the system in an organization and thereby assists in developing solutions to take the functions ahead.

Later on, in 1979, Nolan recommended that these four stages are not sufficient to depict the growth of IT in an organization so; he enhanced his four stage model to six stage by introducing stage 5 and stage 6. Different stages of this model are shown in Figure 1.13. This growth curve takes the shape of a double 'S'. It shows that the growth rises sharply in the first and the second stage and then become stable by the end of the third stage. Again for the fourth stage, growth increases but only to get a steady shape at the last stage of the growth curve.

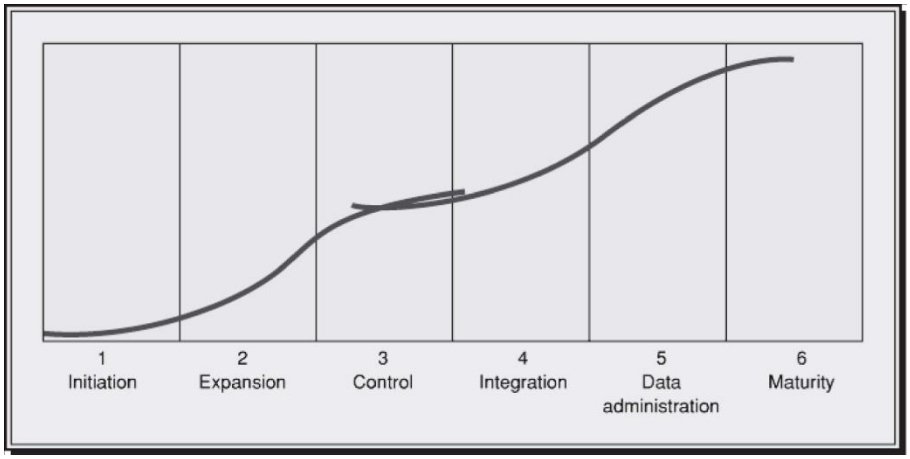


Fig. 1.13 *Six Stages of Nolan Model*

Stage 1: Initiation

The first growth stage is known as initiation stage. During this stage, information technology is introduced into the organization. The organization buys and installs computer systems, and few applications are computerized to meet the basic organizational needs. However, at this stage the number of users using the computers is less due to unfamiliarity with the new technology. Thus, this stage is characterized by decentralized control and minimal planning. Since most medium and large-sized companies have already installed computer systems, this stage has already been achieved by most of the organizations.

Stage 2: Contagion

This stage is also known as expansion stage. This is the phase when most of the organizations wish to have an access to the computer hardware, develop software and have the trained manpower working. Every organization head wishes to have some computer resources controlled by them. This leads to the uncontrolled growth of computer resources and variety of IT applications. Due to which budget goes high and becomes the cause of concern for management.

Stage 3: Control

This stage is also known as formalism stage. During this stage, management notices that benefits derived from MIS activity are not in proportion to the actual expenditure spent on it. So, organizations exercise control over resources by implementing various formal control processes and standards. At this stage, the management puts some constraints in sanctioning the budgets. The MIS budgets are also checked with the result so that the users get aware of the fact that information technology should not be misused.

Stage 4: Integration

This stage is also known as maturity stage. By this stage, organizations gain enough experience and maturity in IS applications. So, this stage mainly focuses on the integration of applications so as to avoid duplications of efforts and systems. In this stage, controls are adjusted and planning is performed in well-organized manner hence, this stage is called the 'stage of perfection'.

NOTES

Stage 5: Data administration

This stage puts emphasis on managing corporate data rather than IT. So, management of data becomes the crucial step at this stage. Database administrator (DBA) plays an important role in the management of data. Since the data is being stored, used, manipulated and processed from integrated files in the database, it is the responsibility of DBA to plan, supervise, control and secure the data.

Stage 6: Maturity

This is the final stage of enhanced Nolan model. It shows that application portfolio (tasks like orderly entry, material requirements planning, etc.) is completed and hence information flows within an organization. It is assumed that by this stage, the applications have been incorporated into the organizational functioning and these are as per the strategic requirements of the organisation. In addition, the technology has become an integral part of the organizational thinking, philosophy and systems.

SUMMARY

- Information is a processed form of data. According to Davis and Olson, 'Information is data that has been processed into a form that is meaningful to the recipient and is of real or perceived value in current or prospective actions or decisions.'
- A system which processes information to control the environment and activities of a business organization is generally known as information system.
- The information system is a type of data processing systems which collects the data from different sources, processes that data and generates information from the data to use them for different applications within the organization.
- An information system provides flexibility to the organization in adopting new methods and technologies by making flow of information more fluent and effective.
- Strategic information helps the top management to devise the strategies that need to be implemented in an organization.
- Tactical information helps the middle-level management to devise the strategies that need to be implemented in an organization. Tactical information is vital for making control-related decisions in an organization.
- The business dimension of information helps determine the relevance of information at the various levels of the management. The business dimension of information at the top-level management is totally different from the business dimension of information at the lower-level management.
- Management Information System or MIS is a well-structured method which combines the principles, theories and practices of management using an information system.
- MIS is an integrated system which collects, maintains, correlates and selectively displays information to meet the specific needs of the various levels of management. It helps in making decisions and taking actions for fulfilling the objectives of an organization.
- The primary goal of MIS is to improve the management of an organization and for achieving this, timely and reliable information on various fields such as marketing, finance, and human resource of the organization play a significant management role.

Check Your Progress

7. What is the use of real-life business subsystem?
8. Define decomposition of system.

- The system in MIS is defined as a set of elements that are joined together to achieve a common objective. These elements are interrelated and interdependent. A system is made up of various subsystems which in turn are composed of other subsystems.
- Management support systems include those information systems which emphasize on providing information and support for effective decision-making by the managers of an organization.
- Decision Support Systems (DSS) are information systems that support decision-making in an organization. DSS is also used in planning and error handling in the organization. A DSS has three elements, namely database, model base and user interface.
- Executive Support System (ESS) extends the management information system and includes the functionality of a DSS that helps support the decision-making of the chief executives in an organization.
- An information system consists of many subsystems. Subsystem refers to a part of information system that plays a specific role in the working of information system. An information system becomes effective only when all its component subsystems work properly.
- Real-life business subsystem is responsible for collecting information about the organization and its business environment. This information is very important to implement an information system in the organization because the information system of the organization must be compatible with each and every business activities of the organization.
- Marketing subsystem is responsible for collecting information about acquisition, transportation, storage and delivering of the product of the organization. All the data, which are required for the marketing subsystem of the information system, are gathered from the records of the marketing department of the organization.
- Financial subsystem is responsible for collecting all the information related to financial management of the organization.
- Nolan stage model is developed by Richard Nolan in 1974 to provide framework for information system planning in which the various features of information system correspond to the stages of growth. This model very clearly explains the stage by stage development of an information system in an organization.
- Initially, the model consisted of four stages; initiation, expansion or contagion, formalism or control, and maturity or integration. The basic principle behind this model is that an organization must go through each stage of growth before progressing to the next stage.

KEY TERMS

- **Information system:** A system which processes information to control the environment and activities of a business organization is generally known as information system.
- **Graphical User Interface (GUI)**: This is an interface for the users of information system to work with information on the computer system. A user can operate, process and retrieve information from the computer storage using GUI.

- **Planning:** Planning is the process of determining the goals and objectives of a project before starting the implementation of the project. Planning helps bridge the gap between the current and the final position of the project.
- **Organizing**: Organizing is the process of arranging the activities which are required to meet the objectives determined in the planning for a project.
- **Staffing**: Staffing is the process of assigning the right person for the right job. It means allocating a job to a person as per his/her skills or identifying the persons in the organization that are suitable for accomplishing a particular job.
- **Hardware**: Hardware refers to the components of an information system that includes the physical data processing equipment and the peripheral devices used in the information system. The examples of hardware are Central Processing Unit (CPU), monitor, keyboard, printer, disk drives, etc.
- **Database**: Database refers to an organized collection of data used by application software in an information system. Examples of databases include Access, MySQL, etc.
- **Decision Support Systems (DSS):** DSS are information systems that support decision-making in an organization. DSS is also used in planning and error handling in the organization.

ANSWERS TO 'CHECK YOUR PROGRESS'

1. Information is a processed form of data that is used in decision-making in an organization.
2. Information can be broadly categorized into the following types:
   - Strategic information
   - Tactical information
   - Operational information
3. The various dimensions of information are as follows:
   - Economic
   - Business
   - Technical
4. MIS is an integrated computer-based user-machine system that provides information to support the operations, management analysis and decision-making functions in an organization.
5. The three major goals of MIS in an organization are as follows:
   - To provide information to managerial end-users to support their day-to-day decision-making needs
   - To produce reports for specific time periods designed for managers responsible for specific functions in an organization. For example, departmental expense reports and performance reports
   - To provide correct information to the concerned manager at the right time
6. The prime objective of MIS in an organization is to obtain management information which can be used by the managers of the organization for decision-making.

7. Real-life business subsystem is responsible for collecting information about the organization and its business environment.
8. Decomposition of system refers to the division of system into various subsystems. The decomposition of system into various subsystems allows you to perform complex tasks with greater ease.

EXERCISES AND QUESTIONS

Short-Answer Questions

1. Write a short note on the single and the multiple process management information systems.
2. List various types of subsystem.
3. What do you understand by decomposition of subsystem?
4. Define the term 'management support system'.

Long-Answer Questions

1. Explain the concept of MIS in detail. What is the primary goal of MIS?
2. What is office automation system? Explain with examples.
3. Explain the structure of MIS.
4. Discuss the various characteristics of MIS.
5. Explain the various functions of MIS.
6. Discuss the various approaches that help describe the structure of MIS.
7. What are the bases for classifying MIS? Explain the different categories of MIS?

FURTHER READING

Goyal, D.P. 2006. *Management Information Systems – Managerial Perspectives*. Noida: Vikas Publishing.

Davis, Gordon B. and Olson, Margrethe H. 1985. *Management Information Systems*. New York: McGraw-Hill.

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UNIT-2 INFORMATION SYSTEM DEVELOPMENT

Structure

INTRODUCTION

Communication between different departments of an organization is crucial for ensuring efficient business operations. The flow of information between varied departments is handled through the information system. Effective designing of the information system then is an important facet of the information flow. The System Development Life Cycle is a process of not only analysing but also designing an information system following a phase-wise approach. Apart from designing the information system, it is also important to ensure that the accurate collection and transmission of data or the material, this is taken care by the fact finding technique. The direction and the path of the information dispersion is controlled through the data flow diagram. Also, the logical steps of the procedure are depicted through the flow chart. But even after all these efforts, there are certain security and control related issues which crop up in the information system and an understanding of these problems is essential to find remedies and improve the system. In this unit, you will learn about the concept of system development life cycle and its phases, fact finding technique, data flow diagram (DFD), flowchart and the security and control issues in information system.

UNIT OBJECTIVES

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

- Explain SDLC and its phases
- Describe the fact finding technique
- Discuss the concept of data flow diagram
- Assess flow chart
- Analyse the security and control issues in information system

SYSTEM DEVELOPMENT LIFE CYCLE

System Development Life Cycle is a set of activities carried out by the systems analysts and system designers to develop an information system.

The concept of System Development Life Cycle (SDLC) model comes from the system life cycle which is defined as the period of time that starts with the conceptualization of a system and ends when the functioning of the system is over. In other words, SDLC models represent descriptive and diagrammatic model of a software product with a series of identifiable phases through which the software product goes during its lifetime.

The fundamental need for using a life cycle model is to provide a basis that helps in controlling the various activities required for developing and maintaining a system. In addition, it establishes a precedence ordering among the various activities and helps the development team in facilitating and understanding the activities involved in the project. The primary task of the development team, while developing a system, is to identify a suitable life cycle model and follow the model throughout the life cycle of the product. Adhering to the life cycle model helps them in developing the system in a systematic and disciplined manner.

Another need for using a life cycle model is that it helps in defining the entry and exit criteria for every phase of the system life cycle. This enables the system project managers to easily monitor the progress of the system development process and also helps in controlling and systematically organizing the various activities of its life cycle. Apart from these uses, SDLC also provides following advantages which help in supporting the need for the life cycle models in the life cycle of various system products:

- **Enables effective communication**: SDLC enhances the understanding of the system life cycle and provides a specific basis for the execution of software development life cycle.
- **Facilitates process reuse**: System development is a time-consuming and expensive activity; therefore, the system development team utilizes the existing processes for different projects.
- **Effective**: The reusable system life cycle models provide an effective means for system development.

Some of the well-known SDLC models include the following:

- Classic waterfall model
- Prototyping model
- Spiral model
- Rapid Application Development (RAD) model
- Incremental model
- V Model
- Build and fix model
- Evolutionary development model
- Synchronize and Stabilize Model

SDLC follows a phased approach for the development of the system. In the phased development process, the process that is used to develop information system is divided into phases. Each phase ends with a defined output. The division of the development process into phases lowers the overall cost of the development because

each phase handles a different part of the entire software development process. In addition, the phased development process allows you to check the quality of the information system and progress of the development process at the end of each phase.

2.2.1 Phases of SDLC

A general process model consists the following phases:

- Requirement analysis
- Software design
- Coding
- Testing
- Implementing and evaluating

Requirement Analysis

The requirement analysis phase determines the functionality of information system and constraints under which the system will work. The requirement analysis phase is divided into two activities, problem analysis and requirement specification. In problem analysis, the problem that will be solved by the information system is determined. After the problem is analysed, the requirements are specified in the requirements specification document. The requirements specification document specifies all the functional and non-functional requirements, input and output format of all the phases of the information system development process and the constraints under which the system will work.

Software Design

In the software design phase, solution to the problem that is analysed in the requirement analysis phase is planned. This phase is the most crucial phase as it affects all the later phases of the information system development process.

Software design involves specifying the methods that can be used for dealing with the problems that can occur during the system development process. Some of the problems that can occur in the system development process are as follows:

- **Problem of scale**: The problem of scaling arises because different sets of methods are used to develop a large software project as compared to the methods used to develop a small software project.
- **Problem of quality**: Problem of quality arises if the quality of software cannot be determined using single parameter and the parameters, on which the quality depends, are specific to a software project. The goal of a software project should be to satisfy the quality that is specified before developing the project process. Reliability of a software project determines the quality of the software and the unreliability of software is due to the defects in the software. A defect in software is defined as a problem that causes software crash or incorrect output.
- **Problem of productivity**: Productivity of a software project is determined by the manpower employed for developing the software. If the productivity of the manpower employed to develop software is high, the cost of the software will be low.
- **Problem of cost**: The cost of developing software includes the cost of resources involved in the software development process such as hardware

and manpower. The cost of software is measured in terms of total number of persons-months spent in the software project including the cost of overheads such as hardware and tools. Persons-months are defined as the amount of work done by a person in one month.

- **Problem of scheduling**: The scheduling of a software project is affected by the market competition which specifies that the time involved in the development of software must be small as compared to the other software in the market. The software projects where the schedule and cost of projects exceed the predicted limits are categorized as runaway projects. To reduce the problem of unreliability and delays, organizations need to take advice from the consultants of the organizations to improve the performance of Information system of the organization.
- **Problem of consistency**: Problem of consistency is one of the major challenges that affect the software development process. The problem of consistency arises if a software project does not repeat the successful results of previous software projects and the consistency in the quality of the previous software projects. The main aim of an organization involved in software development is to develop high quality products consistently with high productivity.

The output of the software design phase is in the form of three documents: architecture design, high-level design and detailed design. The architecture design document specifies software as a collection of different components and the relationship between the components. The high-level design document specifies the modules and their specifications that are required to develop the software. A module is a collection of components that are dependent on each other for their functioning. In addition, the high-level design document specifies the data structures that are required to implement the modules. The detailed design document specifies the implementation logic of the modules specified in the high-level design document.

Coding

In the coding phase, the modules designed in the software design phase are implemented using a programming language. The purpose of this phase is to implement the modules in an optimized manner. In addition, the code should be simple to read and understand. An optimized code reduces the testing and maintenance effort. The output of the coding phase is the software that satisfies the information system requirements.

Testing

The purpose of the testing phase is to detect defects in the information system. This phase detects defects in all the previous phases of a system development life cycle. Testing of information system involves:

- **Unit testing**: It involves testing of different components of the information system to ensure whether or not the components are functioning correctly.
- **Module testing**: It involves testing of modules to ensure whether or not the modules are functioning properly.
- **Subsystem testing**: It involves testing of subsystems to ensure whether or not the subsystems are functioning properly. A subsystem is a collection of dependent modules.

- **System testing**: It involves testing of the complete information system. System testing detects the errors that occur in the software due to interaction of subsystems and modules.
- **Acceptance testing**: It involves testing of the software with the user-supplied, real-time data to demonstrate the use of software to the user.

The testing phase is the most time-consuming phase of the SDLC. To test information system, a test plan is developed that specifies all the testing-related activities, schedule of testing-related activities, resources for the testing-related activities and guidelines for testing. The test plan also specifies all the units to be tested and the conditions under which the units of the system will be tested. After developing a test plan, a test case specification document is developed which specifies the test cases for all the units of the system. After developing the test case specification document, testing is done by using test cases and the actual results are compared with the predicted results.

The output of the testing phase is in the form of two types of reports, test and error reports. The test report contains the test cases and corresponding results of executing the test cases. The error report contains the errors occurred during testing and the solutions to the errors.

Implementing and Evaluating the System

Implementation is a process of ensuring that the information system is operational and then allowing the users to use and evaluate it. Implementing a system also involves training the users to handle the system. The systems analyst needs to plan for a smooth conversion from the old system to the new one by converting files from old formats to new ones. The total evaluation of the system is done in this final phase. After the system is installed, it must be maintained for the following two reasons:

- To find out system errors
- To enhance the system's capabilities

Training

Training is a process of providing knowledge about the system to the users. Systems analyst engages in educational processes with the users through training. The trainer and the trainee determine training strategies. The systems analyst ensures that all the end users affected by the new information system are properly trained. Possible training sources include the following:

- Vendors
- Systems analysts
- External paid trainer
- In-house trainers
- Other system users

Guidelines for training are:

- Establishing measurable objectives
- Using appropriate training methods
- Selecting suitable training locations
- Employing understandable training materials

Following are the objectives of a training programme:

- To enhance communication among the members of the development team

- To provide knowledge about the new system to the employees of the company
- To increase user awareness
- To obtain support for the new system from the top management
- To provide information to the employees and the top management about the problems and issues that can be handled by the new system

Conversion

Conversion is the method to replace the old system with the new one. A conversion plan includes a description of all the activities that must occur during the implementation of a new system. Following are the five strategies for converting the old information system into the new one:

- Direct changeover
- Parallel conversion
- Gradual (Phased) conversion
- Modular Prototype conversion
- Distributed conversion

Security of computer facilities, stored data and information generated are part of a successful conversion. The three interrelated aspects of security are:

- Physical Security
- Logical Security
- Behavioural Security

Evaluation

Many different evaluation approaches are available for evaluating information systems including cost-benefit analysis, the revised decision evaluation approach and user involvement evaluation. The information system utility approach is a comprehensive and useful technique for evaluating and measuring the success of a developed system. Following are the utilities that are used to evaluate the system:

- **Possession utility**: It answers the questions who should receive the output.
- **Form utility**: It answers the question what kind of output is provided to the decision maker.
- **Place utility**: It answers the question where the information is distributed.
- **Time utility**: It answers the question when the information is delivered.
- **Actualization utility**: It involves how the information is introduced and used by the decision maker.
- **Goal utility**: It answers the question whether the output has value in obtaining the objectives of an organization.

FACT FINDING TECHNIQUE

Fact finding technique is a process of ensuring that the information gathered is the actual required information. To gather the actual required information, you need to use the fact-finding techniques. The various types of fact finding techniques are:

- Review of Literature, Procedures and Forms
- On-site observation

Review of Literature, Procedures and Forms

Various kinds of reports and records that store the information related to the existing system are maintained in an organization. These reports and records can provide valuable information related to the organization, its operations and activities to the system analysts. A review of available documentation is a logical starting point when seeking insight into a system. It helps people gain some knowledge about the organization or to perform operations by themselves before they impose upon others.

Procedure manuals and forms are excellent sources of information because they describe the format and functions of the present system. Update manuals can provide lots of information which saves a lot of time. Recent developments in the area of Information Technology (IT) have made it possible to avail all the updated documentations about most of the systems within a short span of time.

The existing forms can provide a clear understanding about the transactions that are handled in the organization. An input form can be used to identify the various data items that are captured for processing. An output form or report can be used to evaluate the performance of the process or to notice different information products that are being generated from the system. When the analyst analyse the existing forms, the following question must be pointed out:

- Who are the users of forms?
- How important are these forms to the user?
- Does the form contain all the required information?
- Is it required to add or delete any items?
- What is the frequency of use of each form?
- How many users receive the forms?
- Is it readable or ambiguous?
- Does the information in the form help the users to make decisions?
- How does it help the user in decision making?

Analysing quantitative documents

Each of the quantitative documents has a specific purpose and an audience to which they are targeted. Various reports are used for decision making such as sales, production and inventory reports. Sales reports might help the decision maker to readily spot the trend. These reports supply strategic overviews of the organizational plans. Beyond these key reports, many summary reports are used by the decision makers to provide the background information and spot exceptions to normal circumstances.

Performance reports

Performance reports provide the information related to the performance of the system. It helps in analysing the varying trends in the performance and in implementing the required changes. Following are the main functions of the performance reports:

- They report the actual versus the intended performance.
- They help the systems analyst to assess the size of the gap between the actual and intended performance.
- They indicate whether this gap is widening or narrowing.
- These performance reports show whether the goals are achieved or not.

Records

Records are maintained to help the system analyst determine the functioning of the system. The records are maintained daily, monthly or yearly based on the requirements and the time period specified for analysing the reports. Following are the main functions of records:

- They provide a periodic update of what is occurring in the organization.
- They help the analyst to check for errors in amounts and totals.
- They help in observing the number and type of transactions.
- By inspecting the records, the systems analyst can think about improving or changing the recording form design.
- It helps find instances when computers can simplify the work further.

Data capturing forms

Data capturing forms helps in collecting the specific information related to the requirement of the system. Following are the factors to be considered while using data capturing forms:

- The organizational system is to be understood before changing the information flow in the organization.
- Blank forms, along with their instructions for completion and distribution, can be compared to filled-in forms for analysing the collected information. It also verifies whether the people who are supposed to receive the forms actually get them and follow the standard procedures for using, storing and discarding the forms.

Analysing qualitative documents

Analysing the qualitative documents helps understand how the organizational members engage in the process of organizing. The types of qualitative documents are memos and sign-on bulletin boards and in work areas, manuals and policy handbooks.

Memos

Memos are qualitative documents which help in providing the details regarding the daily activities of the organization. Maintenance of memos on daily basis helps in understanding the environment of the organization. Following are the functions of memos:

- Analysis of memos provides insight into the metaphors that guide the organization's thinking.
- While analysing memos, it should be determined who sends the memos and who receives them.
- Memos represent the clear picture of the values, thoughts and beliefs of the employees of an organization.

Manuals

Manuals are the qualitative documents pertaining to the working area of any system. These manuals can be based on the functioning of an organization or the system and help in analysing their performance. Following are the facts related to the manuals:

- Systems analysts should examine the organizational manuals, computer system manuals and different kinds of online manuals.

- Manuals present the ideal way in which machines and people are expected to behave.
- Examining the current manuals helps determine the way things ought to happen.

Policy handbooks

Policy handbooks are the documents that provide the information regarding the policies and rules of the organization or the system. Following are the facts related to the policy handbook:

- They indicate the company's ideal way of doing things and achieving goals.
- Some computer policies may appear on the screen whenever a particular programme is run.
- Sometimes the members are not aware of some particular policies.
- Policies are sometimes purposely avoided in the name of efficiency or simplicity.

Unfortunately, documentation seldom describes a system completely and often it is not up to date. A search of literature through professional references, user manuals, textbooks and company or government publications can be availed. Sometimes it is difficult to get certain reports and publications. Sometimes, it may be too expensive and time-consuming. Record inspection can be performed at the beginning of the study as an introduction which can help the analyst to understand the history of the system as well as later on the study.

On-Site Observation

On-site observation allows analysts to gain information they cannot obtain by any other fact-finding methods. With thorough on-site observation, you can gain the first-hand information. Whereas by reviewing the documents, you get only secondary information. This method is really useful, when analysts want to observe how transactions are handled, when and where the documents are captured, how the data flows or activities are carried out and so on. According to Harper Boyd and Ralph Westfall, observation is the process of recognizing and noting the people, objects and occurrences to obtain information.

The objective of on-site observation is to get as close as possible to the actual system being studied. As an observer, analysts follow certain rules. While observing, they are more likely to listen than talk with a sympathetic and genuine interest when information is conveyed. Proper care is taken not to argue with the persons being observed. Observation provides a more tangible perspective of what is described in the documentation. It also brings out the aspects of the documentation that are incomplete or outdated.

Steps for observation

Following is the sequence of steps that must be followed while carrying out on-site observation:

- Decide what is to be observed
- Decide the level of activities
- Create categories for capturing key activities
- Prepare materials for observations
- Decide the time for observation

On-Site observation methods

When humans are observed, four alternative observation methods are considered which are as follows:

- **Natural observation**: Natural observation takes place in a setting such as at an employee's work place.
- **Contrived observation**: It takes place in a set-up by the observer such as laboratories. For example, checking bugs in the individual system and checking the progress of trainees in a training programme.
- **Obtrusive observation**: Obtrusive observation takes place with the knowledge of the respondent. For example, visiting of external auditor in the organization comes under obtrusive observation.
- **Unobtrusive observation**: It takes place without the knowledge of the respondent. For example, surprise internal audit comes under unobtrusive observation.
- **Direct observation**: Direct observation takes place when the observer observes the system at work by being physically present at the actual work place.
- **Indirect observation**: This type of on-site observation makes use of secondary devices such as video cameras to capture information. For example, daily proceedings of the bank may be observed with the help of video camera.
- **Structured observation**: Structured observation is a type of on-site observation that takes place in a formal way in which each activity in the observation process is predefined. For example, while tracing the route of sales invoice in a system.
- **Unstructured observation**: In this type of on-site observation, observer observes whatever might be pertinent at the time. For example, observer wants to create a list of activities of production supervisor by observing him from the remote location.

Time sampling

Time sampling is also an information collection technique which helps the system analyst to maintain a definite time interval between two subsequent observation of various activities of managers and decision makers. For example, observing a decision maker during five randomly chosen ten-minute intervals throughout a week. Time sampling cuts down the bias that might affect the observation made just anytime. Time sampling gives a representative view of the activities that occur frequently. Following are the advantages of time sampling:

- Reduces the chances of faults
- Provides a descriptive view of activities

The disadvantages of time sampling are:

- Gathers data in a fragmented form
- Overlooks uncommon but important decisions

Event sampling

Event sampling involves sampling of entire events such as meetings and conferences. Event sampling provides observation of an integral behaviour in its natural context. Following are the advantages of event sampling:

- It helps examine the behaviour of various events of a software system.

- Event sampling helps examine the important event of a software system more clearly.

Following are the disadvantages of event sampling:

- Event sampling is a time-consuming process.
- It does not provide the descriptive sample of frequent decisions.

Adequate training and preparation is required for an on-site observation because interfering into the user-affected areas often results in adverse reactions by the staff. Observations are subject to error because sometimes the observers may be biased or misinterpretations of facts, with or without their knowledge, may occur. Another disadvantage of this method is that it consumes a lot of time. Too many hours or days are often spent in an attempt to observe specific, one-time activities. Observation is then a basic method of gathering information for the system analyst.

Examining behaviour of decision makers

To obtain the information about how tasks related to a software system are done, you need to observe each task carefully. It must be structured in order to be interpretable. Reasons for observation are to gain information which cannot be acquired by using any other method and to confirm or negate what has been found through other methods. By observing the activities of the decision makers, the analyst can gain insight about what is to be actually done. It is important to observe the relationship between the decision makers and the other organizational members. The analyst examines the physical elements of the decision maker's workspace for their influence on decision-making behaviour.

Through the method of observation, it is important to comprehend the influence of the decision maker on others in the organization. Observations must be structured and systematic in order to correctly interpret the findings. The analyst must know what is being observed. He must know who will be observed and when, where, why and how.

Physical environment observation

Generally, this means systematically examining the offices of decision makers since offices are their primary workplace. Decision makers influence and in turn are influenced by their physical environment. The method for Structured Observation of the Environment (STROBE) provides a standard methodology and classification for the analysis of those organizational elements that influence decision making. STROBE allows other systems analysts to apply the same analytic framework to the same organization. Following are the key points that the analyst note while conducting STROBE:

Office location

- Accessible or inaccessible?
  - **Accessible**: Tends to increase interaction frequency and informal messages.
  - **Inaccessible**: Decreases the interaction frequency and increases task-orientated messages.
- Stationery office equipment:
  - No file cabinets or bookshelves imply that the decision maker keeps very little personal information.
  - Trade journals and newspapers.

- Source of information frequently used:
  - o External, e.g., journals or newspapers.
  - o Internal, e.g., reports or policy handbooks.
- Office lighting and colour
  - o Incandescent lighting allows easy personal communication.
  - o Bright lighting allows formal communication.
- Clothing worn by decision maker
- Formal/informal?
  - o Formal clothes imply maximum authority.
  - o Casual clothes imply more participative decision making.

Analysts can choose among many application strategies while using the STROBE approach.

Photograph analysis

Photograph analysis includes the activity of photographing the environments of decision makers and then analyzing the photographs. The advantages are the following:

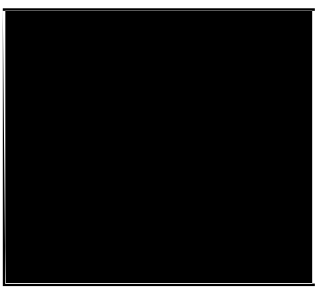
- Photographs can be referred to repeatedly.
- A photograph can focus specifically on some element of STROBE.
- A photograph can supply details that are easily overlooked during personal contact.
- All members of the systems analyst's team for analyzing purposes can use a photograph.

DFD (DATA FLOW DIAGRAM)

Data Flow Diagram (DFD) is a technique which is used to specify how the data flows between the functions of the system. The basic purpose of the diagram is to show how the system is currently implemented. Larry Constantine first developed DFD as a way of expressing system requirements in a graphical form. A DFD is the starting point of the design phase that functionally decomposes the requirement specifications down to the lowest level of detail.

Elements of DFD

A data flow diagram illustrates the flow of data through a system and the work performed by that system. In data flow diagrams, the symbol set comprises diagram, data flow, entity, data store and process.

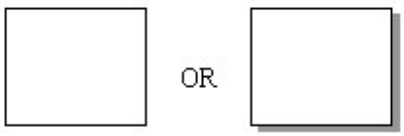
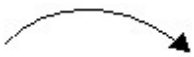
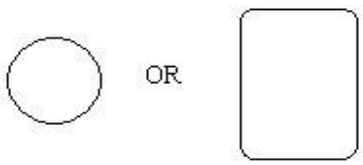
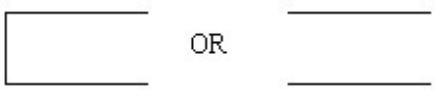


An entity is used to define the boundaries of the system. It is an external component of the system such as a department, a person or a business that interacts with the existing system. It also provides data to the system and receives data from the system. An entity is represented by a rectangle. A process is work or action performed by people, machines, etc. within the system. It is used to transform input of a system into an output. In DFD, process is represented by bubbles. In DFD, data store is used to store data and it is represented by open box. A data flow is any item that carries data to, within or from the system. That is, it is used to represent inputs and outputs of the system. In DFD, flow of data is represented by arrows.

Physical DFD

There are basically two types of DFD, one is called physical DFD and other is known as logical DFD. A physical DFD is an implementation dependent view of the current system, showing what functions are performed. A physical diagram provides details about hardware, software, files and people involved in the implementation of the system. Physical characteristics include name of the people, departments, files, hardware, locations, procedures, forms, documents, etc. Table 2.1 lists the various data flow diagram basic symbols.

Table 2.1 *Basic Symbols for Data Flow Diagrams*

Symbol Name	Symbol	Symbol Meaning	Comments
Square		Source or destination of data	May be one customer or a number of customers with customer orders
Arrow		Data flow	May be physically contained in a purchase order, invoice, etc.
Circle		Process that transforms the data flow	May be an accountant calculating discounts and preparing invoices
Open Rectangle		Data store	Can be a file, magnetic tape, a database on disk, etc.

Logical DFD

Logical DFD is an implementation independent view of a system that focuses only on the flow of data between different processes or activities. Logical diagrams show

how the business operates, not how the system can be implemented. It explains the events of the system and the data required by each event of the system.

Physical DFD differs from the logical DFD in the following ways:

- Physical DFD is implementation dependent whereas logical DFD is implementation independent.
- Physical diagrams in the physical DFDs provide the low level details, such as hardware and software requirements of a system whereas logical diagrams in the logical DFDs explain only the events involved in the system and the data required to implement each event of the system.

Context Diagram

Context diagram helps in understanding the general characteristics of the system under study. It contains a single process and defines the whole system that will be studied. Anything that is not inside the process of the context diagram will not be part of the system study. The inputs and outputs specified at this level remain constant for the other lower levels. Figure 2.1 shows Context Level DFD for Customer Order Processing System.

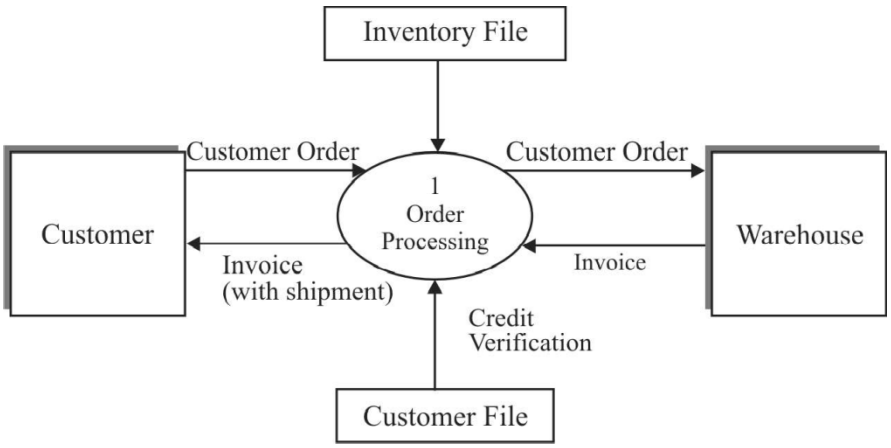


Fig. 2.1 *Context Level DFD for Customer Order Processing System*

Rules to Construct a DFD

Following are the rules that must be followed to construct the DFD of a particular system:

- Each process involved in a system should be named and numbered for easy reference.
- Name of each process should be symbolic.
- The direction of flow of information in a DFD should be from top to bottom and from left to right.
- When a process is divided into several lower level processes, each low-level process should be numbered.
- The names of the data stores, sources and destination should be in capital letters.

Zero Level DFD

Zero level DFD provides more detail than the context diagrams by exploding them. By exploding context diagram processes into subprocesses, the system analyst begins to

fill in the details about the flow of data within the system. Each subprocess in the zero level DFD is numbered with an integer. Generally, this number starts from the upper left corner and proceeds towards the lower right corner of the zero level DFD.

Figure 2.2 shows zero level DFD for Customer Order and Credit Verification System Child Diagram.

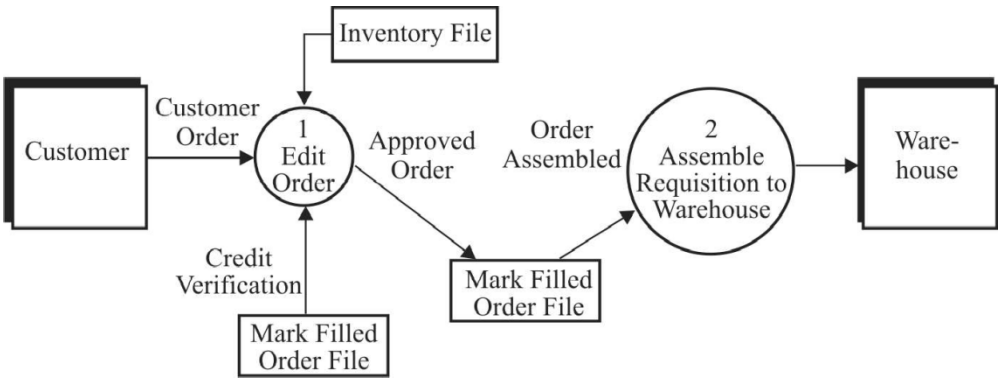


Fig. 2.2 *Zero Level DFD for Customer Order and Credit Verification System Child Diagram*

Each process in zero level DFD may in turn be exploded to create a more detailed child diagram. The process of zero level DFD that is exploded is called the 'parent process' and the resultant diagram is called the 'child diagram'.

The primary rule while creating child diagram is that the child diagram can not receive input or produce output that are not produced or received by its parent process. That means any data that are flowing in or out of the parent process should be shown flowing into or out of the child diagram.

The processes in the child diagram are numbered using the parent process number, a decimal point and a unique number assigned for each child process of the child diagram.

Figure 2.3 shows First Level DFD, Elaborating Customer Order Processing and Shipment System.

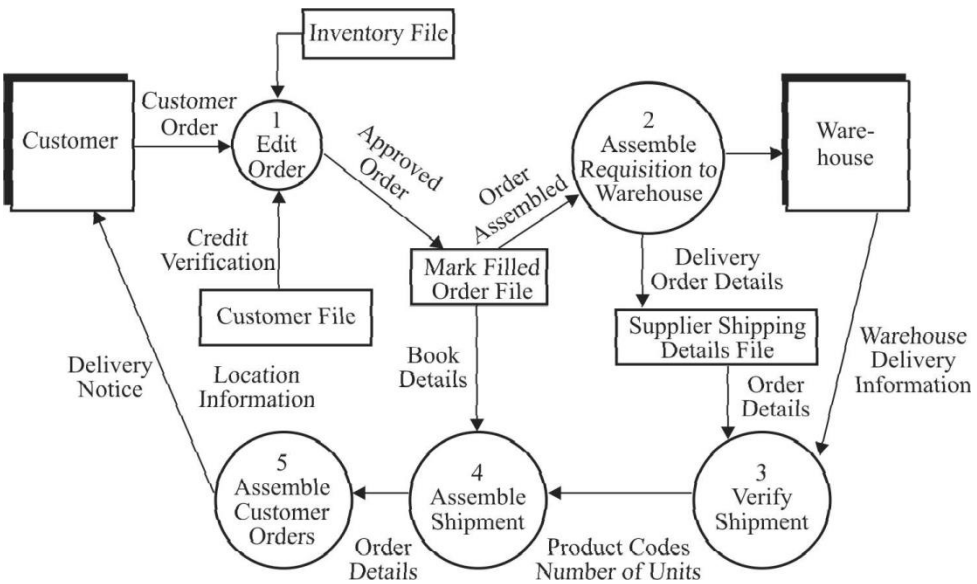


Fig. 2.3 *First Level DFD, Elaborating Customer Order Processing and Shipment System*

FLOW CHART

Flow chart can be defined as a graphical picture of the logical steps and sequence involved in a procedure and programme. Flow chart is basically a graphical representation of an algorithm or process. Algorithm is a set of ordered stepswhich are used to solve a problem. It is designed by a user to make a problem more understandable. In order to solve a problem, a user has to first design an algorithm related to the solution of that problem.

It represents the flow of data from one stage to another stage of solving a problem. In a flow chart, some specific rules or conventions are used to show various blocks of a flow chart. As per standard conventions, some shapes are used to show particular part of a flow chart. For example, a rectangle with rounded edge is used to represent START and END of a flow chart.

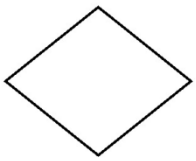
S. No.	Geometry Shapes	Use
1.	 Parallelogram	Input and Output Operations
2.	 Rectangle	Execution Operations
3.	 Diamond	Decision Operation
4.	 Rounded Rectangle	Start and Stop Operation

Fig. 2.4 *Shows Different Geometry Shapes and their use in Flow Chart*

SECURITY AND CONTROL ISSUES IN INFORMATION SYSTEM

The primary concern of an information system is the data stored in computer files that can be easily accessed by a large number of people in the organization and by groups of people outside the organization. Hence, the information system should be able to process any transactions involving data and maintain the data in a secured manner. An organization should use a well-structured life cycle for maintaining security of the information during the transmission of information from one place to another place.

When large amount of data is stored in digital form, it becomes vulnerable to many kinds of threats. As in communication networks, information systems at different locations are interconnected to each other. So the potential for unauthorized access, misuse or fraud is high at any access point in the network.

Why Systems Are Vulnerable

In the multi-tier client or server-computing environment, vulnerability exists at each layer in the communication system. Figure 2.5 illustrates the multi-tier architecture which is one of the most common threats to the information system.

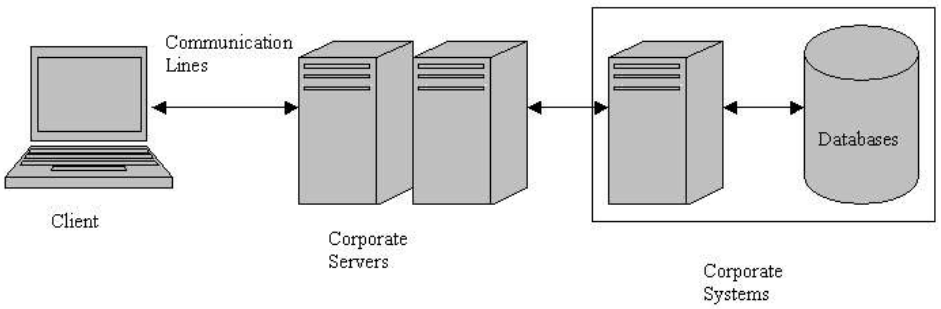


Fig. 2.5 *Multi-tier Architecture*

The figure shows that at the client layer, the users can face some problems due to various causes such as unauthorized access and database errors. At the communication lines, various vulnerabilities such as tapping, sniffing, theft and fraud can occur due to the data flow over the network. At the server layer, various vulnerabilities such as hacking and virus attack can occur due to the interconnection of multiple servers. These servers provide data to the clients and to each other. At the corporate system layer, various vulnerabilities such as copying and alteration of data as well as hardware and software failures can occur due to the connection of database and server.

Concerns for System Builders and Users

Every system builder and the user should be concerned about the destruction of the information systems on which they work. Following are the three concerns which an organization needs to keep in mind for information security:

- **Disasters**: Disaster includes natural calamities such as fire, flood and earthquake that can occur any time.
- **Security**: Security includes policies, procedures and technical measures used to prevent unauthorized access, alteration, theft or physical damage of information systems.
- **Control**: Control consists of all the methods, policies and organizational procedures that ensure the safety of an organization. It also ensures the accuracy and reliability of its records and operations for adhering to management standards.

Hence, many companies create fault-tolerant systems that are used as back-ups to recover any file if the main system goes out.

Internet Hackers

Hackers are those who intentionally cause damage to a computer system. Many companies do not report the attempts of hackers because they do not want people to realize that their computer systems are vulnerable. Some hackers use special computer systems that continuously check for password files which can be copied. The hackers

also look for open ports in a computer so that they can easily break the system security. Sometimes hackers do not do any damage but they often steal data from the computer system for their own use. Hackers attack the computer systems because of some personal or professional reason that encourages them to destroy the data stored in the computer systems. So, password theft is the easiest way for hackers to access the data of a computer system. Hackers generally use written software programmes which can generate multiple passwords that help retrieve the passwords of users and security systems. The hacker can use these passwords to break the security system of an organization. The organization takes utmost care while setting the passwords. The passwords are set using odd combinations of letters and numbers that are not associated with the username. The longer the password, the harder it is to generate a crack for the password.

To spread a virus rapidly through the network, the hackers can copy a file from an infected source and send it to the organization network. In this way, the virus spreads from one computer to another. In March 1999, a virus called Melissa was written by a hacker and sent out through an e-mail attachment. However, the virus did not damage any computer files, but it severely hampered normal operations of many companies and Internet Service Providers. Some sites had to take their mail systems offline.

The end-users should be conscious about virus and hackers while surfing on the Internet from their Personal Computer (PC). Software manufacturers suggest the end-users to install antivirus software to protect their computer against virus attacks. Antivirus software can check the presence of virus in the computer. It checks every incoming file and alerts you when there is an infected file in the computer. The antivirus software also allows you to delete or clean the infected file. This software is updated every 30 to 60 days because new viruses are constantly being written and passed around.

System Quality Problems: Software and Data

Every computer system uses different software to organize the data inside the computer. The performance of the computer also depends on the quality and performance of the software used to organize the data. The quality of software can also affect the performance of the information system. An error in software can create a constant threat to information systems that reduces the quality and productivity of a system. Following are the major problems with information systems:

- Bugs in software
- Maintenance issues
- Data quality problems

Bugs in software

Bugs are the defects in the programme code that are hidden in a software programme. It is virtually impossible to eliminate all the bugs from large programmes, but a number of bugs can be reduced using an efficient testing system. A testing system allows the developers to reduce the number of bugs in the development phase of the software. The main source of bugs arises due to the complexity in the decision making part of the code. It is impossible to identify all the errors within the million lines of code in a programme. There can be a bug in the software when the software manufacturer releases it in the market. After identifying a bug, the software manufacturers also provide free updates and fixes of programme code on their Websites. It is, therefore,

sometimes referred to as a good practice of not buying the original version of software but waiting until other users have found a bug in it.

NOTES

Maintenance issues

Every system requires maintenance to provide optimum results. The information system also needs constant attention of the technical staff of an organization to devote time for maintenance of the information system. To perform the maintenance, you need to consider the organizational changes, and for this you need to identify the changes to be made in the information system that can support the business unit.

Data quality problems

The primary function of an information system is to store the data securely and make a smooth flow of the data between the different departments of an organization. The data should be stored in the original form to maintain its quality. When the data are transferred through different mediums, they become vulnerable to changes. The organization can use different software to check the originality of the data. You can also use the software to recover the original data if there is some change in the data. The quality of an information system can be defined by the security of data present in the information system.

The Control Environment

The various controls of the computer systems are combination of general and application controls. General controls depend on the design, security and use of computer programmes or data files throughout the Information Technology (IT) infrastructure of an organization. Application controls are specific controls such as word processing, payroll or order processing. The application controls consist of those controls which are applied to the business functional area of a particular system and also include the programmed procedures.

General controls

General controls help provide a well-designed infrastructure for an information system. The various types of general controls are:

- **Software controls**: These controls analyse the use of system software and prevent unauthorized access to software programmes. It is an important control because it provides the overall control functions for the programmes which directly process the data or data files.
- **Hardware controls**: These controls ensure that the computer hardware is physically secured against any sort of automatic or manual damage. The computer hardware should be protected against fire, temperature and humidity.
- **Computer operations controls**: These controls analyse the work of the computer department to ensure that programmed procedures are consistently and correctly applied to store and process the data. These also help control over the computer processing jobs, computer operations and backup and recovery procedures for data processing.
- **Data security controls**: These controls monitor the data files which are stored in a hard disk against unauthorized access, change or destruction.
- **Implementation controls**: These controls analyse the information system development process at various points to ensure that the process is properly controlled and managed by the technical department. The information system

development consists of formal reviews of the system which are performed by the users and the management at various stages of development.

- **Administrative controls**: These controls display the standards, rules and procedures which ensure that the general and application controls of an organization are properly executed.

Application controls

Application controls include both automated and manual procedures which ensure that only authorized data are processed completely and accurately by the information system. Application controls can be classified as input, processing and output controls. Input controls check data for accuracy and completeness at the time of input of data into the computer system. There are specific input controls for input authorization, data conversion, data editing and error handling. Processing controls monitor that the data are complete and properly updated by the application during updating process. Output controls ensure that the results of computer processing are accurate, complete and properly distributed. Following are the controls that are used in every type of application controls:

- **Control of total value**: This control is used for both input and processing controls. The total can range from a simple document count to totals for quantity fields, such as total sales amount. Computer programmes count the total controls from transactions input or processed data.
- **Edit checks**: These controls are programmed routines that can be used to edit input data for errors before they are processed. Transactions that do not meet edit criteria are rejected.
- **Computer matching**: It matches input data with the information held on master files. For example, a matching programme can match employee time cards with a payroll file and report for missing or duplicate time cards.
- **Run control totals**: It provides the total number of transactions and processed transactions.
- **Report distribution logs**: It facilitates the distribution of the reports to the authorized recipients. It also allows the checking of critical documents with the reports.

Creating a Control Environment

Protection of resources for information system requires a well-designed set of controls such as software and hardware controls. For creating a control environment in the information system, you need to design a control structure.

Designing a control structure

Information resources require a sophisticated control structure. It has been observed that technology could have protected the system from being hacked or from virus attack. Protection of information requires a well-designed set of controls. Organization needs to know which information need protection and up to what extent before allocating its resources to controls. Here risk assessment is done which is calculating the level of risk involved if a particular activity is carried out or is not properly controlled. Once risk assessment is done, system control builder can focus on the weak and vulnerable points in the system. Risk assessment can not always precisely predict the threats to the system and the impacts of these threats on the system. The outcome of risk

assessment should be the minimum cost and maximum defence. System control builders have an uphill task of determining the correct control for a given system within a given budget. Sometime it is necessary to build strong control structure at each point of the system because system is continuously under the external and internal attack. The combination of all the controls for the system determines the overall level of control.

Security policy is developed after determining the kind and level of risk involved for the system. A security group is created to tackle the issue of educating and training users, making the management aware of security threats and maintaining the security tools. A security policy involves determining the level of information risks, finding out the security goals and achieving these goals. Management have to calculate the cost of securing the entire system using control system. There are following two types of security policies involved in system control:

- **Acceptable use policy (AUP)**: It defines the acceptable use of the information resources and equipment such as desktop and telephones of the firm. This policy deals with the issue of privacy and user responsibility. A detailed AUP must involve the accepted and unaccepted behaviour of each and every user.
- **Authorization policy**: It determines the various levels of access to information for different users. This policy deals with restricting the user to access certain parts of Websites and corporate database.

The role of auditing in the control process

Audits play an important role in assessing the performance of an organization by evaluating the cost of services and the revenues generated by these costs. Every organization conducts comprehensive and systematic audits to access the performance of the services. Audits help identify all the controls that govern individual information systems and access their effectiveness. To accomplish the audit, the auditor must acquire a thorough understanding of operations, physical facilities, telecommunications, security systems, security objectives, organizational structure, personnel, manual procedures and individual applications used in an organization.

The auditor usually interviews key individuals who use and operate a specific information system for their activities and procedures. The auditor should trace the flow of sample transactions through the system and perform tests, using appropriate and automated software. Security audit should review technologies, procedures, documentation, training and personnel to minimize the security risks. A very thorough audit will simulate an attack or disaster to test the response of the technology, information systems staff and the employees of the organization. The audit lists and ranks all control weaknesses and estimates the probability of their occurrence. It then accesses the financial and organizational impact of each security threat.

Protecting the Digital Firm

You can protect a digital firm by using various software such as firewalls and antivirus that help prevent unauthorized access to private networks. Following are the security mechanisms that are used to protect the information in a digital firm:

- Firewall
- Intrusion Detection Systems
- Antivirus Software
- Securing Wireless Networks
- Encryption and Public Key Infrastructure

1. Firewall

Firewall is a security software which is used to prevent unauthorized users from accessing private networks. Firewall software controls the flow of incoming and outgoing network traffic. It is generally placed between the private internal networks of an organization and un-trusted external networks such as the Internet. There are two types of firewalls:

- **Personal firewalls**: It is a software application which filters traffic entering or leaving a computer.
- **Network firewalls**: It is a firewall that filters all traffic entering or leaving the connected networks. Network firewall runs on a dedicated network device or computer positioned on the boundary of two or more networks.

The firewall acts as a gatekeeper that examines the identity of each user in a network. It identifies names, Internet Protocol addresses, applications and other characteristics of incoming traffic. It checks this information against the access rules that are programmed into the system by the network administrator. It prevents unauthorized communication into and out of the network, allowing the organization to enforce a security policy on traffic flowing between its network and the Internet. In large organizations, the firewall often resides on a computer which is dedicated for this work.

Following are the types of firewall screening technologies that are used with the firewall to provide firewall protection:

- Packet Filtering
- Network Address Translation (NAT)
- Application Proxy Filtering

(a) Packet filtering

The data, which are transmitted over a network, are divided into packets of specific size. The size and structure of the data packets are determined by the underlying communication protocol which is being used by the communicating networks. Each data packet is divided into two parts, packet header and data part. The packet header contains the information regarding the host network and the destination network. The data part of the packet contains the data which are needed to be transmitted from one computer to another. The packet filtering screening technology examines the selected fields in the headers of data packets flowing back and forth between the trusted network and the Internet. This filtering technology can save the computer from many types of attacks. The stateful inspection of data packets provides additional security by determining whether or not a packet is a part of an ongoing communication between a sender and a receiver. It helps set the state tables to track information over multiple packets. The packets can be accepted and rejected based on whether they are part of an approved conversation to establish a legitimate connection.

Packet filters are host-based or appliance-based applications which block or allow network traffic based on a set of rules defined by the network administrator. The packet filters which are used commonly on various versions of UNIX are ipf, ipfw (FreeBSD), pf (OpenBSD), iptables (Linux) and ipchains (Linux).

The administrator starts the packet filtering process on the network device and composes the set of rules which are applied to the incoming network traffic. The network traffic can be permitted or denied to enter or leave the organization network on the basis of these rules.

Modern packet filters can filter network traffic based on many packet attributes like source IP, source port, destination IP or port, destination service like WWW or FTP. They can filter the traffic on the basis of protocols, TTL values, netblock of originator, domain name of the source and many other attributes.

(b) Network address translation (NAT)

It allows a local area network to use one IP address for internal addresses and another IP address for outside public addresses. It can provide another layer of protection when static packet filtering and stateful inspection are employed in the local network. NAT uses the IP addresses of the host computer of the organization to prevent sniffer programmes outside the firewall from accessing the internal network. A sniffer programme is network-monitoring programme that can be used for both unauthorized and authorized network management functions.

Before NAT, the network administrators used to face difficulty in reserving the IP addresses for a particular computer system or task. NAT provided a way to deal with the Ipv4 address shortages. NAT allows the networks which require a Class B IP range or a block of Class C network addresses to connect to the Internet with single IP address. To implement NAT, you need the computer systems which require true bi-directional and seamless connectivity supplied with a real IP address. It also allows you to use the computer systems that do not provide services to outside users which are kept away behind NAT with only a few IP addresses used to enable Internet access.

In addition to the convenience and low cost of NAT, the lack of full bi-directional connectivity can be regarded in some situations as a feature rather than a limitation. NAT helps prevent malicious activity initiated by outside hosts from reaching those local hosts. This can enhance the reliability of local systems by stopping worms and enhance privacy by discouraging scans.

(c) Application proxy filtering

It examines the application content of IP data packets. It uses a proxy server to stop the data packets entering into the organization's private network that are originated outside the organization. It passes a proxy to the other side of the firewall to communicate with the outside world. If a user outside the organization wants to communicate with a user inside the organization, the outside user first talks to the proxy application and the proxy application communicates with the internal computer of the firm. Similarly a computer user inside the organization goes through the proxy to talk with computers which are outside the organization network.

There is one more type of firewall, called application proxy firewall. In a proxy firewall, every packet is stopped and checked by the firewall before entering and leaving the organization network. The packet is then examined and compared to the rules which are configured into the firewall by the network administrator. To go out of the organization network, the packet needs to pass the firewall examinations. If a packet passes the firewall examination, it is re-created and allowed to send out of the organization network. The distortion and re-creation of every packet allows the application proxy firewall to prevent unknown attacks. These unknown attacks can prove harmful to the organization network because of the loopholes in the TCP/IP protocol suit. These attacks are not easily prevented by the packet filtering firewall. To implement application proxy firewall, you need a separate application proxy for each application. For this, you require an HTTP proxy to control the Web traffic, an FTP proxy for file transfers and a Gopher proxy for Gopher traffic.

Application proxy firewalls operate on Layer 7 of the OSI model which is called Application Layer.

Every firewall system on a network uses an application gateway which is also known as application proxy or application-level proxy. In order to make a connection to a destination service, the client programme first needs to connect to an application gateway or proxy. After establishing a connection with the application gateway or proxy, a client can negotiate with the proxy server to communicate with the destination service. The proxy acts on behalf of the client, hides and protects the computers behind the firewall and establishes the connection with the destination behind the firewall. The proxy creates two connections: first between the client and the proxy server and second between the proxy server and the destination service. After connecting, the proxy makes all packet-forwarding decisions. As all communication passes through the proxy server, it protects the computers which are behind the firewall.

2. Intrusion Detection Systems

An intrusion is an entry to the prohibited area by a software programme. An intrusion detection system detects such unauthorized access into the computer by the software programmes, mainly from the Internet. The commercial security vendors provide intrusion detection tools and services to protect against unauthorized network traffic and attempts to access files and databases by unauthorized computer programmes from the Internet. This system provides a full-time monitoring tool placed at the most vulnerable points of corporate networks to detect intruders continually. If an intrusion is detected, this system generates an alarm to alert the network administrator. It also uses the scanning software which looks for patterns indicative of known methods of computer attacks such as wrong passwords. It also checks to see if important files have been removed or modified and sends warnings of vandalism or system administration errors. The network administrators can also use the intrusion detection tools in a customized manner to shut down a particularly sensitive part of a network, if it receives unauthorized access.

3. Antivirus Software

Antivirus software consists of computer programmes which help identify and eliminate computer viruses and other malicious software from a computer. Antivirus software uses two different techniques to accomplish this task:

- Scanning of files to look for signatures of virus matching in an available virus dictionary.
- Identifying the behavior of any computer programme which indicates the presence of virus. This analysis may include identification of data captures and port monitoring.

When the antivirus software examines a file, it refers to a dictionary of known viruses that the authors of the antivirus software have identified. If a piece of code in the file matches any virus identified in the dictionary, then the antivirus software can take one of the following actions:

- Attempts to repair the file by removing the virus from the file.
- Restricts the file in a way such that it remains inaccessible to other programmes and its virus can no longer spread.
- Deletes the infected file.

However, most antivirus software is effective only against viruses already known when the software was written. The antivirus software must be continually updated for maintaining their effectiveness. Dictionary-based antivirus software examines files when the operating system of a computer creates, opens, closes or e-mails them. In this way, it can detect a known virus immediately upon receipt. Although the dictionary approach can effectively restrict virus outbreaks in the right circumstances, virus authors have tried to stay a step ahead of such software by writing oligomorphic, polymorphic and more recently metamorphic viruses.

4. Securing Wireless Networks

These networks provide Wi-Fi Protected Access (WPA) specification to the vendors of Wi-Fi equipment. This specification can also work with future wireless LAN products and can update the equipment. WPA improves data encryption by replacing the static encryption keys that are harder to crack. WPA provides a mechanism based on the Extensible Authentication Protocol (EAP) that works with a central authentication server to authenticate each user on the network before the user can join it.

5. Encryption and Public Key Infrastructure

Encryption is the coding and scrambling of messages to prevent unauthorized access to the data. Applying a secret numerical code, called encryption key so that the data can be transmitted as a scrambled set of characters, can encrypt a message. To read the encrypted data, it can be decrypted with a matching key. There are several methods of encryption, but public key encryption is the most popular encryption method.

The public keys are mathematically related to each other so that the data which are encrypted with one key can be decrypted using only the other key. Communicators first create separate pairs of private and public keys to send and receive message. The public key is kept in a directory and the private key is kept secretly. The sender encrypts a message with the public key of the recipient. On receiving the message, the recipient uses the private key to decrypt it.

Ensuring the System Quality

A system quality can be defined as the performance of software quality assurance techniques which help improve the quality of data used in the information management system. The quality of the system depends on the methodologies and the tools used to maintain the quality of the software which is used to maintain the management information system in an organization. To ensure the system quality, you also need to analyze the security vulnerabilities, data quality audits and data cleansing.

Software Quality Assurance Methodologies

To maintain the quality standards for software, you need to perform various tasks such as using a suitable systems development methodology and ensuring optimum utilization of available resources to handle different software quality problems. Following are the methods to handle software problems:

- Structured methodologies
- Structured analysis
- Structured design
- Structured programming

Structured Methodologies

In structured methodologies, structured refers to the approach which is carefully employed in a step-by-step manner and methodologies are the process-oriented methods. So structured methodologies is a collection of methods used to develop, analyze, design and implement any document in an information system. Its primary function is to provide a proper sequence to the entire development process.

Structured Analysis

Structured analysis provides a logical graphic model of information which depends on the information flow in a system. The components of a system are divided into modules by using a Data Flow Diagram (DFD). DFD is a graphical representation of the components of a system and shows the flow of different processes of the system. Every process contains some information regarding the functioning of the system.

Structured Design

Structured design provides a set of design rules and techniques used to provide clarity and simplicity to a programme. Structured design helps reduce the time and effort required for coding, debugging and maintenance of a programme. In structured design, each level is defined in a proper way and the lowest level describes the actual processing that occurs at the design time. In this design, a top-down structure chart is created which shows each level of design, the relationships with other levels and its place in the overall design structure.

Structured Programming

Structured programming follows a structured design to write software programmes which are easy to write, understand and modify. Structured programming defines the control paths that can be easily understood and modified. These programming structures include only one entry point and one exit point. Following are the three basic constructs which are used to create a structured programme in a system:

- Sequence
- Selection
- Iteration

A structured programming consists of a number of logical units called modules which performs one or more operations in a programme. Modules are represented as boxes in a structured programme. A sequence construct executes statements in the order in which they appear, one by one, with controls passing unconditionally from one statement to the next. For example, a programme executes Statement A, then Statement B and then Statement C and passes the control to the calling statement. A selection construct is a logic pattern in programming where the stated condition determines which of the two alternative instructions can be chosen. For example, in a programme, if C is true, then statement D is executed. If C is false, then statement F is executed. Iteration construct is a logic pattern where actions are repeated until conditions are met. For example, in a programme, if E is true, statement F is executed and control returns to E. If E is false, E is skipped and the control passes to the next statement.

Software Quality Assurance Tools

A system uses a number of techniques for the analysis and design of a software programme. The design phase of a software programme can be implemented by

using the standard language called Unified Modelling Language (UML). It allows developers to represent various views using various types of graphical diagrams and various models to integrate these views during analysis, design and implementation of a software programme. Following are the various tools which can be used to develop a software programme:

- Computer-Aided Software Engineering
- Software Matrices
- Testing

Computer-Aided Software Engineering (CASE)

Computer-aided software engineering helps automate the task involved in the development of different software systems. This helps in minimizing the amount of rework which is done by the developer to add functionality in an existing software programme. CASE provides automated graphics facilities for creating charts and diagrams, screen and report generators, data dictionaries, extensive reporting facilities, analysis and checking tools, code and documentation generators. CASE provides various tools to increase the productivity and quality of software by using the following techniques:

- Implement a standard development methodology and a design discipline
- Improve communication between users and technical staff
- Organize and connect design components and provide rapid access to them
- Automate check error-prone portions of analysis and design phase of a system
- Automate check code generation, testing and control in a system

Software Matrices

Software matrices allow the information systems department and the users to jointly measure the performance of the system and identify problems as they occur.

Testing

Testing begins at the design phase to test a specific design document by a small group of people. In the testing period, when errors are found in the source code at the coding time, then these errors are eliminated at the debugging time.

Analysing Security Vulnerabilities

Security vulnerabilities refer to the weakness in a system that allows the hacker to break up the integrity, access control, availability and consistency of the system data or applications. Vulnerabilities are found as bugs in the system. Vulnerabilities have some significant features such as the programme performing authentication task or providing easy access to the user data. The examples of security vulnerabilities are:

- Stack Smashing
- Symlink Races
- Input Validation Errors
- Time-of-Check-to-Time-of-Use Race Conditions
- Session Hijacking

Stack Smashing

It refers to various techniques for detecting buffer overflows on stack-allocated variables as they occur and preventing them from becoming serious security vulnerabilities.

Symlink Races

A symlink race is a kind of software security vulnerability that creates files in an insecure manner. So a malicious user can create a symbolic link to a file. When the privileged programme creates a file of the same name, then Symlink race creates the link to that file and checks to see if a file by the same name already exists; then it creates a new file.

Input Validation Errors

It is the process of ensuring that a programme operates on clean, correct and useful data. It uses routines that check for correctness or meaningfulness of data which is provided as input to the system. The data validation verifies that the characters provided come from a valid set of characters. For example, telephone numbers should include the digits and possibly the characters +, " and the parentheses. A more sophisticated data validation routine would check to see that the user has entered a valid country code; the number of digits entered matches the convention for the country or area specified. Incorrect data validation can lead to data corruption or security vulnerability.

Time-of-Check-to-Time-of-Use Race Conditions

A time-of-check-to-time-of-use bug is a software bug which is caused due to changes in a system between the condition of checking and the results of that check. For example, a Web application allows a user to edit pages, but also allows administrators to lock pages to prevent editing. In such a situation, a user request for edit can provide a form for altering the contents of the form. However, the administrator can lock the page before the user submits the form preventing the user to further edit the form. Here the user is authorized to edit before the administrator locks the form while he becomes an unauthorized user immediately after the administrator locks the form.

Session Hijacking

Some vulnerability arises from ambiguous user inputexecut command. Vulnerability can also arise when the programmer fails to check the size of data buffers which can then be overflowed causing corruption of the stack or heap areas of memory,

Data Quality Audits and Data Cleansing

Identifying and correcting the faulty data can improve information system quality. The analysis of data begins with a data quality audit which provides a structured survey to check the accuracy and level of completeness of the data in an information system. Data quality audits are accomplished by:

- Surveying end-users for their perception about quality of data
- Surveying entire data files
- Surveying samples from data files

Regular data audits allow an organization to know the extent of inaccurate, incomplete or ambiguous information contained in the information system. Data cleansing has become a core requirement for data warehousing, customer relationship management

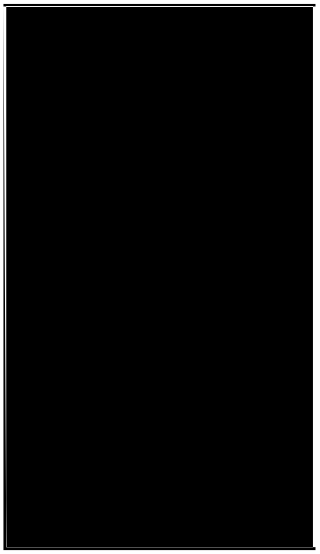
and Web-based business. It corrects errors and inconsistencies in data to increase accuracy so that the data can follow the company standards.

Data quality problems are caused by redundant and inconsistent data produced by an organization. During the system design, data describing entities such as system name and password should be named and defined consistently for all business areas. Most data quality problems such as misspelled names, transposed numbers or incorrect or missing codes occur during data input. This type of problem arises in a company when they move their business to the Web and allow customers and suppliers to interact directly through the internal system of the company. Analysis of data quality often begins with a data quality audit which is a structured survey of the accuracy and level of completeness of the data in an organization. Audits can be performed by surveying the entire data files to investigate the quality of data.

Data cleansing also known as data scrubbing consists of the activities of detecting and correcting data in a file that is incorrect or redundant. Data cleansing not only corrects data but also enforces consistency among different sets of data in a firm. Specialized data cleansing software can automatically check data files, correct errors in the data and integrate the data in a consistent company-wide format.

SUMMARY

- SDLC includes various steps to develop an effective information system in the organization. It is responsible to identify problems and opportunities of the organization.
- SDLC also includes steps for documenting, testing and maintaining the system. All the processes in various stages of SDLC are responsible for ensuring security of the information.
- The phases of SDLC include: requirement analysis, software design, coding, testing and implementing and evaluating.
- Fact-finding analysis is a process of ensuring that the information gathered is the actual required information. The various types of fact-finding technique are: review of literature, procedures and forms and on-site observations.
- Data flow Diagram (DFD) is a technique which is used to specify how the data flows between the functions of the system. There are two types of DFD: physical DFD and logical DFD.
- Flow chart can be defined as a graphical picture of the logical steps and sequence involved in a procedure and programme.
- The three concerns which an organization needs to keep in mind for information security are: disasters, security and control.
- Hackers are whose who intentionally cause damage to a computer system. Hackers attack the computer systems because of some personal or professional reason that encourages them to destroy the data stored in the computer systems.
- An error in software can create a constant threat to information systems that reduces the quality and productivity of a system. The major problems with information systems are: bugs in software, maintenance issues and data quality problems.
- The various controls of the computer systems are combination of general and application controls. General controls depend on the design, security and use of computer programmes or data files throughout the Information Technology (IT) infrastructure of an organization. Application controls are specific controls such



as word processing, payroll or order processing. The application controls consist of those controls which are applied to the business functional area of a particular system and also include the programmed procedures.

- Protection of resources for information system requires a well-designed set of controls such as software and hardware controls. For creating a control environment in the information system, you need to design a control structure.
- There are various software through which unauthorized access to private networks can be prevented: firewall, intrusion detection systems, antivirus software, securing wireless networks and encryption and public key infrastructure.
- A systems quality can be defined as the performance of software quality assurance techniques which help improve the quality of data used in the information management system. These methods can be divided as structured methodologies, structured analysis, structured design and structured programming.
- Computer-aided software engineering, software matrices and testing are the types of tools which can be used to develop a software programme.
- In an organization, the information system becomes vulnerable when the information is transferred from one computer to another computer over a network in a secured way.
- The examples of security vulnerabilities are: stack smashing, symlink races, input validation errors, time-of-check-to-time-of-use race conditions and session hijacking.

KEY TERMS

- **SDLC:** System Development Life Cycle is a set of activities carried out by the systems analysts and system designers to develop an information system.
- **Fact Finding Technique:** It refers to a process of ensuring that the information gathered is the actual required information.
- **Data Flow Diagram:** It is a technique which is used to specify how the data flows between the functions of the system.
- **Flow Chart:** It is a graphical picture of the logical steps and sequence involved in a procedure and programme.
- **Security Vulnerabilities:** It refers to the weakness in a system that allows the hacker to break up the integrity, access control, available and consistency of the system data or applications.

ANSWERS TO 'CHECK YOUR PROGRESS'

1. Coding is the phase of SDLC which fulfils the purpose of implementing modules in an optimized manner.
2. Vendors, systems and analysts, external paid trainer, in-house trainers and other system users are the different sources for information system training.
3. Actualization utility is a type of utility for evaluation which involves how the information is introduced and used by the decision maker.
4. Manuals are the qualitative documents pertaining to the working area of any system.

5. Unobtrusive observation is a type of on-site observation method which takes place without the knowledge of the respondent.
6. The two disadvantages of event sampling are:
   - It is a time-consuming process.
   - It does not provide the descriptive sample of frequent decisions.
7. Process is the element which is represented through bubbles in the DFD.
8. Logical DFD is the type of DFD which is implementation independent.
9. Child diagram is the resultant diagram which comes forth while exploding a zero level DFD.
10. A diamond geometrical shape in a flow chart represents a decision operation.
11. At the corporate system layer, various vulnerabilities can occur such as copying and alteration of data as well as hardware and software failures due to the connection of database and server.
12. Bugs in software, maintenance issues and data quality problems are the major quality problems with information systems.
13. Data security controls are general controls which monitor the data files which are stored in a hard disk against unauthorized access, change or destruction.
14. NAT is the type of firewall which provides a way to deal with the Ipv4 address shortages.
15. Symlink race is a kind of software security vulnerability that creates files in an insecure manner.

EXERCISES AND QUESTIONS

Short-Answer Questions

1. List various steps involved in SDLC.
2. What do you understand by training and evaluation steps of SDLC?
3. Mention the five strategies for converting the old information system into the new one.
4. What is a personal firewall?
5. What do you understand by system analysis?
6. Explain various types of DFD's.
7. What do you mean by flow chart? Explain with a suitable example.

Long-Answer Questions

1. Explain different steps involved in SDLC.
2. Explain packet filtering.
3. Discuss the working of an intrusion detection system.
4. Explain the different quality problems associated with an information system.
5. Explain the controls that are need to protect the resources for an information system.
6. What are the methods for handling software problems? Explain briefly.
7. What do you understand by fact-finding technique?
8. List various methods used in on-site observation.

9. Write short notes on following topics:
   - Zero level DFD
   - Context diagram
   - Policy handbook
10. Explain the different security vulnerabilities.

FURTHER READING

Goyal, D.P. 2006. *Management Information Systems – Managerial Perspectives*. Noida: Vikas Publishing.

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UNIT-3 INFORMATION SYSTEM IN BUSINESS

Structure

INTRODUCTION

The most commonly used information systems that are helpful in the execution of various business activities are functional system, production system, decision support system, executive support system and human resource information system. Decision-making process is the core of managerial functions in MIS. It is a process in which one option is selected from two or more options with the intention of finding the best result with the least unwanted consequences.

Decision is thus, the final product of decision making. Decision-making includes various processes that can be used for setting short-term and long-term goals, solving business problems, finding appropriate solution and calculating risk involved with each option. A decision maker, who is an official at the managerial post in an organization, carries out the decision-making process. Decision-making process involves three phases: intelligence, design and choice.

In this unit, the various information systems have been explained in detail. The importance of MIS in decision-making has also been analysed.

UNIT OBJECTIVES

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

- Discuss different areas of business in which information system is used
- Explain different support systems which are used to perform important tasks in business
- Define the concept of decision-making and the Simon's model of decision-making
- List the various types of processes for carrying out decision-making
- Describe the concept of utility, decision tree and optimization techniques
- Differentiate between decision-making and Management Information System (MIS)

INFORMATION SYSTEM IN DIFFERENT AREAS OF BUSINESS

Information system deals with the functional areas of the business. The business activities are grouped on the basis of functions such as production and finance performed

by a specific department of a business organization. These departments are commonly termed as the functional areas of the business. These functional areas have unique information needs and require information system support that is specifically designed for a particular functional area.

In addition, MIS is an integration of information systems that are designed to support the functional subsystems of the business. Each subsystem requires applications to process all the information related to a particular functional area. Initially, it should be noted that each functional subsystem contains applications for transaction processing and strategic planning. Secondly, different functional systems should be considered dependent on each other. It is so because all functional systems are the part of the organizational system and interact with other subsystems with the help of information. Lastly, it should be considered that there is no standard classification of such subsystems in an organization. Amanufacturing organization includes the following set of functions:

- Production
- Marketing
- Finance and accounting
- Materials
- Personnel systems
- Logistics
- Information processing

Information systems that are developed around the functional areas of a business organization are known as functional information systems. Various types of functional systems include:

- Financial Information System
- Marketing Information System
- Production/Manufacturing Information System
- Human Resource Information System
- Decision Support System
- Group Decision Support System
- Executive Support System

Marketing Information System

The term 'marketing' is a broad term and includes many functions. All activities that are necessary to direct and facilitate the production and usage of goods and services for a society are included in marketing. Marketing information system provides information about various functions of the marketing system of an organization. Marketing is another functional area of a business organization that is engaged in marketing or selling the organizational products to the customers.

In the words of professor Philip Kotler, marketing information system is defined as 'A social and managerial process by which individuals and groups obtain what they need and want through creating, offering and exchanging products of value with others.'

The concept of marketing has assumed a great importance in every field, irrespective of the degree of industrialization. The concept of modern marketing is

that it focuses its attention on the customers. The organization earns profits after satisfying the needs and requirements of the customer. In addition, it achieves profits through an integrated and corporate-wide set of marketing activities.

Marketing not only includes the activities like selling, advertising or distribution of products but also involves the interaction of several business activities. The objective of these activities is the satisfaction of the needs and desires of the customers. Thus, in this approach, before the production of the product, marketing comes into focus. It means the needs and desires of the customers are understood and then the product is designed as per the preferences of the customers. Contrary to this concept, in traditional practice of marketing, the existing products are launched into the market after implementing aggressive selling and promotional pressures.

Various important marketing functions are as follows:

- **Marketing identification**: It means that the determination of the potential buyers and their characteristic is important in order to satisfy the needs and desires of the customers. This enables the wholesaler or the retailer to know:
  - Where the buyers are located?
  - When do they buy?
  - How frequently do they buy?
  - What quantity do they buy?
- **Purchase motivation**: It refers to the assessment of various social, economic and psychological forces that influence the purchase behaviour of the market.
- **Product adjustment**: It includes all such activities that are necessary to match the product and services offered in the market. As the needs and desires of customer keeps on changing, an equivalent adjustment is required in terms of product planning.
- **Physical distribution**: It refers to the actual movement of goods from points of production to points of consumption. The function involves decisions regarding optimum integration of transportation, warehousing and merchandising economics.
- **Communication**: It refers to the communication of information and messages between buyers and sellers. This function includes decisions about activities such as personal selling and sales promotion.
- **Transaction**: It refers to the inclusion of activities such as invoicing and billing that are needed to facilitate the transfer of title of ownership of goods or services between the parties involved in a transaction.
- **Post-transaction**: It refers to the feedback about the performance of the product or service that is obtained from the customer, so that quality product or service may be assured for the satisfaction of the customer.

To carry out the mentioned marketing functions, the marketing manager needs timely, accurate and relevant information to take an array of decisions. Thus, every organization needs to organize the flow of marketing information to its marketing managers. This marketing information is developed with the help of internal company records, marketing intelligence activities, marketing research and marketing decision support analysis. Figure 3.1 shows the concept of marketing information system.

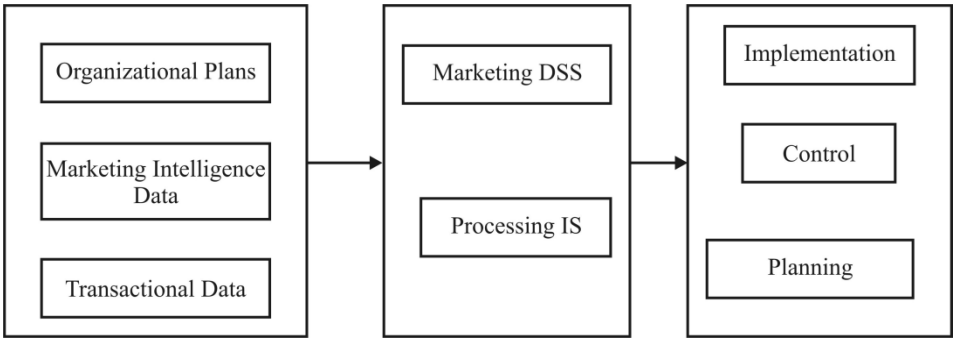


***Fig. 3.1** Marketing Information System*

Various options used in marketing information system are as follows:

- **Transaction**: It specifies that the reports on orders, sales, prices, inventory levels and receivables are obtained from the internal records of the organization. The analysis of this information helps marketing managers in identifying the important opportunities and problems. Sometimes, marketing managers need focused studies of specific problems and opportunities for which they collect marketing research data. Such research data could be gathered through marketing survey, a product-preference test, a sales forecast by region or an advertising-effectiveness study.
- **Marketing intelligence**: It specifies the relevant developments in the marketing environment. The marketing intelligence type of data can be collected by reading books, newspapers and trade publications, and by talking to customers, suppliers and distributors.

To arrive at marketing decisions, a marketing manager needs information on different aspects of marketing. The marketing information systems consist of statistical techniques and decision models that assist marketing managers in carrying out better analyses and decisions. Marketing information system, after collecting various types of data, processes the data and distributes the processed data and information to the marketing managers for further decision-making process.

Human Resource Information System

Human resource information system supports the functions of human resource management of an organization. The human resource management function is also known as personnel management. Human resource information system also deals with employee compensation, wages, salary administration, labour relations and employee services and benefits.

Various options used in human resource information system are as follows:

- **Transaction**: It is the basis for various types of output information or analysis. These data include employee number, name, qualification, experience and joining date of the employee. They also include the categories and grades of posting and daily performance of the employees.
- **Environmental**: It includes data about the availability of personnel, trends in the labour force, competition, market offerings to the employees, government and labour laws. The human resource information system

gathers environmental data from journals, news items, research studies, seminars and informal talks by the managers.

- **Organizational Plans**: It provides an important input data to the human resource information system. On the basis of these data, future planning for recruitment and job assignment is done. The human resource information system processes all these types of data to convert it into information which supports decision-making of human resource managers.

Various important functions of the human resource management are as follows:

- **Manpower planning**: It involves taking decisions about the present and future manpower needs in an organization.
- **Staffing**: It involves recruitment, selection and placement of employees in an organization. It also involves the development of new sources and the need for attracting a large number of potential applicants. The recruitment process is followed by selecting the right person from the large number of potential candidates. The selection process involves development of application blanks, valid and reliable tests, interview techniques, employee referral systems and evaluation and selection of personnel in terms of job specifications.
- **Training and development**: It involves training and development of the employees to bridge the gap between the job requirements and competence or ability of an employee. It also develops lower level managers to assume higher level responsibilities. It is a continuous activity that includes the following tasks:
  - o Identification of training and development needs of personnel at all levels.
  - o Development of suitable training and employee development programmes.
- **Performance evaluation**: It involves evaluating the performance of an employee at work in terms of pre-determined standards and norms. Evaluation or performance appraisal includes the formulation of performance appraisal plans, development of appraisal techniques and programmes.
- **Separation activities**: It involves promoting employee-employer relations that may come to an end due to the resignation of an employee, lay-off, death or retirement. Separation activities also analyzes the causes for increased labour turnover in an organization.

Note: *Human resource management is also responsible for the wages and salary administration, sustaining and maintaining the workforce in an organization and maintaining healthy and peaceful labour-management relations.*

Financial Information System

A financial information system is defined as a subsystem of the organizational management information system that supports the decision-making process of financial functions at the organizational levels. The financial decisions of an organization need to answer the following questions:

- Where to invest funds and to what extent?
- Where to raise funds and to what amount?
- How much to pay as dividends in case of a public company?

A brief description of each of the financial decisions that a financial manager needs to take is as follows:

- **Capital budgeting**: Allocates the funds for long-term assets that yield benefits/ returns in the future. For example, funds allocated for land, building and machinery. It should be noticed that before investing in the long-term assets, the financial manager should evaluate the prospective profitability of the new investment.
- **Financing**: Refers to when, where and how to acquire funds to meet the investment needs of the organization. The financial manager needs to decide about the proportion of equity and debt capital. In addition, he needs to determine the areas where the use of debt capital affects the return and poses a risk to shareholders. The return on equity may increase, but so will the risk. So, there needs to be a proper balance between the return and the risk.
- **Dividend**: Relates to the dividend policy of the organization. A decision whether the organization should distribute all profits or retain them or distribute a portion and retain the balance is taken by the financial managers.
- **Current asset management**: Refers to the management of current assets of the organization in order to safeguard the organization against illiquidity. Illiquidity refers to the situation when someone does not posses cash. Investment in current assets affects the profitability, liquidity and risk of an organization. If the sufficient funds are not invested in current assets, the organization may become illiquid. But the organization would lose profitability if idle current assets would not earn any profits. Thus, a suitable trade-off needs to be achieved between profitability and liquidity.
- In addition to the mentioned managerial functions, other functions of financial systems are summarized as follows:
- Controlling the receipt and payments
- Maintaining statutory records
- Preparing periodic reports for statistics, performance and results for internal control and audit.

Financial information systems also include accounting systems as these systems are concerned with recording the business transactions. Such transactions include wages, salaries and all other types of income and expenditure related to an organization. The records of these transactions become the basis for preparing periodic or annual profit and loss accounts, balance sheets, etc. in the organization.

Accurate and precise financial information system needs to be supplied to the financial manager in order to perform the above activities and functions. These systems involve large amounts of data which are concerned primarily with historical and internal information.

Financial information systems are computerized:

- To provide information and analytical support to financial managers to aid them in their decision-making.
- To improve the speed and accuracy of reporting.

Figure 3.2 shows a financial information system.

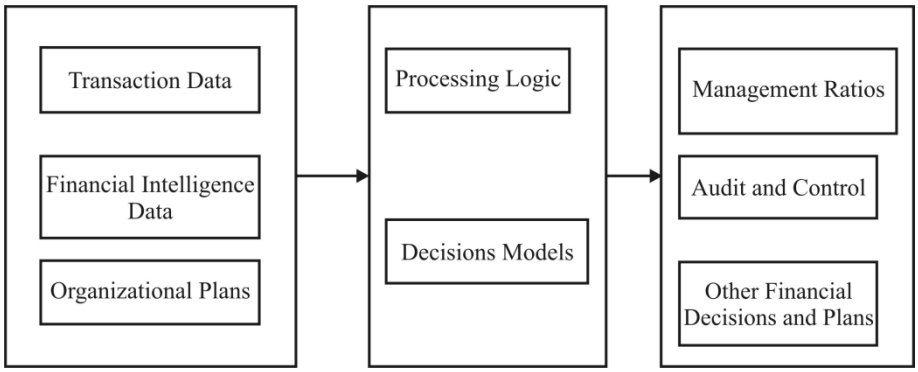


Fig. 3.2 *Financial Information System*

Various terms used in the above figure are explained as follows:

- **Transactional data**: It includes credit applications and payment vouchers and these data are the basis of any type of organizational analysis.
- **Financial intelligence data**: These are collected from banks and stock markets and processed to determine their impact on the economy of the organization.
- **Organizational plan**: It depicts the objectives of the organization. The organizational plan needs to be reflected in the output of the financial information system which may be in the form of financial plans.

Software packages on financial accounting such as Tally and BMS that provide complete information on the financial accounting are available in the market. The financial planning software packages namely IFPS are used for managerial decision making at higher levels.

Production/Manufacturing Information System

Manufacturing is another important functional area of an organization that is engaged in producing goods from raw materials. It should be considered that manufacturing is not an activity for every organization that deals in selling of goods. Some of the organizations can only be involved in the trading business. Trading of goods means buying goods from one organization and selling it to the customers. Such organizations that deal in trading of goods are also called merchandising organizations. A production or manufacturing information system provides information on the production or operation activities of an organization and facilitates the decision-making process for the production managers of the organization.

Production management is an area that deals with decision making related to the production process so that the resulting goods and services are produced in accordance with the quantitative specifications and demand schedule with the minimum cost.

Figure 3.3 shows the manufacturing information system.

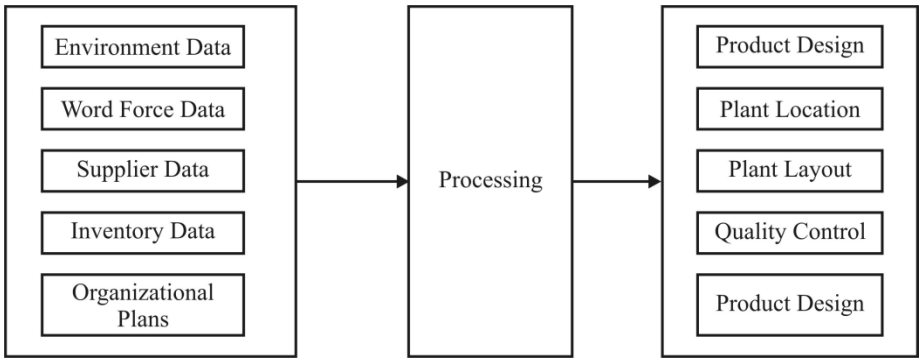


***Fig. 3.3** Manufacturing Information System*

The main decisions to be taken in the manufacturing system are related to the following areas:

- **Product design**: It includes the development of entire product through all initial stages until actual manufacturing starts. It also includes activities such as preparation of drawings and developmental efforts involved in the product design. Nowadays, Computer Aided Design (CAD) and Computer Aided Engineering (CAE) approaches are used in designing products.
- **Plant location**: It determines how an organization is established at a particular place. Plant location is a continuous process as there is always scope for making improvements over the existing design. However, it must be kept in mind that the decision of plant location is dynamic in nature and thus, location study needs continuous monitoring.
- **Plant layout**: It involves arranging machines, equipment and other services within a pre-designed building to ensure steady, smooth and economical flow of material. Similar to the plant location, plant layout is also a continuous process that provides scope for making improvements over the existing design. Plant layout designs can be prepared using mathematical and simulation models that are created with the help of computers. The plant layout software can be used to establish a new plant or improve an already existing one.
- **Production planning**: It is responsible for planning, directing and controlling the material supply and other production processing activities.

The task of production planning is accomplished by using the following options:

  - **Routing**: Determines the path or route over which each piece of raw material needs to travel during the transformation of raw materials into the finished product.
  - **Scheduling**: Decides the time for carrying out each operation in a production process.
  - **Loading**: Provides information about whether the workload is greater or lesser than the capacity of the equipment. It also helps determine the situation when a particular equipment or machine will be available for work on each order or item.

- **Production control**: It regulates an orderly flow of material and coordinates various production operations. The production control activity is carried out in order to ensure that the desired items are produced in the right quantity with the desired quality at the required time and at the optimum cost.

- **Quality control**: It refers to the activities that ensure that the finished product confirms to the standard specifications laid down either by the manufacturer or the customer. Various techniques that are used in controlling the quality of a product include inspection, statistical quality control and control charts.
- **Workforce**: It includes data about the labour market and performance of workers. The workforce data are essential for production scheduling and plant utilization.
- **Environment**: It includes data related to technology trends, raw material prices, labour force economics and dynamics. The environmental data help the production manager to plan and control activities related to the production processes in a better way.

The manufacturing information system gathers different types of data from various sources. After gathering data, it processes data to transform them into meaningful information. This information is then provided to the production managers to facilitate decision making at the various levels of management. Information that is required for manufacturing decisions is processed from data that are gathered from a wide variety of sources. These various types of data are discussed as follows:

- **Production**: It includes production orders, assembly orders, finished items and scrap.
- **Inventory**: It includes data related to the inventories of raw materials, goods in process and finished goods.
- **Supplier**: It provides information about the sources of raw materials. The materials manager maintains the supplier data.

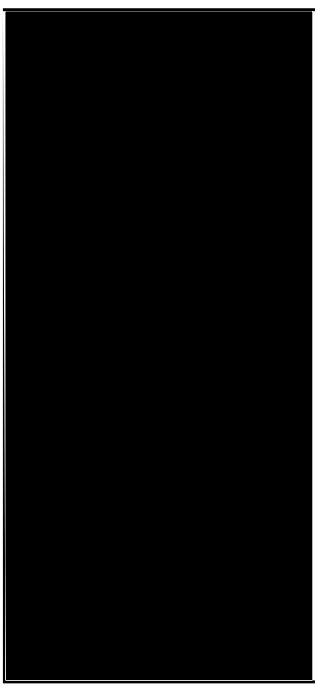
IMPORTANCE OF INFORMATION SYSTEM IN DECISION-MAKING

Decision Support System (DSS) is a model that helps the management of an organization in taking decisions related to the functioning of the organization. DSS involves three phases: intelligence, design and choice. During the intelligence phase of DSS, the main objective of the management is to identify the problem for which the decision needs to be taken. In the design phase, all possible solutions for the problem are determined. After determining all the possible solutions for the problem in the design phase, the best solution is selected in the choice phase. The criterion for choice phase varies from problem to problem. Therefore, it is necessary to go through these phases repeatedly until an optimum solution is achieved. DSS is useful in the organizations where the managers need to take decisions that deal with complex data and need to use several methods to find the best solution.

Concisely, you can say that DSS is a computer-based system that helps end-users to use data and models for solving unstructured problems in an organization. DSS helps the management in taking various decisions such as the following:

- Optimum product mix
- Alternative loading pattern
- Alternative assignment of jobs and machines
- Alternative material, tools and process

These decisions are supported by various programming models, simulation techniques, material planning systems and planning and scheduling systems.



Types of DSS

DSS provides various support systems such as data-driven DSS and knowledge-driven DSS which help identify the appropriate decisions. Following are the different types of DSS:

- **Communication-driven DSS**: This provides support to internal teams including partners in organizing business meetings in an organization. Communication-driven DSS is implemented in an organization using either Web or client server technology. Some of the examples of communication-driven DSS are chats and instant messaging software, net-meeting systems and online collaboration.
- **Data-driven DSS**: This helps the managers, staffs and product or service suppliers of an organization in taking organizational decisions. Data-driven DSS helps filter only the required information from a database or data warehouse in order to obtain specific results for specific objectives. Data-driven DSS is implemented in an organization using the mainframe and client server technology.
- **Document-driven DSS**: This is used for larger base of user groups. Document-driven DSS helps search Web pages and documents related to an organization on the basis of certain keywords and search items. Document-driven DSS is implemented in an organization by using either the Web or a client server technology.
- **Knowledge-driven DSS**: This covers a broad range of users which includes all the users of the concerned organization as well as the individuals such as consumers of a business working with that organization. Knowledge-driven DSS is also known as knowledge base. Knowledge-driven DSS helps the management in taking managerial decisions and selecting suitable products or services. Knowledge-driven DSS is implemented in an organization by using either the client server technology or the Web.
- **Model-driven DSS**: This helps the management in evaluating several available decisions and selecting the best decision out of them. Model-driven DSS is primarily used by the managers and staff members of an organization. This DSS can also be used by the other individuals associated with the organization depending upon the type of model set-up, scheduling and decision analyses. Model-driven DSS is implemented in an organization by using the client server technology, the Web and the software or hardware in stand-alone computer systems

Components of DSS

DSS contains various components that help manage information for the decision-making process of an organization. Following are the components of DSS:

- **User interface**: It is a means through which a user interacts with the machine or a device. The term user interface is often used in the context of computer systems and electronic devices.

- **Database**: It is a collection of current and historical records stored in a systematic manner. The information retrieved from the database can be used in decision-making by the DSS of an organization. The computer programme used to manage and query a database is known as a Database Management System (DBMS).
- **Network**: It is a collection of terminals, computers, servers and components which allow the information flow and sharing of resources among different users.
- **DSS software system**: It is a collection of mathematical and analytical tools used to perform various operations on the information stored in a database. The DSS software system provides information necessary for the decision-making process of an organization.

Applications of DSS

DSS is a computer-based system that provides the information used for accounting, strategic planning and decision making in an organization. The various DSS applications include the following:

- **Business and management**: DSS provides information that help in strategic planning and decision-making process. DSS generates payrolls, inventory and financial reports to assist the top management in decision-making process of an organization. For example, Executive dashboards and other business performance software allow faster decision making, identification of negative trends and better allocation of resources of the organization.
- **Banking**: DSS enables the employees of banks to perform day-to-day banking transactions easily and efficiently. For example, the bank loan officer can use DSS to verify the credit of a loan.
- **Railway**: In railways, DSS can be used to test the equipment on a regular basis and also to set time for the arrival and departure of trains. DSS helps reduce worn-outs and defective rails and in turn reduces train accidents due to derailment.
- **Hospitals**: DSS can be used in hospitals for various purposes such as medical diagnosis.
- **Airlines**: DSS can be used for various purposes such as flight scheduling and passenger demand forecasting.
- **Oil refineries**: In oil refineries, DSS can be used to determine the potential drilling sites for oil.

Group Decisions Support Systems

GDSS is a decision support system meant to support a group of personnel in taking complex decisions related to an organization. Each individual included in the group responsible for taking a particular decision communicate with other individuals with the help of a computer or network in order to obtain the organization objective. GDSS, also known as Group Support System (GSS) and electronic meeting system, is evolved from MIS.

Figure 3.4 shows the components of GDSS.

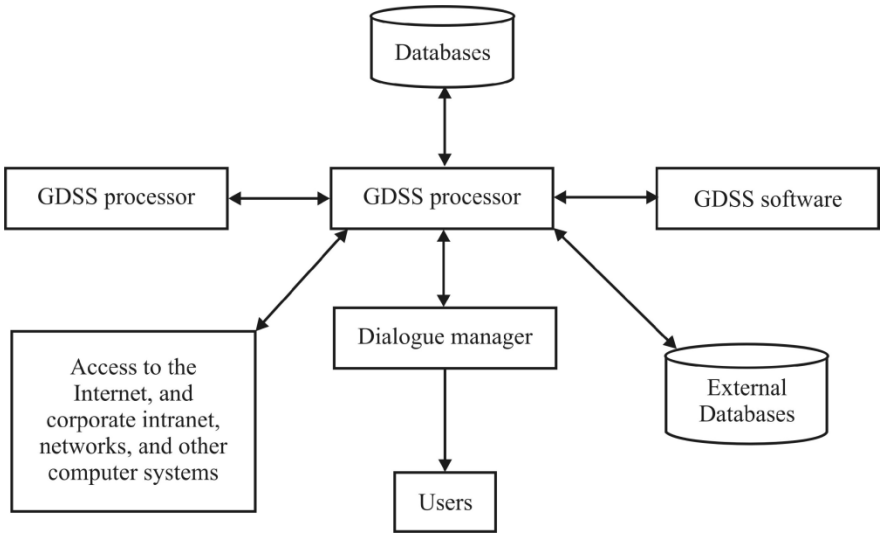


Fig. 3.4 *Components of GDSS*

Following are the characteristics of GDSS:

- Special design
- Easy to use
- Flexibility
- Decision-making support
  - o Delphi approach
  - o Brainstorming
  - o Group consensus
  - o Nominal group technique
- Anonymous input
- Reduction of negative group behaviour
- Parallel communication
- Automated record keeping
- Cost, control, complexity factors

GDSS Software Tools

GDSS provides different software tools such as electronic questionnaires and idea organizers to make it easy to plan, generate, organize and evaluate the ideas for solving a particular problem related to an organization. Following are the different GDSS software tools:

- **Electronic questionnaire**: This helps the group members in performing pre-meeting planning which involves determination of important issues and information required for taking a particular decision. Therefore, this tool helps ensure that the information important for taking a particular decision is not ignored.
- **Electronic brainstorming tools**: These allow the group members to provide suggestions to help the management in taking certain decisions related to the organization.

- **Idea organizers**: These help categorize different ideas provided by each group member during the process of brainstorming.
- **Questionnaire tools**: These help the group leaders in collecting information required for taking a particular decision.
- **Tools for voting or setting priorities**: These provide different methods to the group leaders for establishing priorities among the ideas generated by the group members during brainstorming. Various methods that you can use to establish priorities are voting, ranking the available ideas and using weighted techniques.
- **Stakeholder identification and analysis tools**: These provide structured methods to determine the influence of the emerging proposal on the working of the organization. These tools also help determine the shareholders of the organization and influence of the shareholders on the implementation of the selected project.
- **Policy formation tools**: These help create an agreement based upon the policy statements.
- **Group dictionaries**: These help record the important terms related to the proposed project.

Figure 3.5 shows the various software tools used in GDSS.

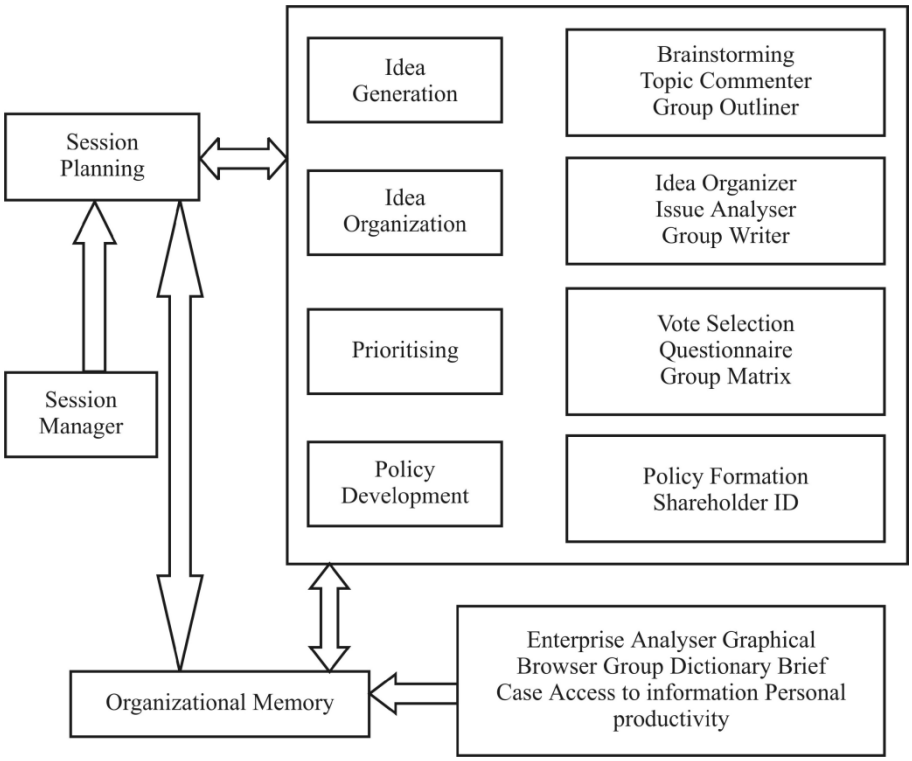


Fig. 3.5 *Various Software Tools used in GDSS*

Benefits of GDSS

GDSS provides a number of benefits that help in enhancing group decision making in an organization. The various benefits provided by GDSS are:

- **Improved pre-planning**: Pre-planning is important for any group meeting as it prepares members beforehand. GDSS provides different tools, such as

electronic questionnaires, word processors and outlining software that aid in improving the pre-planning.

- **Increased participation**: GDSS helps leverage simultaneous employee participation for contributing towards the goals of the organization that facilitates efficient use of meeting time.
- **Open meeting atmosphere**: GDSS provides an unbiased and collaborative decision.
- **Evaluation objectivity**: As GDSS provides secrecy to the source of idea, it prevents criticism of the source. This anonymity allows participants to detach and evaluate their own ideas. It has been observed that evaluation in an anonymous atmosphere increases critical feedback and also even stimulates the creation of new ideas.
- **Idea organization and evaluation**: GDSS software tool allows each participant to classify and then propose their idea to the group.
- **Documentation of meetings**: The minutes of the meeting can be documented and later provided to those who did not attend the meeting. Also this information can be referred later to develop the idea further.
- **Access to external information**: Sometime participants tend to indulge in argument over an incorrect data provided. GDSS is used to provide easy access to reliable information, so the participants have correct and reliable information to discuss.

Executive Support System

An Executive Support System (ESS) is a computer-based system which helps senior executives to easily access internal and external information required to take strategic decisions. ESS has an easy to use graphical user interface and offers strong reporting. It helps top-level executives to supervise performance by analyzing, comparing and highlighting important variables.

With the emergence of Local Area Network (LAN), the popularity of ESS has increased. Following are the different categories in which component of ESS can be classified:

- **Hardware**: The hardware components required to implement ESS in an organization are easy to use and less expensive. The executive decides the hardware to be used according to his needs. Computer hardware for an ESS includes the following three components:
  - o Input data-entry devices, which help the employees of an organization to input and modify the information necessary for decision making.
  - o The Central Processing Unit (CPU), which helps manage the functioning of various components such as monitor and keyboards of the computer.
  - o Output devices, which provide an interface to the employees of an organization to visualize the output of a particular operation. You can use various output devices such as monitor and printer to visualize the information stored in the organization database.
- **Software**: It is necessary to select appropriate software components for developing an effective ESS. Following are the software components required to develop an effective ESS:
  - o **Text base software**: This helps the employees of an organization to record and update the information about day-to-day transactions.

- **Database**: This is used by the employees of an organization to store and access information related to the organization in a tabular form.
- **Graphic base**: This helps an end-user to convert large quantity of information into various kinds of charts such as scatter chart, bar charts, pie charts and moving graphics.
- **Model base**: This helps in analyzing the statistical and financial information stored in the organization database.

Executives need to choose appropriate software because ESS will be used by the non-technical people. The software should provide advanced documentation, should be easy to use, supported by the existing hardware and reasonably priced.

- **Interface**: It is required to access data by a user. There exist several kinds of interfaces such as questionnaires and formatted reports. Interfaces should be designed keeping in mind the need and technical expertise of end-users. Interfaces should have consistent look, should be flexible enough to meet the changing needs of end-users, and should have provision for help and error reports.
- **Telecommunication**: It is used to establish an organization in the market and meet the executives' need to access and transmit data from one source to another. This is important because organizations have distributed databases at different geographical locations.

Role of ESS

Executives use ESS to explore information according to the requirement of the user. ESS has the ability to differentiate between essential and rarely used data. ESS helps assess whether or not the company is meeting its corporate objectives. ESS can be used in the following fields:

- **Manufacturing**: It is defined as converting unprocessed materials into finished goods. Manufacturing process involved in operational control effectively and efficiently manages daily activities. Executives have to alter their decisions to produce meaningful managerial and operational information for controlling the manufacturing operations. ESS critically evaluates vendors, buyers and purchased materials. Executives can manage and analyze the purchasing operations effectively with ESS.
- **Marketing**: The marketing executives can use ESS to perform the marketing involved in an organization. The role performed by the marketing executives is to create strategy for future. They use available marketing resources to create a more effective future, by judging the risk and ambiguity of the project. Marketing executives assess risks involved with a project and its implication on company. ESS helps end-user to take valuable decisions. It also helps in predicting sales and product price which helps end-user to compare predicted sales with previous sales. Executives can control data with the help of ESS by studying previous trends and audits of the sales data.
- **Financial**: The financial executives can use ESS to perform financial role in an organization. For this the financial executives decide the investment strategies with the help of financial ratios and cash flow analysis. By using the quality information provided by ESS, an end-user can estimate budget and set standards for cost. ESS also helps in long-term plans by making it easier for end-users to keep a track of cash flow and expanding needs of an organization.

Benefits of ESS

The use of ESS is very easy and provides various benefits to the executives of an organization.

- It is not necessary for the users to be an expert in using computers.
- It helps provide summarized information to the concerned authority on time.
- It provides information in a form which is easy to understand.
- It can sort data into different categories.
- It helps to keep track of information.
- It helps to take efficient decision.

Enterprise Resource Planning System

ERP system is a type of information system that is used to integrate all the data and processes of the organization into a cohesive system. ERP system is regarded as the enterprise-wide framework that includes all the major departments of the organization such as sales, marketing, production, inventory management, accounts, finance and human resource department. These departments are considered as the backbone of the organization.

ERP system is the cross-functional enterprise framework that handles the processes related to all the departments and helps the organization to use the available resources in an efficient manner. This system helps the organization to analyze the production capacities and logistics management and take decisions about the financial implications. The ERP system follows the philosophy of handling and integrating all the processes at all levels. The ERP system also manages the resources of the organization in an efficient manner so that it can satisfy the needs of the customers in a convenient manner. This system enables the management of the organization to view the business as a whole rather than having a small view of the business functions. This helps the management to achieve the goals and objectives of the organization. The changes that are required to be incorporated in the business processes can be easily done with ERP system with no extra effort, because changes have to be incorporated in one place that affect the complete process of information system automatically. Figure 3.6 shows the typical ERP system in which the sales order processing interact with the inventory system, work order maintenance and accounts receivable subsystems. Therefore, the ERP system integrates the marketing, production and finance of business. The ERP system also integrates the other business activities such as production planning, production scheduling, procurement of raw materials and Material Resource Planning (MRP).

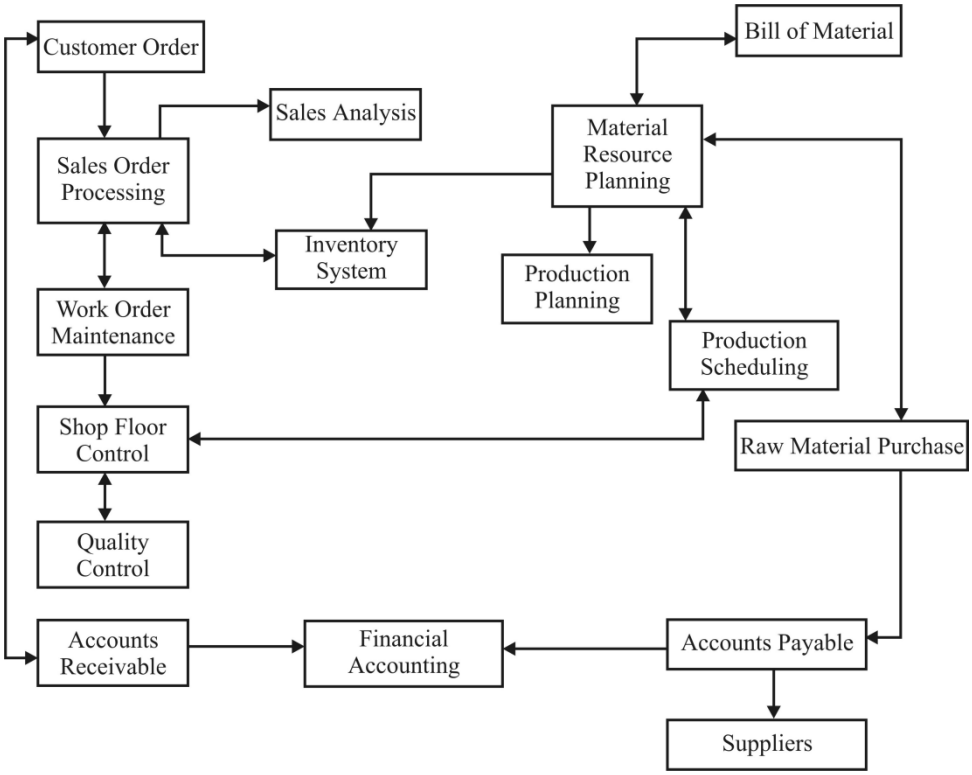


Fig. 3.6 *ERP System of an Organization*

Table 3.1 shows some of the ERP software vendors.

Table 3.1 *ERP Software Vendors*

ERP Software Vendor	ERP Software Name
SAP	SAP R/3
Baan	Triton
PeopleSoft	PeopleSoft
J.D. Edwards	Word Software
QAD	MFG/Pro
Ross Systems	Irenaissance
Oracle	Oracle Manufacturing

ERP system consists of different modules such as manufacturing, distribution, sales, accounting and human resource (HR) management. These modules further consist of different processes under them. For example, the manufacturing module consists of material requirements planning, production planning and capacity planning processes. Figure 3.7 shows the major functional components of the ERP system.

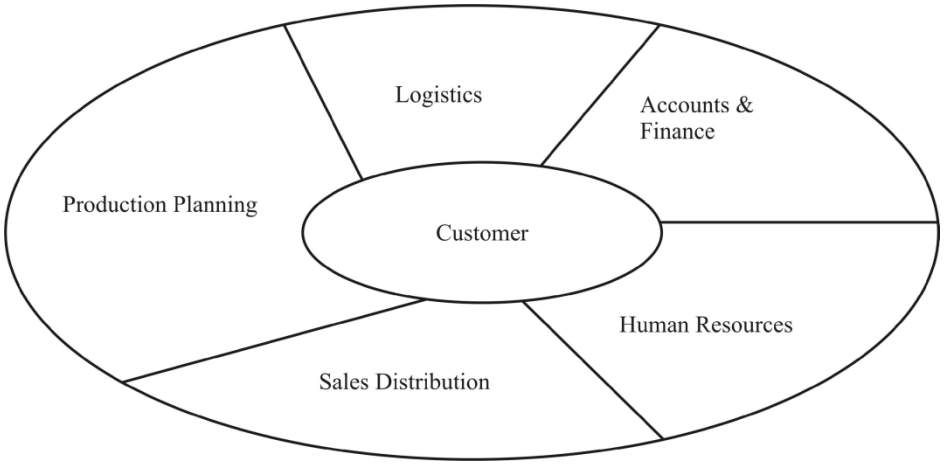


Fig. 3.7 *Major Functional Components of the ERP System*

ERP Challenges

Companies have to face many problems while implementing the ERP system. The first problem the organization has to face is about the selection of the ERP vendor. Most organizations face ERP challenges in three areas which are:

- **Integration of ERP modules**: Different ERP vendors sell their ERP software package consisting of production planning, inventory control, finance and HR. The organizations have to install all these modules in the beginning phase of ERP implementation. The companies also have to purchase some other ERP modules from different vendors. The integration of the modules purchased from different vendors is one of the major challenges for the organizations.
- **Integration of e-business applications**: E-Business applications consist of strategies, technologies and processes that integrate the internal and external business processes electronically. E-Business software system falls into four categories. These categories are:
  - Enterprise Resource Planning (ERP)
  - Customer Relationship Management (CRM)
  - Supply Chain Management (SCM)
  - Knowledge Management (KM)
- **Integration with legacy systems**: A legacy system is the existing computer system or application implemented in the organization to handle different business processes. This legacy system consists of vast amount of data that are crucial for the survival, operations and expansions of the organizations. Integration of ERP systems with the legacy systems requires the installation of the third-party software that can be used as an interface between the ERP systems and the legacy systems.

MIS and Decision-Making

The information system in an organization plays an important role in decision-making process. Decision making means making a choice from the given alternatives by a

manager or a decision maker. The decision-making process lets a manager come to a conclusion about a given situation. Therefore, decision making may be defined as a process of selecting an optimum and best alternative from a couple of given alternatives to accomplish a particular task. Decision-making process is the core of managerial functions in MIS. It is said that the decision-making process considers two or more alternatives from which a final decision could be made. But if only one alternative is available, then no decision could be made. A decision-making process involves the entire process of establishing goals, defining activities, searching for alternatives and finally the development of plans. In addition, the decision-making process includes all the activities of problem solving, co-ordinating, information processing and evaluating alternatives that usually precede a decision. On the basis of the purpose of the decision-making activities, the organizational decisions are divided into the following three different categories:

- **Strategic planning**: These are the decisions in which a decision maker develops objectives and allocates resources to achieve these objectives. Decisions in this category are of long-time period and involve a large investment and effort. Such decisions are taken by the strategic planning level managers who belong to the top level of the management hierarchy in an organization. Examples of such decisions may include introduction of a new product and acquisition of another firm.
- **Management control**: These are the decisions taken by the management control level managers who are from the middle level of the management hierarchy in an organization. These managers deal with the use of resources in the organization. Analysis of variance, product mix and planning decisions fall in this category of decisions.
- **Operational control**: These are the decisions dealing with the day-to-day problems that affect the operation of an organization. For example, the decisions such as production scheduling and the inventory control fall in this category. In these decisions, the product to be produced for the day or the items and their quantities to be ordered are operational control decisions. Such types of decisions are normally taken by the operational level managers who are at the bottom level of the management hierarchy in an organization.

Simon's Model of Decision-making

In organizations, the decision-making process is considered as a rational process. It means the decision-making process is based on the following three phases as given by Herbert A. Simon in his model of decision-making:

- Intelligence phase
- Design phase
- Choice phase
- Implementation Phase

Figure 3.8 shows the decision-making process model.

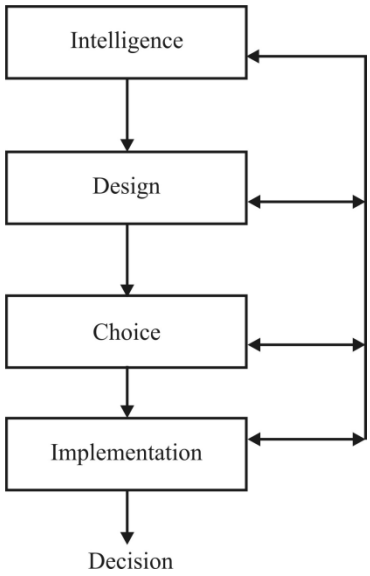


Fig. 3.8 *Decision-making Process Model*

The phases are discussed in detail as follows:

Intelligence Phase: A decision maker studies the environment and identifies the problem or opportunity. The scanning of environment may be continuous or intermittent. For example,

A. Reviewing of daily scrap report by a production manager to check the problems related to quality control. This is an example for continuous scanning.

B. Periodic visiting of a sales executive to the key customers to review possible problems and to identify new customer needs. This is an example for intermittent scanning.

The Intelligence phase of the decision-making process involves:

- **Problem searching**: Refers to the difference between the expected and real result obtained after making a decision which is given by the following formula:

  (Desired/Expected) – (Actual/Reality) = Difference/Problem

  For example, a sales manager sets a sales target of certain amount, say five lakhs, in a particular month as his expected target, which is expected but he could achieve only four lakhs worth of sales for that particular month, which is reality. Therefore, the difference between expected and reality value of the target, that is, one lakh, is the problem. This difference worries the sales manager.

  In actual practice, the reality or actual is compared to some standard desired model. Then the differences are measured and evaluated to determine the problem or difference. Various types of models that are used to compare reality are:

  - Historical models based on estimated information
  - Planning model

- Extra organizational models in which expectations are derived from customers, consultants and competition
- Models used by employees in an organization

o **Problem formulation**: Refers to the proper identification of the problem to avoid the risk of solving the wrong problem. To avoid such a risk, it is very important to understand the problem well and state it clearly. Sometimes, the process of clearly defining the problem is sufficient; but in other cases, we have to simplify the problem by determining its boundaries. Boundaries are simplified by breaking the problem into smaller manageable sub-problems. In problem formulation, establishing relations with some problems that are solved earlier prove quite useful.

Design Phase: A decision maker identifies alternative courses of action to solve the problem. Design phase includes inventing or developing various alternatives in order to get the best possible alternative. Developing alternatives is a time-consuming and crucial activity, as the decision maker has to explore all the possible alternatives. Decision-maker should not take the risk of missing any alternative since the missed-out alternative might be the best one from the given alternatives. Developing alternatives is a creative activity which can be enhanced by various aids such as brainstorming, checklists and analogies.

Choice Phase: Refers to the selection of the alternative developed in the design phase as the decision by the decision maker. A decision maker makes a detailed analysis of each and every alternative for performing this selection. After making the decision, the decision is implemented. However, at any phase, the decision maker may return to the previous phase. For example, the decision maker in the choice phase may reject all alternatives and return to the design phase for developing more alternatives.

Implementation Phase: Refers to the phase in which the final decision made by the decision maker during the design phase is implemented. It should be noted that the completion of this phase means successful completion of the decision-making process. In case of any discrepancies, the decision maker might return to the previous phase or phases to carry out the decision-making process. The implementation phase includes training of the personnel, who implement the decision put forward by the decision maker. In addition, this phase may require additional support from the top-level management of the organization for implementing the decision. This additional support may be personnel or financial support.

Role of Information System in Decision-making

Information system plays its role in all the different stages of the decision-making process. The stages of the decision-making process are: intelligence, design and choice. The role of information system in these three stages of the decision-making process is discussed as follows:

- **Intelligence stage**: Information systems may provide information about internal as well as external environments of the decision-making process. Internal information is generated from the functional areas but the external information is collected from various sources such as newspapers and personal contacts. Availability of a large amount of information in this stage makes it necessary to scan the data sources to get the relevant information. As a result, information system is used to scan the business environment of an organization. In order to

get the required information in the intelligence phase of the decision-making process, information system must be designed so as to answer pre-specified and ad hoc queries made by a decision maker.

- **Design stage**: Information systems provide support by quantifying and automating a decision-making process during the design stage while considering structured decisions. At this stage, various alternatives are developed and evaluated. On the other hand, for semi-structured and unstructured decisions, the support of information system provides the following abilities:
  - o To reach a decision in an interactive process which includes DSS capability
  - o To make ad hoc queries for information in the organizational databases
  - o Therefore, information systems should be designed to incorporate various models of business operations and advanced statistical and optimization techniques

Choice stage: Information systems provide summarized and organized information to the decision makers at this stage of the decision-making process. It is the stage in which a course of action is selected and feedback is collected on the implemented decision. Information system also provides the feedback support to decision-makers in case they want to return to the preceding stages of the decision-making process in order to gather more information. Models such as optimization and suggestion should be used to select the most appropriate alternative which helps the decision makers in selecting the best course of action.

SUMMARY

- The business activities are grouped on the basis of functions such as production and finance performed by a specific department of a business organization.
- MIS is an integration of information systems that are designed to support the functional subsystems of the business.
- Information systems that are developed around the functional areas of a business organization are known as functional information systems.
- Marketing information system provides information about various functions of the marketing system of an organization.
- The concept of marketing has assumed a great importance in every field, irrespective of the degree of industrialization.
- Marketing not only includes the activities like selling, advertising or distribution of products but also involves the interaction of several business activities.
- Contrary to this concept, in traditional practice of marketing, the existing products are launched into the market after implementing aggressive selling and promotional pressures.
- To arrive at marketing decisions, a marketing manager needs information on different aspects of marketing.
- The marketing information systems consist of statistical techniques and decision models that assist marketing managers in carrying out better analyses and decisions.
- Human resource information system supports the functions of human resource management of an organization.

- Human resource information system also deals with employee compensation, wages, salary administration, labour relations and employee services and benefits.
- A financial information system is defined as a subsystem of the organizational management information system that supports the decision-making process of financial functions at the organizational levels.
- Capital budgeting allocates the funds for long-term assets that yield benefits/ returns in the future.
- Financial information systems also include accounting systems as these systems are concerned with recording the business transactions.
- Accurate and precise financial information system needs to be supplied to the financial manager in order to perform the above activities and functions.
- Manufacturing is another important functional area of an organization that is engaged in producing goods from raw materials.
- A production or manufacturing information system provides information on the production or operation activities of an organization and facilitates the decision-making process for the production managers of the organization.
- Production management is an area that deals with decision making related to the production process so that the resulting goods and services are produced in accordance with the quantitative specifications and demand schedule with the minimum cost.
- Decision Support System (DSS) is a model that helps the management of an organization in taking decisions related to the functioning of the organization.
- DSS is useful in the organizations where the managers need to take decisions that deal with complex data and need to use several methods to find the best solution.
- DSS provides various support systems such as data-driven DSS and knowledge-driven DSS which help identify the appropriate decisions.
- DSS contains various components that help manage information for the decision-making process of an organization.
- DSS is a computer-based system that provides the information used for accounting, strategic planning and decision making in an organization.
- GDSS is a decision support system meant to support a group of personnel in taking complex decisions related to an organization.
- GDSS provides different software tools such as electronic questionnaires and idea organizers to make it easy to plan, generate, organize and evaluate the ideas for solving a particular problem related to an organization
- GDSS provides a number of benefits that help in enhancing group decision making in an organization.
- An Executive Support System (ESS) is a computer-based system which helps senior executives to easily access internal and external information required to take strategic decisions.
- Enterprise Resource Planning system is a type of information system that is used to integrate all the data and processes of the organization into a cohesive system.

- The ERP system also integrates the other business activities such as production planning, production scheduling, procurement of raw materials and Material Resource Planning (MRP).
- The information system in an organization plays an important role in decision-making process.
- A decision-making process involves the entire process of establishing goals, defining activities, searching for alternatives and finally the development of plans.
- Information system plays its role in all the different stages of the decision-making process.

KEY TERMS

- **Financial information system:** It refers to a subsystem of the organizational management information system that supports the decision-making process of financial functions at the organizational levels.
- **Purchase motivation**: It refers to the assessment of various social, economic and psychological forces that influence the purchase behaviour of the market.
- **Decision Support System (DSS):** It refers to a model that helps the management of an organization in taking decisions related to the functioning of the organization.
- **Executive Support System (ESS):** It refers to computer-based system which helps senior executives to easily access internal and external information required to take strategic decisions.
- **Implementation Phase**: It refers to the phase in which the final decision made by the decision maker during the design phase is implemented.
- **Problem formulation**: It refers to the proper identification of the problem to avoid the risk of solving the wrong problem.

ANSWERS TO 'CHECK YOUR PROGRESS'

1. The different functional systems are dependent on each other because all the functional systems are a part of the organizational system and interact with other subsystems with the help of information.
2. The main functions of a manufacturing organization are as follows:
   (a) Production
   (b) Marketing
   (c) Finance and accounting
   (d) Materials
   (e) Personnel systems
   (f) Logistics
   (g) Information Processing
3. The financial information systems are computerised because of the following reasons:
   (a) To provide information and analytical support to financial managers to aid them in their decision-making.
   (b) To improve the speed and accuracy of reporting.

4. The main objective of marketing activities is the satisfaction of the needs and desires of the customers.
5. Training and development is considered as a continuous activity because it includes the following processes:
   (a) Identification of training and development needs of personnel at all levels.
   (b) Development of suitable training and employee development programmes.
6. The main characteristics of group decision support systems are special design, easy to use, flexibility, decision–making support, anonymous input, reduction of negative group behaviour, parallel communication, automated record keeping, cos, control and complexity factors.
7. The following are advantages of the executive support system:
   (a) It can sort data into different categories.
   (b) It helps to keep track of information
   (c) It helps to take efficient decision.
   (d) It provides information in a form which is easy to understand.
8. The various categories of E-business software system are:
   (a) Enterprise Resource Planning (ERP)
   (b) Customer Relationship Management (CRM)
   (c) Supply Chain Management (SCM)
   (d) Knowledge Management (KM)
9. The decision-making process involves various activities such as establishing goals, defining activities, searching for alternatives and development of plans. It also includes activities like problem-solving, co-ordinating, information processing and evaluating alternatives.
10. The main objective of the intelligent phase of decision support system is to identify the problem for which the decision needs to be taken.

EXERCISES AND QUESTIONS

Short-Answer Questions

1. What are the types of functional systems?
2. How is the task of production planning accomplished?
3. State the various types of manufacturing data.
4. What are the types of group decision support system tools?
5. How is the organization structure divided according to decision-making activities?
6. State the difference between transaction and post-transaction.

Long-Answer Questions

1. Explain the various types of financial decisions.
2. Discuss the types of marketing functions.
3. Describe the different types of decision support system models.
4. Analyse the relation between MIS and decision-making.
5. Discuss the role of information system in decision-making.
6. Explain Herbert A. Simon's model of decision-making.

FURTHER READING

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UNIT-4 OVERVIEW OF DATA COMMUNICATION

Structure

INTRODUCTION

Data communication and networks deal with data or information transmission. There are two ways to communicate, display, store or manipulate information. They are analog and digital. In the analog form of electronic communication, information is represented as a continuous electromagnetic wave. Digital communication represents information in binary form through a series of discrete pulses. These days, Internet has become the most used medium for dissemination of information and communication. In this unit, you will study about the use of communication devices, LAN, WAN and MAN, Internet, protocols of Internet, Internet services and applications.

UNIT OBJECTIVES

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

- Prepare an introduction of data communication
- Interpret communication devices
- Define LAN, MAN and WAN
- Mention the protocols of Internet
- Discuss Internet services and Internet applications

INTRODUCTION: DATA COMMUNICATION

A data communication system is made up of the message, the source, the destination, the medium and the protocol. Message is the information needs to be communicated. Source is the device that sends the message to the destination. Destination is a device to receive the message. Medium is the physical path through which the message is transmitted for the destination. Protocol defines a set of rules for communication. Figure 4.1 shows a simple data communication system.

A network is a connection of independent computers to communicate with one another over a shared network medium. The physical layer deals with transmission

medium to transport information in the form of bits between different computers on the network. The physical layer is responsible for communicating 0s and 1s across a medium. It does so through the variation of some physical property, such as current or voltage. This layer also ensures the reliable delivery of bits. It means that when the sending side sends 1 bit, it is received by the receiving side as 1 bit, not as 0 bit. Hence, it defines the mechanical and electrical aspects of interfacing to a physical medium for disconnecting, maintaining and setting up physical links as well as for transmitting data. It is primarily concerned with moving bits from one node to the next over the physical link. The issues concerning the physical layer involve amplitude of the pulses to define 1 and 0 level, width of the pulse in microseconds, types and modes of communication, establishment and breaking of connections at the time of communication, types of connectors, etc.

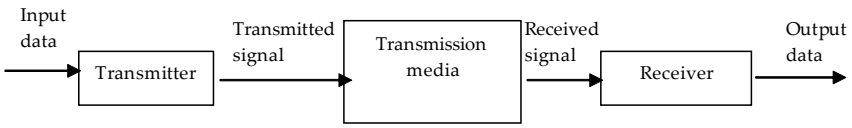


Fig. 4.1 *Simple Data Communication System*

A physical layer of a network accepts data from the data link layer in bit streams for subsequent transmission over the physical medium. At this layer, the mechanical (connector type), electrical (voltage levels), functional (ping assignments), and procedural (handshake) characteristics are defined. RS-232C/D is an example of a physical layer definition. The bit stream is represented as a function of time and can be analysed mathematically. Analysis is required to know the physical characteristics of a signal as it travels across some physical media. Even if there are some changes in the properties of the signal, it is important to know how it can be reproduced in its original form, so that the receiver receives it as sent by the sender.

Analog and Digital Communication

Data communication and networks deal with data or information transmission. Data can be represented in many ways, such as a human voice, a bunch of numbers, images, text and sounds, etc. There are two ways to communicate, display, store or manipulate information. These are as follows:

- Analog
- Digital

In the analogue form of electronic communication, information is represented as a continuous electromagnetic wave form, as shown in Figure 4.2. Digital communication represents information in binary form through a series of discrete pulses, as shown in Figure 4.3.

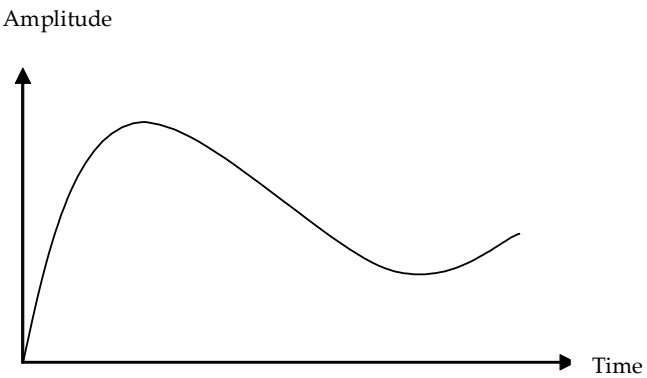


Fig. 4.2 *Representation of Analog Signals*

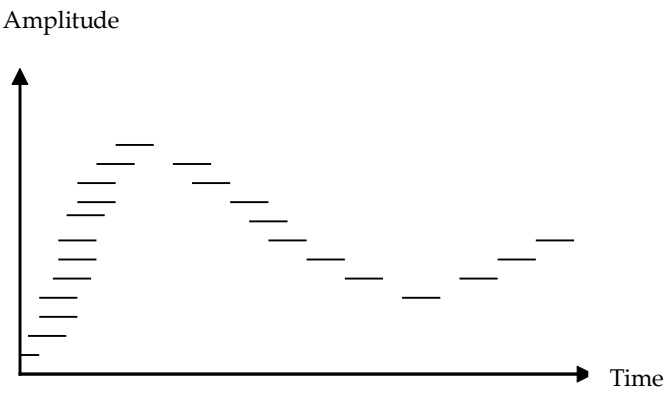


Fig. 4.3 *Representation of Digital Signals*

Analog Signal

Analog is best explained by the transmission of such signals as human speech or sound, over an electrified copper wire. In its native form, human speech is an oscillatory disturbance in the air as shown in Figure 4.2, which varies in terms of its volume, or power (amplitude) and its pitch or tone (frequency). Analog signals are, therefore, defined as continuous electrical signals varying in time as shown in Figure 4.4. Analogous variations in radio or electrical waves are created in order to transmit the analogue information signal for video or audio or both over a network from a transmitter (TV station or CATV source) to a receiver (TV set, computer connected with antenna). At the receiving end, an approximation (analogue) of the original information is presented. Information that is analogue in its native form (image and audio) can vary continuously in terms of intensity (brightness or volume) and frequency (color or tone), as shown in Figures 4.2 and 4.3. These variations in the native information stream are translated, in an analogue electrical network, into variations in the frequency and amplitude of the carrier signal. In other words, the carrier signal is modulated (varied) in order to create an analogue of the original information stream.

The electromagnetic sinusoidal waveform or sine wave as shown in Figure 4.4 can be varied in amplitude at a fixed frequency, using Amplitude Modulation (AM). Alternatively, the frequency of the sine wave can be varied at constant amplitude, using Frequency Modulation (FM). Additionally, both amplitude and frequency can be modulated simultaneously. Figures 4.5 and 4.6 represent a sinusoidal waveform in amplitude and frequency form. The example of analogue signal in the field of data communication is telephone voice signal in which the intensity of the voice causes electric current variations. At the receiving end, the signal is reproduced in the same proportion.

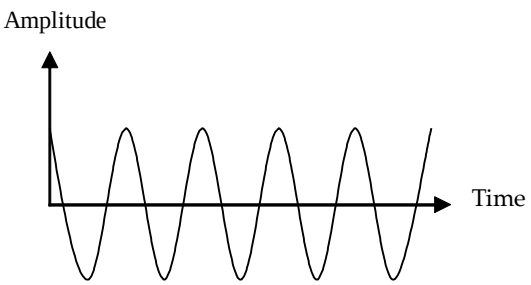


Fig. 4.4 *Waveform in the Form of Sine Wave*

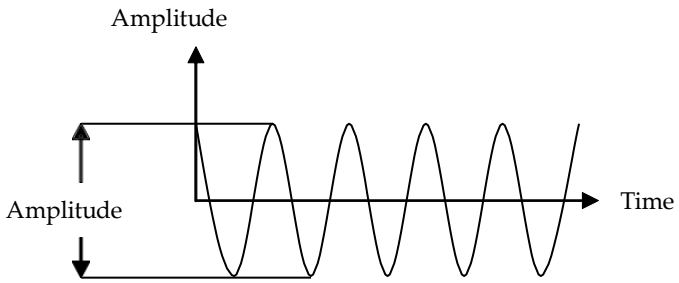


Fig. 4.5 *Amplitude*

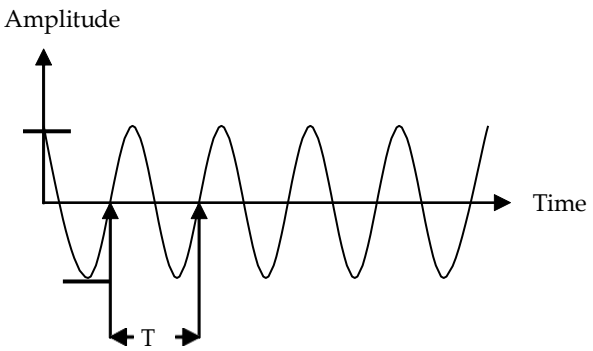


Fig. 4.6 *Frequency Representation*

Voice: A voice grade channel is approximately 4,000 Hz or 4 kHz. Approximately kHz (200 Hz to 3,500 Hz) is used for the voice signal itself. The remaining bandwidth is used for the purpose of network signaling and control in order to maintain separation between information channels. While human speech transmission and reception encompasses a much wider range of frequencies, 4.3 kHz is considered to be quite satisfactory and cost-effective. Band-limiting filters are used in carrier networks to constrain the amount of bandwidth provided for a voice application.

Video: A CATV video channel is approximately 6 MHz. Approximately, 4.5 MHz is used for information transmission, while the balance is used for guard bands to separate the various adjacent channels using the common, analogue coaxial cable system.

Digital Signal

Computers are digital in nature. Computers communicate, store and process information in binary form, i.e., in the combination of 1s and 0s, which has specific meaning in computer language. A binary digit (bit) is an individual 1 or 0. Multiple bit streams are used in a computer network. The computer systems communicate in binary mode through variations in electrical voltage. The digital signals that are non-continuous change in individual steps consisting of digits or pulses with discrete values or levels. The value of each pulse is uniform but there is an abrupt change from one digit to the next. They have two amplitude levels, which are specified as one of two possibilities like 1 or 0, high or low, true or false, and so on. In other words, the digital signaling, in an electrical network, involves a signal which varies in voltage to represent one of two discrete and well-defined states as depicted in Figure 4.7, such as either a positive (+) voltage and a null or zero (0) voltage (unipolar) or a positive (+) or a negative (–) voltage (bipolar).

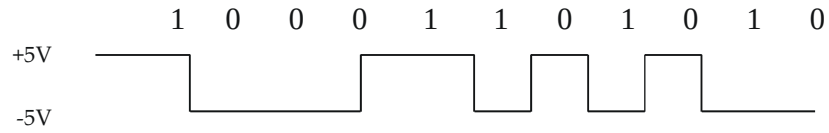


Fig. 4.7 *Binary Representation Forming Digital Signal*

Data and Signals

For transmission across a network, data has to be transformed into electromagnetic signals. Both, data and signals can be either of analogue type or digital type. A signal is termed periodic if it has a continuously repeating pattern. Therefore, the data and signals are two essential building blocks of any computer network. Signals are the electric or electromagnetic encoding of data specifically used for data transmission. A digital signal is a composite signal with an infinite bandwidth.

Signals

Information exchange is an essential part of communication. It may be exchange of information among users or equipment in the communication system. In the communication context, signaling refers to the exchange of information between components required to provide and maintain data communication service. In case of PSTN (Public Switched Telephone Network), signaling between a telephone user and the telephone network may include dialling digits, providing dial tone, accessing a voice mailbox and sending a call-waiting tone. Looking at networking perspectives, it is transmission of service information, such as addresses, type of service, etc., between nodes and/or terminals of a network. In other words, it is a process of exchanging and generating information between components of a telecommunications system to establish, release, or monitor connections (call handling functions) and to control related network and system operations (other functions).

Signaling System 7 (SS7)

Signaling System 7 (SS7) is the protocol designed for public switched telephone system for providing services and setting up calls.The various value-added features, such as providing intelligence to PSTN services come under the service of SS7. Earlier the same physical path was used for both the call-control signaling and the actual connected call. This is called in-band signaling technique. This method of signaling was inefficient and replaced by out-of-band or common-channel signaling techniques. Out-of-band signaling performs its job by utilizing two networks in one. As we know that in PSTN, our voice and data is carried over circuit-switched network. It provides a physical path between the destination and source. The other one is the signaling network, which carries the call control traffic. It is a packet-switched network using a common channel switching protocol.

Functions of SS7

- It controls the network.
- The SS7 network sets up and tears down the call.
- It handles all the routing decisions and supports all telephony services including Local Number Portability (LNP), remote network management, called ID and forwarding.

In order to accomplish the above functions, SS7 uses voice switches, which are known as Service Switching Points (SSPs). They handle the SS7 control network as well as the user circuit-switched network. Basically, the SS7 control network tells the switching office which paths to establish over the circuit-switched network. SSPs also query Service Control Point (SCP) databases using packet switches called Signal Transfer Points (STPs). The STPs route SS7 control packets across the signaling network. The concept of SSP, STP and SCP has been illustrated in Figure 4.8.

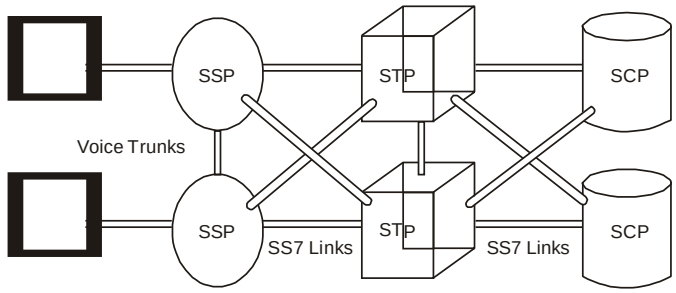


Fig. 4.8 *SS7 Signaling Points*

Comparison of Analog and Digital Data Transmission

Digital signals are identified through bit interval and bit rate. The bit interval is the time occupied by a single bit and the bit rate is the number of bit intervals per second which is expressed in bits per second or bps. Although analogue voice and video can be converted into digital, and digital data can be converted to analogue, even then, each format has its own advantages.

Advantages of Analog Transmission

The advantages of analogue transmission are as follows:

- Analog transmission offers advantages in the transmission of analogue information. Additionally, it is more bandwidth-conservative and is widely available.
- Analog has an inherent advantage as voice, image and video are analogue in nature. Therefore, the process of transmission of such information is relatively straightforward in an analogue format, whereas conversion to a digital bit stream requires conversion equipment. Such equipment increase cost, are susceptible to failure and can negatively affect the quality of the signal through the conversion process itself.
- More bandwidth is consumed by a raw information stream in digital than in analogue form. This is particularly evident in CATV transmission, where 50 or more analogue channels are routinely provided over a single coaxial cable system. Without the application of compression techniques on the same cable system, only a few digital channels could be supported.
- Finally, analogue transmission systems are already in place, worldwide. Interconnection of these systems is very common and all standards are well established. As the majority of network traffic is voice and as the vast majority of voice terminals are analogue devices, therefore, voice communication largely depends on analogue networks. Conversion to digital networks would require expensive, wholesale conversion of such terminal equipment.

Advantages of Digital Transmission

The following are the advantages of digital transmission:

- **Digital Data:** When it comes to the transmission of binary computer data, the advantage is with digital transmission. The equipment required for converting digital data to an analogue format and sending the digital bit streams over an analogue network can be expensive, susceptible to failure, and can create errors in the information.
- **Compression:** It is relatively easy to compress digital data, thus, the efficiency of transmission increases. As a result, image, video, voice and data information can be transmitted in substantial volumes using relatively little raw bandwidth.
- **Security:** Digital systems offer better security while analogue systems offer some measure of security through the scrambling of several frequencies. Scrambling is fairly simple to defeat. Digital information, on the other hand, can be encrypted to create the appearance of a single, pseudo-random bit stream. Thereby, the true meaning of, sets of bits and individual bits or the total bit stream that cannot be determined without the key that unlocks the encryption algorithm that has been employed.
- **Quality:** Digital transmission offers improved error performance (quality) as compared to analogue. This is due to the devices that boost the signal at periodic intervals in the transmission system in order to overcome the effects of attenuation. Additionally, digital networks deal more effectively with noise, which is always present in transmission networks.
- **Cost:** The cost of the computer components required in transmission and digital conversion has dropped considerably. At the same time, the reliability and ruggedness of those components has increased over the years.
- **Upgradability:** It is relatively simple to upgrade digital networks as the comprise of computer (digital) components. Such upgrades can enhance functionality improve error performance and increase bandwidth. Some upgrades can be effected remotely over a network, eliminating the need to dispatch expensive technicians for that purpose.

Switching Techniques

In the mainframe and minicomputer environment, each user is connected to the main system through a dumb terminal is unable to perform any of its own processing tasks. In this computing environment, processing and memory are centralized. However, this type of computerization has its merits but the major disadvantage is that the system could get easily overloaded as the number of users and consequently terminals increase. Second, most of the information is centralized to one group of people, the systems professionals rather than the end-users. This type of centralized processing system differs from the distributed processing system used by LANs. In distributed processing system, most of the processing is done in the memory of the individual PCs or workstations besides sharing expensive computer resources like software, disk files, printers and plotters, etc. There is always a limit to how many hosts can be attached. It also raises question why any number of PCs cannot be connected together in point-to-point manner. The point-to-point scheme provides separate communication channels for each pair of computers. When more than two computers need to communicate with one another, the number of connections grows very quickly as number of computer increases. Figure 4.9 illustrates that two computers need only one connection, three computers need three connections and four computers need six connections.

Figure 4.9 illustrates that the total number of connections grows more rapidly than the total number of computers. Mathematically, the number of connections needed for N computers is proportional to the square of N.

Point-to-point connections required = $(N^2 - N)/2$.

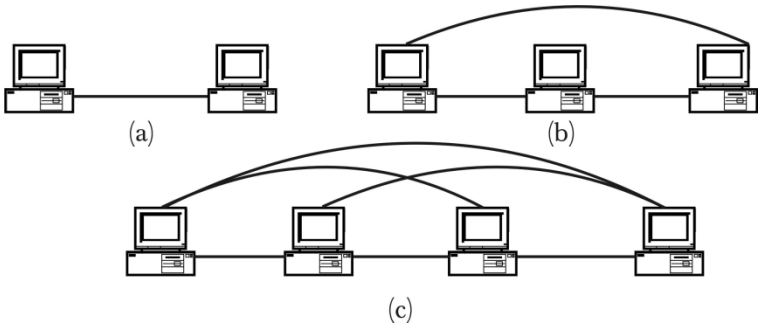


Fig. 4.9 *(a), (b), (c) Number of Connections for 2, 3, 4 Computers, Respectively*

Adding the Nth computer requires N-1 new connections which becomes a very expensive option. Moreover, many connections may follow the same physical path. Figure 4.10 shows a point-to-point connection for five computers located at two different locations, say, ground and first floor of a building.

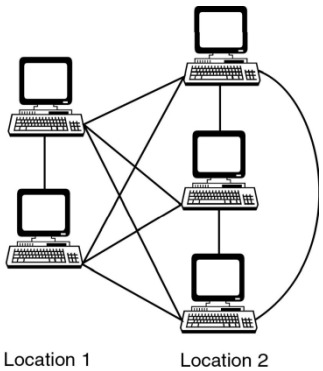


Fig. 4.10 *Five PCs at Two Different Locations*

As there are five PCs, total ten connections will be required for point-to-point connection. Out of these ten connections, six are passing through the same location and thereby making point-to-point connection an expensive one. Increasing the PC by one in the above configuration at location 2, as shown in Figure 4.10, will increase the total number of connections to fifteen. Out of these connections, eight connections will pass through the same area. Likewise, an Ethernet can connect up to only 1024 hosts. There is also a distance limit as Ethernet can span only 1500 meters which also restricts our aim to build a global network and to connect hosts of other networks. Like telephone exchange where a switch provides a connection with the party at the called end via circuit switching (to be discussed later on) instead of providing direct line-to-line connection as shown in Figure 4.10. Similarly, computer networks use packet switches (to be discussed subsequently) to facilitate the transfer of information in the form of small packets, even when no direct connection exists between those hosts. A switch is a device with several inputs and outputs leading to and from the hosts that the switch interconnects. Aswitch needs to perform several jobs to accomplish a connection successfully. These are store and forward, routing and congestion control. The subsequent discussion will describe the different types of switching techniques that are in use for data communication in computer networking. Figure 4.11 depicts a

view of switching network where any computer may exchange information with any other computer. This is the switching technology which allows us to establish a Wide Area Network or WAN and the Internet.

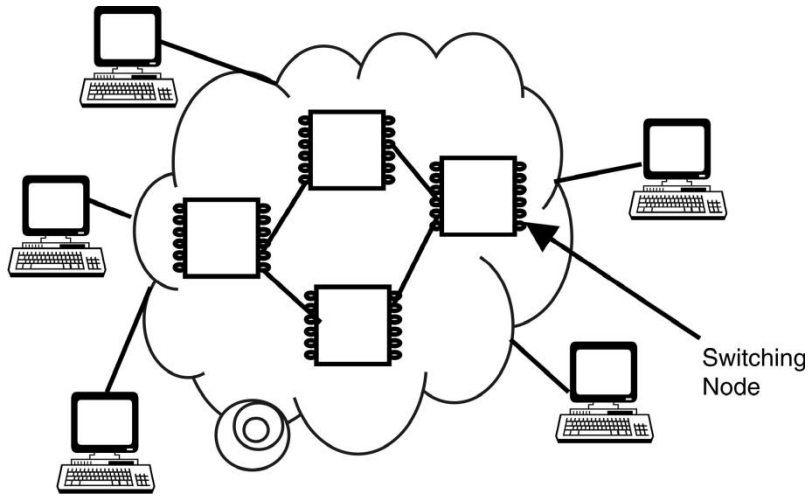


Fig. 4.11 *Switching Network*

Message Switching

Message switching refers to a method of handling message information over a channel through a switching node where the message information is stored and forwarded to reach the destination. A connection from the source to the destination need not be established. Figure 4.12 explains the concept of message switching by considering a connection between two sources and destinations DTEs Tx and Rx. A connection from Tx to Rx is having a number of links as Tx to Tx_1, Tx_1 to Tx_2, Tx_2 to Tx_3, Tx_3 to Rx.

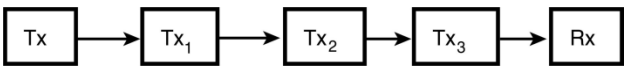


Fig. 4.12 *A Connection between Two Systems Tx and Rx through 3 Links*

Any message information transmitted from Tx traverses via Tx_1 and then to Tx_2, and so on, to reach the destination Rx. The Tx_1, Tx_2 and so on are the different message switch nodes which receive the message, store it and lastly forward the message to the neighbouring message switching node after making a connection with the near by message switch. It is also called store-and-forward switching as the messages are saved at intermediate nodes enroute to their destinations.

Transfer of Information using Message Switching

Figure 4.13 illustrates the transfer of message from Tx to Rx. A message is sent from one switching node to another when the link connecting them establishes a connection. Figure 4.13 also shows queuing delays, which occur because at the node there may be more messages which keeps this message in a queue waiting for the connection to be established. When the link is established, the message is stored and will be forwarded only when the next connection is established for the succeeding nodes. This process is repeated until it reaches its final goal.

Message switching is also employed in conjunction with circuit switching. Although message switching is still in use, it has largely been replaced by packet switched network.

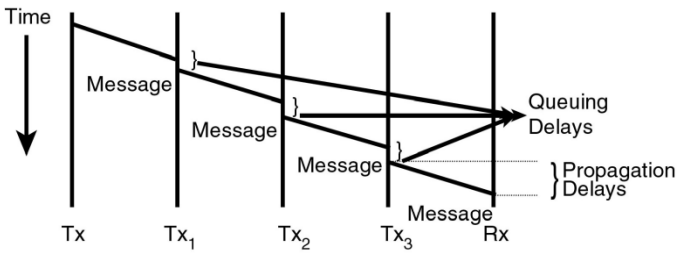


Fig. 4.13 *Transfer of Information using Message Switching*

The difference between packet switching and message switching may be understood by the size of packets. In case of packet switching, the size of packet is very short compared to the size of message in message switching. This short size packet takes less time and a sequence of packets does not require a dedicated connection for transmission of each packet. This means that packets of other messages are simultaneously send in between. Packet switching also extends its benefits through the pipelining in which a continuous flow of packets takes place from source DTE to destination DTE via intermediate switching nodes. Therefore, a link from source DTE to destination DTE and intermediate nodes are used to transmit packets simultaneously that enhances the channel efficiency and reduces the total delay for transmission across a packet network as compared to message switching.

Packet Switching

In packet switched data networks, the source Data Terminal Equipment (DTE) divides all user data that is to be transmitted into one or more message units called packets. These packets are of different length and each packet is given an address and the necessary control information. In each switching node, packets are received, stored briefly and passed on to the next node. Switching nodes are shown in the Figure 4.14 and Figure 4.15. The source and the destination DTE network addresses are included in these packets. Every switching node consists of a routing directory. This directory specifies the outgoing links to be used for every network address. The switching node receives each packet. After receiving each packet, it moves forward the packet on the appropriate link. It moves it at the maximum available bit rate. This is not possible in case of circuit switching. Each packet is received at each intermediate switching node along the route. Then it is forwarded on the proper link intermixed with other packets being forwarded on that link. The destination-switching node is determined by the address within the packet. The packet is passed to the destination DTE in the end.

When and When Not to Do Packet Switching

Packet switching is used for passing a message. The message (text, audio, etc.) is split into small chunks called packets before routing over the network.

Packet switching is done in the following situations:

- It works with the block data traffic called ‘packets’ of 128 bytes.
- Different messages use the same network resources within the same time period. Protocols are used to avoid wastage of resources when no data is transmitted. Packet switching is used efficiently in transmitting messages, such as e-mail messages and Web pages.

- When network load is distributed to multiple switching sites, the additional communication lines are also attached to the switches. This allows alternate routing which avoids failed or busy nodes.
- It works with the help of data communication traffic using devices, such as keyboard terminals that transmit traffic. When data is sent to the idle node, it produces wasted line capacity. So, packet switching interleaves into the channels.
- It uses multiple user sessions on a single communication port on the computer. Therefore, instead of dedicating one port to one user, it interleaves the bursts of traffic from multiple users across one port.
- Packet switching also works to connect the terminals and computers together for a session because dedicated leased lines are available for multiple users to transmit and receive data packets as well as switches. It facilitates the slow connected time which is associated with multiple telephone circuit switches because leased lines are very expensive and are used for applications that cannot tolerate dialling delays.

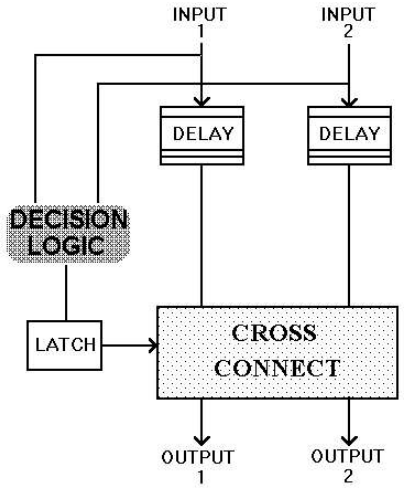


Fig. 4.14 *Set-up for Packet Switching*

- Packet switching is done with ITU-Ts X.25 standard because it provides several interface options for connecting users to the network including reverse charge, call and delay negotiations.
- Conventional cellular radio and landline telephony use circuit switching. Services like Cellular Digital Packet Data or CDPD, by contrast, employ packet switching. General Packet Radio Service or GPRS, Bluetooth and some aspects of 3G also use packet switching.
- It contains a vendor's proprietary routing protocol tagged with X.75 gateway protocol having a large number of public packet networks.

Packet switching is not done in the following situations:

- Whenever there is one or a combination of three arrangements, such as more input lines than output lines (concentration), more output lines than input lines (expansion) and an equal number of input and output lines (connections), then packet switching is not used. Network designers use circuit switching and message switching instead of packet switching.

- When there is a path for the session between data communications components, such as error checking, session establishment, frame setting and frame flow control without data traffic, then packet switching is not used.
- Other switching options are used to provide additional facilities value added carrier, such as network vendor for basic transmission media, store-and-forward services and protocol conversion.
- It is also not used when the messages temporarily on network are queued on the lower-priority traffic denying peak periods. Queuing is the process in which it decreases the chances of traffic being blocked because of network congestion.
- When network conducted switching types perform polling and selection functions to manage incoming and outgoing traffic, packet switching is not done.
- Conventional cellular radio and landline telephony use other types of switching for network accessing because they dominate PSTN (Public Switched Telephone Network) and they do not care about router set-up and path. Voice data is sent from local loop which hits a telephone switch. In other types of switching networks, a set of resources is allocated so that data must be transmitted quickly for real time data, such as audio and video. Figure 4.15 shows the other option for switching over network.

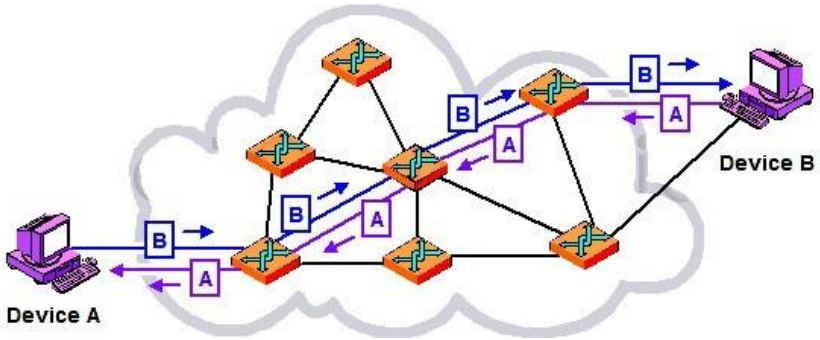


Fig. 4.15 *Other Option of Switching over Network*

Circuit Switching Techniques

Circuit switching is a switching method in which a dedicated communication path in physical form between two stations within a network is established, maintained and terminated for each communication session. It has basically three phases as circuit establishment, data transfer and circuit disconnect. Once the connection is established, the data transfer is transparent. The central aspect of such connections is not only to provide a fixed data rate channel but also that both subscribers must function at this rate. It is considered inefficient compared to packet switching because channel capacity is completely dedicated for duration of connection. If there is no data at any moment of time, channel capacity goes wasted. Moreover, setting up of connection takes time. These differences may be more evident when you will learn about the packet switching.

Circuit switching is a type of communication method in which a dedicated communication path is established between two devices through one or more intermediate switching nodes. Most widely used example of circuit switching is Public Switched Telephone Network (PSTN), which finds extensive use in both voice and data communications today. The major disadvantage of this communication technique lies in its 100 per cent dedicated connection that offers poor efficiency.

You may again recall that while setting up the circuit in order to transfer information, a point-to-point connection is established from endpoints to node with the deployment of internal switching/multiplexing among nodes. Whenever the sender and the receiver wish to disconnect the circuit, they do so. In this manner, a 100 per cent reliable connection is set up between the sender and the receiver but at the cost of scarce network resources.

As we know, circuit switching employs a circuit-switching node, which is a full duplex, digital switch providing transparent signal path between any pair of attached devices. It maintains connection at the convenience of users and breaks off the connection on completion of the transfer of message. A circuit switch is shown in Figure 4.16.

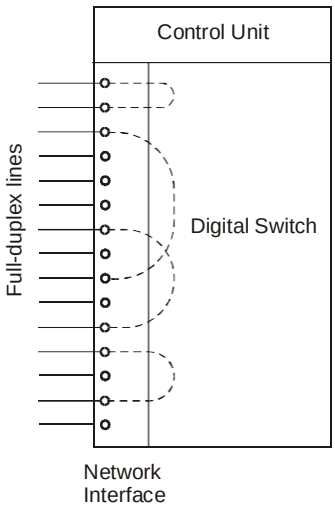


Fig. 4.16 *Circuit Switch*

Other Switching Techniques

The following are the various other switching techniques:

Space-Division Switching: This kind of switch was specially developed for an analogue environment. Subsequently, it was also used for digital communication. The characteristics of these types of switches are that they require separate physical paths for each connection and use metallic or semiconductor gates. Crossbar switches and close network switches are the examples of space division switching.

Crossbar Switch: It is the simplest possible space division switch where each packet takes a different path through the switch depending on its destination. Cross points are used to show the busy point or free point.

Figure 4.17 shows crossbar connections where a crossbar session has been illustrated. The advantages offered are that it is simple to implement and control and is non-blocking, etc. The disadvantages are the many cross points which acquire large VLSI space. It is also vulnerable to single faults. Crossbar switch has the simplest switch fabric and is much faster than a bus-based switch. The cross-points are used to transfer a packet from an input to an output. An arrival pattern for fixed-size packets enables advance computing schedule.

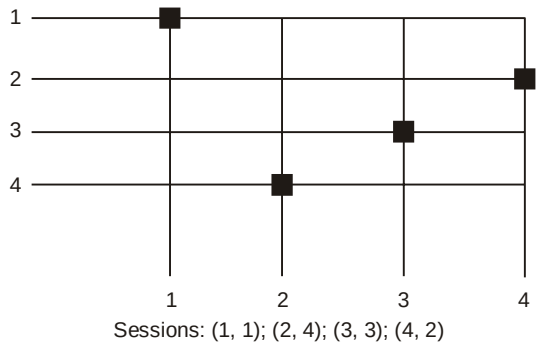


Fig. 4.17 *Crossbar Connections*

Time Division Switching: This technique, based on multiplexing, was developed for digital transmissions. Due to multiplexing, all transmitted signals are time multiplexed to be carried by a single transmission path. The transmission media must have a better throughput than individual I/O lines.

Routing in circuit switched networks is hierarchical. Peer-to-peer trunks are also used at some places. Dynamically routed circuit switched networks are also in use which use all nodes as peer-to-peer, and thus, make routing more complex. However, in circuit switching, communication intended routes between two end points are predefined so as to enable the originating switch to select the best route for each call. The routing paths can be fixed or dynamic.

In managing the establishment, maintenance and termination of signal paths, control signaling is used which includes signaling from subscriber to network and signals within network. Again signaling may be in-channel or common channel for the same channel or independent channels respectively.

Time Space Time (TST) Switching: It allows sending messages both on input and output trunks and is therefore more flexible. This feature gives it a lower call blocking probability.

Telephone Networks

The earliest electronic network is the telephone system. This is shown in Figure 4.18 (a). This telephone network commonly uses analogue technology that was quite different from digital technology used in the computer based networks. The advantages of digital technology over the analogue technology in terms of economics and services forced the telephone industry to move rapidly to install fiber and digital networks. The telephone network transmits analogue signals and, hence, a modem is required whenever a computer or terminal is connected to the telephone line as shown in Figure 4.18 (a). The modem then converts digital data from a computer to an analogue signal that can be transmitted via a telecommunication line and converts the analogue signal received to computer data.

Dial-Up Telephone Networks

The telephone network consists of the subscriber's line, switchboards and trunk lines as shown in Figure 4.18 (b). Each subscriber line has an address, i.e., telephone number. When a caller transmits a dial signal to the switchboard, the switchboard connects the caller's subscriber line to that of the receiver, enabling communication. The trunk line between the caller and the receiver is occupied until either discontinues the communication.

When the telephone system is used to connect to a network, it becomes necessary to dial the telephone number to select the target device on the network as shown in Figure 4.18 (b). A device called Network Control Unit (NCU) performs this and most of the available modems, include this NCU.

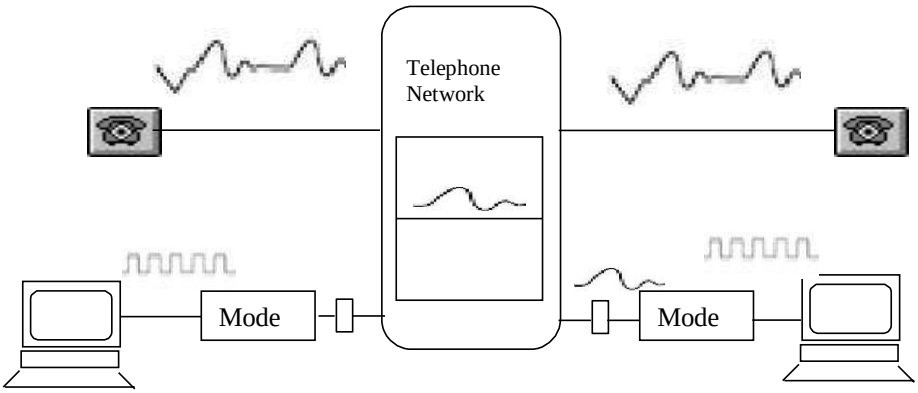


Fig. 4.18 (a) *Telephone Network*

The Computer Communication System – An example

The computer communication system is an example of a system using the telephone network as shown in Figure 4.18 (b). The system is used to send and receive mail, connect to the Internet if the account is TCP/IP, post messages on a Bulletin Board System (BBS) by accessing the host computer system of a ISP through telephone network.

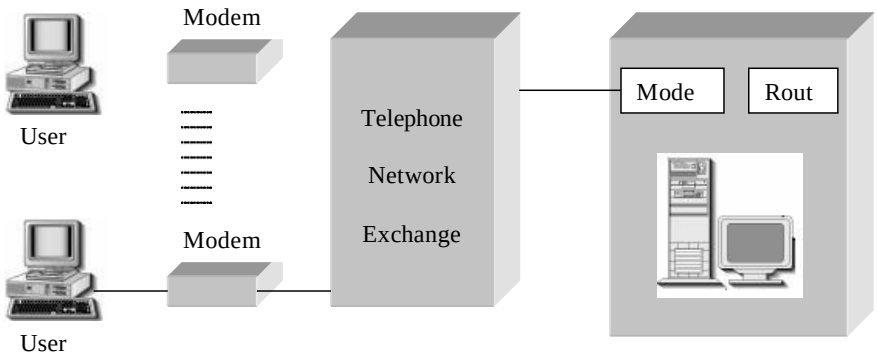


Fig. 4.18 (b) *An Example of a System using Telephone Network*

The following are the advantages and disadvantages of telephone networks.

Advantages

- It is circuit switching network, therefore, any receiver can be selected and there is virtually no transmission delay.
- As it is widely spread, it is available at a low price.

Disadvantages

- It requires a long time for connection. A dial-up operation is necessary before the line can be connected to the receiver. This dial-up time is too long to use in data communication systems.
- It has low transmission speed.

- The line quality is not sufficient for data transmission, and is, therefore, not appropriate for high-speed data transmission because telephone lines were originally developed for audio communication.

Telephone Network Standards

The V Series Recommendations from the ITU-T include the most commonly used modem standards and other telephone network standards. Prior to the ITU-T standards, the American Telephone and Telegraph Company and the Bell System offered its own standards (Bell 103 and Bell 212A) at very low transfer rates. Another set of standards, the Microcom Networking Protocol, or MNP Class 1 through Class 10 (there is no Class 8), has gained some currency, but the development of an international set of standards means these will most likely prevail and continue to be extended. Some modems offer both MNP and ITU-T standards.

In general, when modems handshake, they agree on the highest standard transfer rate that both can achieve.

Leased Lines

A computer can be connected permanently to the Internet using leased lines as shown in Figure 4.18 (c) in addition to a modem and router. These lines are based on speed of the connection, installation cost, and recurring monthly charges.

An example of usage of leased line is a system in which only one terminal is connected to the host computer. Though multiple computers/terminals using multiplexing can be connected to one system via a single leased line. It uses FDM for an analogue leased line or TDM method for digital leased line. DSU (Digital Service Unit) is used instead of modem for digital line. Leased lines may also be used to connect LANs.

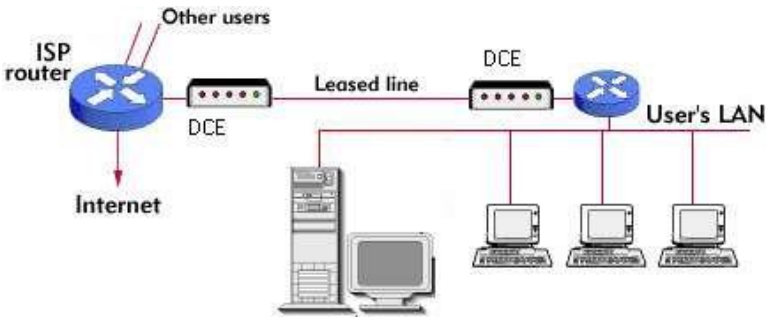


Fig. 4.18 (c) *Leased Line Configuration*

Telephone networks are intended to transmit analogue signals. It uses Layer 1 (Physical Layer) of the OSI model as shown in Figure 4.18 (d). It is the service to provide physical media. Therefore, telephone networks can carry any type of protocol data. The data transmission speed depends on the performance of the modem and quality of the line.

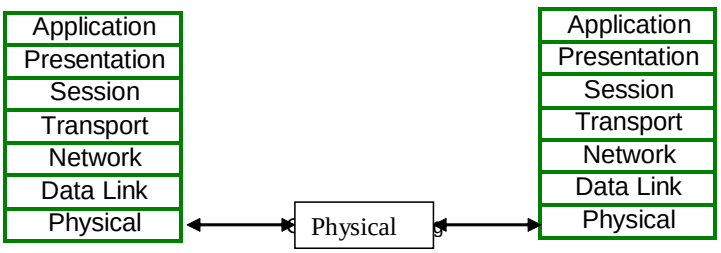


Fig. 4.18 (d) *OSI Model for Telephone Network*

Each telephone user or the subscriber is directly connected to a switch in the central office. This wired connection is called the **local loop**. The standard length of local loop is 1 – 10 km. The switches in the central office to which these local loops are connected are called local exchange. The company which provides local telephone service is termed as a Local Exchange Carrier or LEC, for example Bell Atlantic. A PBX (Private Branch eXchange) is a telephone system which is specifically designed for an enterprise for switching calls within the enterprise on local lines. PBX also allows the users to share a certain number of external lines of the central office. The core function of a PBX is to save the cost by providing shared line for the users to the telephone company's central office.

Thus, the telephone network includes the telephone connection given at home which is connected through the local loop to the central office. Consequently, the central office is connected to the Public Switched Telephone Network (PSTN). For example, consider that Mr. Vikas is a telephone customer of some central office and has a home telephone number of XXX-XXXX. When he calls any number from his home, the call first goes to the central office that has been assigned the first three digits or prefix of this local number. Central offices may have many prefixes but each prefix is specifically held by one assigned central office, for example Central Office 1. The dedicated wire connections are set from the central office to Mr. Vikas home which are used only by that telephone number and are not shared with any other customers. This dedicated pair of wires is called a line circuit or local loop. The call is initiated just by lifting the handset off the telephone which completes a circuit in the telephone and permits current to flow through the loop. This signals the assigned central office that Mr. Vikas wants to make a call.

Upon detecting a current in the local loop, the central office searches for an unused dial register to store the dialed digits. When the register is connected the dial tone is sent to the home telephone number of Mr. Vikas. Upon hearing the dial tone, the subscriber Mr. Vikas dials the desired telephone number.

The central office recognizes this dialed number. If the dialed number belongs to same location (local number) then the call is matured, but if the dialed number contains prefix that is not in the jurisdiction of this central office then the call will not be matured because it will need a trunk service. The central office has some limitations so it cannot directly serve this number. It then looks for a **trunk** (interoffice line) that will connect it to another specific central office (which is in another location) so that the desired call is matured. A trunk circuit provides a signal path between two central offices. Unlike a line circuit or local loop, a trunk circuit is shared by many different subscribers although only one uses a trunk circuit at any given time.

Public Switched Telephone Network (PSTN)

PSTN or Public Switched Telephone Network relates to the public telephone network. It is based on circuit switched connection and can be compared to the Internet terms, referring to a public IP network based on a packet-switched connection. The term PSTN was initially used for fixed-line analogue telephone system but nowadays, due to the advancement in technology, it is also referred for digital circuit- switched telephone network including both mobile and fixed. ITU-T technical standard and an addressing rule (telephone number) E.163/E.164 are followed by the PSTN.

PSTN is the global compilation of interconnects made for assisting circuit switched voice communication. The conventional Plain Old Telephone Service (POTS) is provided by PSTN to dwellers and to various enterprises.

Some of the DSL, VoIP and other Internet-based network technologies also make use of some parts of PSTN .

Almost 64 Kbps bandwidth is supported by the basic PSTN network link. The PSTN lines, in case of residences, are in the form of copper cables transferring the data in such a bandwidth. The dial-up modems make use of 56 Kbps of the total bandwidth while joined to the phone line. The Signaling System#7 (SS7) signaling protocol is used by the PSTN.

The evolution PSTN has gone from analogue technology to digital technology. In analogue technology, the data delivery is directly based on the accessible data. Contrary to that, the digital technology Involves sending data after it has been manipulated into the digital format. DSL (Digital Subscriber Line), ISDN (Integrated Services Digital Network), FTTX (Fiber To The X) and cable modem systems are some forms of digital PSTN.

PSTN require 64 Kbps channel as the vital digital circuit which also known as digital signaling 0/DS0. SS7 is used as a communication protocol between telephone exchanges by which the calls are routed to the destination. Being a circuit switch base communication protocol, SS7 includes all the accessible resources which are used by a single dedicated call connection.

A limitation to the PSTN capacity is DS0, as it is a natural Time Division Multiplexing (TDM) that implies that every call data mix with one another that is time based. In PSTN, the delivery is usually done through multiplexing of various DS0 together with DS1 for optimizing the transmission. DS1 can be sub-divided into two parts, namely, 24 DS0, also called as T1 that is located in North America or Japan and 32 DS0, also called as E1 that is in most of the other countries. Both T1 and E1 are known as the transmission type. The hardware of PSTN can handle only one transmission type due to which it always requires a hardware base that needs to be bought on the transmission plan.

ISDN and other non-PSTN services have comparatively more speed and acquire features due to which they are more preferable for using the Internet. For instance, while using a non-PSTN service like ISDN or DSL, voice and data can be used simultaneously with the use of only one line instead of getting another phone line for accessing the Internet which is the case with other services.

PSDN

Public Switched Data Network (PSDN) is a network that is accessible to the public. It assists packet switched data as well as PSTN.

Earlier PSDN was termed as PSS (Packet Switch Stream) that was a X.25 based packet switched network. The basic purpose of PSS was to present leased line connections between LANs and also the Internet with the help of PVCs (Permanent Virtual Circuits). Now, as technology is advancing day by day, PSDN is not only limited to frame relay and ATM (Asynchronous Transfer Mode) that are as providers of PVCs, but also extended to various other packet switching methods like IP, GPRS, etc.

By watching the working of PSDN, one may consider it to be a replica of the data networks, such as ISDN (Integrated Services Digital Network), ADSL (Asymmetric Digital Subscriber Line), SDSL (Symmetric Digital Subscriber Line) and VDSL (Very-high bitrate DSL). However, a closer study of PSDN shows that it is a lot more than these. The PSTN circuit switched network is used by ISDN whereas,

DSL is point-to-point circuit mode communication services imposed over the PSTN local loop copper wires, commonly used for entry to a network of packet switched broadband IP.

The Integrated Services Digital Network (ISDN)

ISDN, which is short for Integrated Services Digital Network, is a set of CCITT/ITU standards used for digital transmission over ordinary telephone copper wire and other media. This technology uses ISDN adapters in place of modems and provides very fast speed up. ISDN requires adapters at both ends of the transmission.

In reality, a widespread network with the potential to deliver at high data rates is required to deliver multimedia. Currently, ISDN is implemented in the form of the narrow band. This is the best medium available for access and delivery. Many in the industry consider ISDN as the tool for promoting multimedia, a channel through which multimedia will gain acceptance. The governments of various countries are coming out with plans and policies to implement ISDN as soon as possible.

Integrated Services Digital Network in concept is the integration of both analogue or voice data together with digital data over the same network. ISDN integrates these on a medium that is designed for analogue transmission. However, Broadband ISDN (BISDN) will extend the integration of both services throughout the rest of the end-to-end path through fiber optic and radio media. Broadband ISDN will comprise frame relay service for high-speed data capable of being sent in large bursts, the Synchronous Optical NETwork (SONET) and the Fiber Distributed Data Interface (FDDI). BISDN will support transmission from 2 Mbps and much higher but unspecified rates.

Definition of ISDN

ISDN is a network architecture in which digital technology is used to convey information from multiple networks to the end-user. This information is end-to-end digital.

Features

The features of ISDN are as follows:

- It offers point-to-point delivery.
- It has network access and network interconnection for multimedia.
- Different data rates from 64 Kbps up to 2 Mbps are commercially available which can meet many needs for transporting multimedia and is four to many times more than today's analogueue modems.
- Call set-up times are under one second. ISDN can dramatically speed up transfer of information over the Internet or over a remote LAN connection, especially rich media, like graphics, audio or video or applications that normally run at LAN speeds.
- ISDN will be the feeder network for broadband ISDN based on ATM standards.

Although ISDN could be cheaper, particularly in the case of widespread use, it is likely to be cheaper than ATM connections and more widespread in availability for a long time. It is, therefore, an important tool in bringing multimedia applications to a wide range of users.

There are two forms of ISDN service: narrow band and broadband.

Narrow Band ISDN

Narrow band ISDN is digital service where the transport speeds are 1.544 Mbps (T1) or less. Narrow band ISDN provides for the following services:

- **Circuit Switched Voice:** Circuit switched voice service is a digital voice service that offers many of the capabilities of a business. It is centered over a 4-wire ISDN Digital Subscriber Line (DSL).
- **Circuit Switched Data:** Circuit switched data service provides end-to-end digital service to pass data or video information over the public network. ISDN uses out-of-band signaling to establish and maintain data connections, which require special processing.
- **Low Speed Packet:** ISDN lines are equipped with a packet connection that is used to manage ISDN connections. This monitoring capability is provided by using the D channel on a DSL. The D channel is a 16 Kbps X.25 connection that is also capable of passing low speed packet while also relaying call processing information.
- **High Speed Packet:** ISDN lines are also equipped with two B channels. Each B channel is a 64 Kbps channel that can be used for circuit switched voice, circuit switched data, or high-speed packet service. To provision high speed packet service one or two of the 64 Kbps B channels are connected (permanent virtual circuit) to the packet network thus providing a 64 Kbps X.25 connection.

Broadband ISDN Service

Broadband ISDN Service is a digital service in excess of 1.544 Mbps. This digital service can be in the form of Frame Relay, SMDS, or ATM. Broadband ISDN is the service of the future. The higher speeds offered are required to support the many applications of the Information Super Highway. The range of speeds for the Broadband ISDN services usually range from 25 Mbps up to the Gigabit range. The two speeds that are most often discussed are OC 1 that is 155 Mbps and OC 3 that is 622 Mbps.

ISDN Standards

Products for ISDN technology from different vendors even with similar features and options may create some compatibility issues. CCITT after good deliberations over the years published the first significant ISDN standards in a number of red binders in 1984 and they were simply known as the Red Book standards. The group subsequently met four years later which culminated in the publication of the 1988 Blue Book standards. These international publications were the foundation for the evolving ISDN national standards. The CCITT eventually was reformed into the group, which is now called the ITU–T. The standards used to define ISDN make use of the OSI reference model with the first three layers of this OSI reference model.

The two standard ISDN connectors are used as follows:

(i) To access basic rate ISDN, an RJ 45 type plug and socket (like a telephone plug) is used through unshielded twisted pair cable.

(ii) To access primary rate ISDN a coaxial cable is used.

The ISDN passive bus whose maximum length can be 1 km is a cable in user premises. It allows the attachment of up to eight devices to the basic rate ISDN interface. As only two B-channels are available, only two of the eight devices can

communicate at any one time. Therefore, each device is required to compete for access to the passive bus.

The equipment available for ISDN includes the following:

- Video conference PC cards
- Gateways or bridges for LAN access (of which some are based on PC cards or stand alone boxes)
- Terminal adapters
- ISDN internal computer terminal adapter cards

ISDN internetworking equipment

ISDN can be used by many different Internet working devices, such as follows:

- **Terminal Adapters (TAs):** These are external devices that help in connecting X.21 and other conventional data interface to an ISDN circuit. This allows non-ISDN equipment to use the ISDN. Terminal adapters are used by internetworking manufacturers without an approved native ISDN interface for their devices.

  A demerit of this solution is that all information from the D-channel does not pass through the TA. Therefore, full advantage of ISDN facilities cannot be taken by the non-ISDN equipment, such as Calling Line Identification (CLI).

- **ISDN Bridges:** Being rather simple, bridging is amongst the most popular and commonly used methods of linking LANs. One major problem faced with ISDN bridging is the control of its use of the ISDN network. Bridges are simple to set up and use as they forward broadcasts and similar data by default. This implies that over ISDN, calls will be made to convey non-essential data which might prove to be costly in the long run.

  This can be avoided if bridges are configured in such a way that broadcasts from particular addresses are blocked and certain protocols are understood. However, the major plus point of bridges, that is, simplicity, is lost. Bridges are appropriate for backing up ISDN.

- **ISDN Routers:** A much more effective technique of utilizing ISDN for LAN networking is routing. It is the approach adopted by all networking vendors. Data is transmitted over the ISDN network only when it is actually required. In other words, unlike bridges, only necessary broadcast messages are sent to ensure efficient and effective use of bandwidth. It is possible to simplify the configuration. Unnecessary traffic is blocked out using filters.

Merits

(i) High Quality – ISDN connections are digital pipes with low error rate.

(ii) Flexible – ISDN connections can be established between two locations at any time provided the locations have ISDN which is like a configured leased line. It offers an almost transparent and quick call set-up. Therefore, for most users, the nature of dial-up is transparent.

(iii) Economical – Rent is payed for ISDN just as in a telephone call. The cost of using ISDN is similar to that of the

telephone service. It is quite cost-effective when it comes to intermittent LAN to LAN connectivity.

(iv) Widely Available – ISDN is now available widely following government initiatives in various countries.

Internet Service Providers (ISPs)

Internet Service Provider (ISP) is a company that access Internet services. This service provider provides a software package in which you get registration with the providing services. Once you registered with username, password and dialing phone number, you can access ISP by paying the monthly fee. This software package is equipped with modem that is connected with Internet services. Good ISPs have their own leased-line provided by telecommunication providers. Some of the largest and popular ISPs are At&T WorldNet, MCI, IBM Global Network, UUNet, PSINet, Netcom, etc. It is sometimes known as Internet access provider. There are 183 ISPs in India. The Table 4.1 shows the list of ISPs having all India license.

Table 4.1 *ISPs in India*

BSNL	RPGInfotech	Gateway systems	RailTel Corporation	i2i Enterprise
CMC	Sifi	ERNET India	GTL	Tata Power Broadband
Essel	VSNL	Jumpp India	Bharti Infotel	RailTel Corporation
Astro India Network	Primus Telecommunication India	Siti Cable Network	World Phone Internet Services	Escorts Communication
Reliance	L&T Finanace	In2Cable (India) Reliance	Spectra Net Reach	Estel Communication

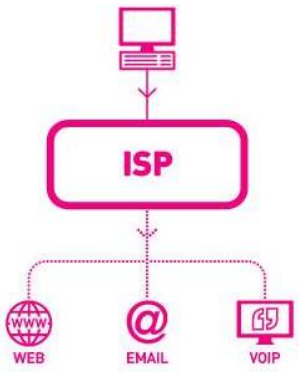


Fig. 4.19 *Services of ISP*

In the Figure 4.19, ISP provides web, E-mail and VoIP, etc., as main services. ISP includes domain name registration and hosting, Internet transmit, dial-up or DSL access, lease-line and collocation. You can take your domain name, secured website and high-availability web servers with this facility. Suppose, a firewall is implemented with two separate Ethernet interfaces. The following Figure 4.20 shows how two ISPs are connected with the Internet.

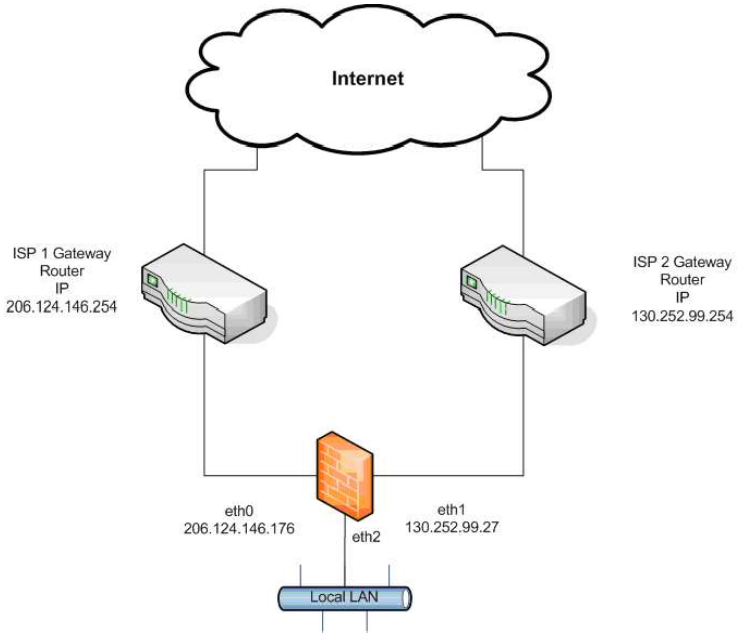


Fig. 4.20 *Two ISPs Connected with Internet*

The explanation can be analysed as follows:

- The Ethernet eth0 connects to ISP1. The IP address of eth0 is 206.124.146.176 and ISP's gateway router has address as 206.124.146.254.
- The Ethernet eth1 connects to ISP2. The IP address of eth1 is 130.252.99.27 and ISP's gateway router has address as 130.252.99.254.
- The Ethernet eth2 connects to local LAN.

Function of ISP

Commercial ISPs easily access and communicate with individual or various organizations across net. They are facilities-based carriers, for example, telephone and cable companies. The interconnected routers are assembled with ISP known as autonomous system (AS). ISP operates AS to information providers via Google and Yahoo search engines. They exchange traffic networking from other network. This process is called peering. The networks are connected to Internet Exchange (IX).

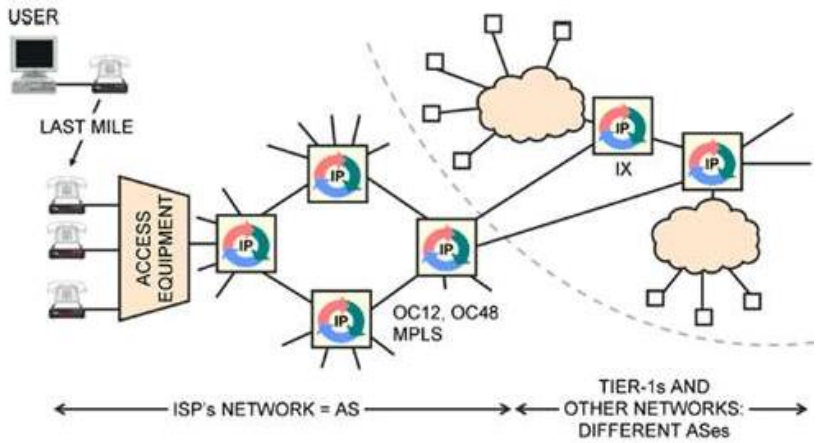


Fig. 4.21 *ISP Network*

In Figure 4.21, ISP interconnects with IX providing Tier-1 and other networks. The Tier-1 network provides the largest service with reference to ISP. Peering is settlement free, therefore, no money transaction is done between ISP and commercial business houses.

COMMUNICATIONS DEVICES

The basic meaning of hub is 'centre.' We know that the central part of a wheel is called a hub. But this term is used not only in a mechanical system but also in electrical, electronics and computer systems. A node in a computer network is also called a hub. In computer network, a hub is a physical device that serves as a central connection point to the network devices and thereby connects them to each other. A USB hub connects many USB devices through a single port. Hubs are the central points for interconnectivity of Local Area Networks (LANs), particularly in a star topology.

Hubs are the most commonly used networking hardware devices. Since hubs are expensive they are being replaced by switches which are comparatively cheaper. As such a hub contains no active electronics. A hub cannot extend a LAN beyond its specified cabling distance. But hubs organize cables. They faithfully relay data signals to computers connected to the LAN in the system.

Hubs are used with twisted pairs. Ports available on the hub connect devices on the network. Computers and devices are connected to individual ports via network cables through the hub. When there are LANs that outnumber the size of a hub, another hub can be used by attaching it to the existing hub using a short cable. This is called daisy-chaining.

Hub contains a number of ports which are usually 4, 8, 16 or 32 in number. They simply recover incoming data to the port in a binary form, and transmit these to the other ports. A hub, like a repeater operates at the physical layer of the OSI reference model, and for this reason it is also known as a multiport repeater. A hub does the job of connecting machines together, in a star topology. All communication received or sent by the machine comes through a hub.

There are broadly three types of hubs: active, passive and intelligent.

Active hubs are those that are connected to a source of electrical power. These refresh signals before sending them to the ports. Passive ports are those that simply forward the signal to all the connected hosts, as it is. Intelligent hubs detect errors and also act like active hubs.

Passive hubs do not amplify the incoming signals prior to their broadcast. Active hubs, on the other hand, amplify signals like a repeater. A passive hub is also called a concentrator and an active hub is termed as a multi-port repeater.

Intelligent hubs have extra features over and above an active hub. An intelligent hub is stackable having capabilities of remote management via SNMP. It is also supported by a virtual LAN (VLAN) support.

Connecting Multiple Hubs

To centralize many machines several hubs can be connected in a daisy chain. For this, hubs have to be connected using a crossover cable, a special cable, which links ports at both the ends. Hubs contain a special port. This port is known as an uplink. This connects two hubs through a cable known as a patch cable. This is illustrated in Figure 4.22.

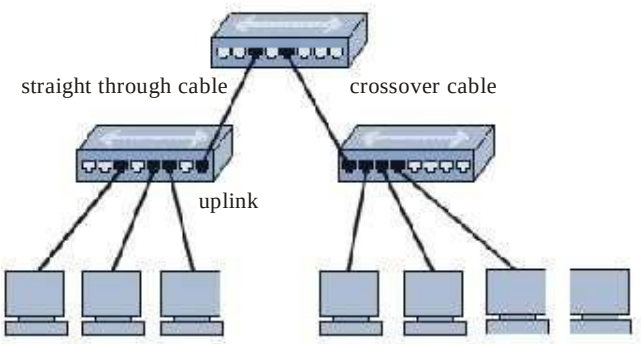


Fig. 4.22 *Connecting Multiple Hubs*

Ethernet Hubs

4-port Ethernet hub

Several hubs are available that cater to the different needs of users. Hubs come with a BNC and/or AUI connector to connect to 10BASE2 or 10BASE5 network segments. Now-a-days low-priced network switches have come to the market making hubs obsolete. All the same hubs are being used in older or specialized installations.

A network hub is a simple broadcast device does which does not manage traffic and packets that enter any port are broadcasted on all the ports connected to it. This may result in collisions of packets causing a problem in the smooth flow of traffic. For this reason there is a limit on the number of hubs used depending on the network. As a thumb rule if the network has a speed of 10 Mbit/s, up to five segments (four hubs) are allowed between end stations. For a higher speed of 100 Mbit/s the limit gets reduced to three segments (two hubs). But this requires hubs to be of low delay variety. A few hubs may have special ports that are stacked allowing them to combine to allow more hubs. But a big network operating on Fast Ethernet will require switches to ride over this limit.

Bridge

Like repeaters, bridges are used to connect similar LANs together. Bridges operate on the two lowest layers of the OSI model, namely, the physical layer and the data link layer as shown in Figure 4.23. As it operates on the second layer of the OSI model, it relays only necessary data to other signals. MAC addresses (physical addresses) are used to determine whether data is necessary or not. It passes information from one segment of LAN to another as per the destination address in the packet. When a bridge receives data through one of its ports, it checks the data for a MAC address. If this address matches that of the node connected to other port, the bridge sends this data through this port. This action is called forwarding. If the address does not mach with any node connected to other port, the bridge discards it. This action is called filtering. This is shown in Figure 4.23. Unlike repeaters, bridges have buffers. These buffers store packets them when the traffic to the destination link is congested and forwards it later on.

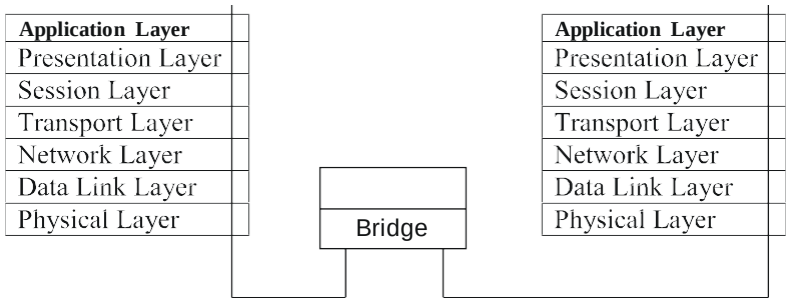


Fig. 4.23 *Bridge and OSI Reference Model Correspondence*

The main advantage of bridge over repeater is that it has a filtering action. If any noise occurs in the electrical signals of an Ethernet because of collision or disturbance in the electrical signal, the bridge will consider it as an incorrectly formed frame and will not forward to the segment connected to other port of the bridge. Note that a bridge can relay broadcast packets and packets with unknown destinations.

In the previous section, we have seen that a maximum of four repeaters are used to connect multiple segments of Ethernet. However, if a bridge is provided between repeaters, this limit is increased. There is no specific limit on the number of bridges that are used.

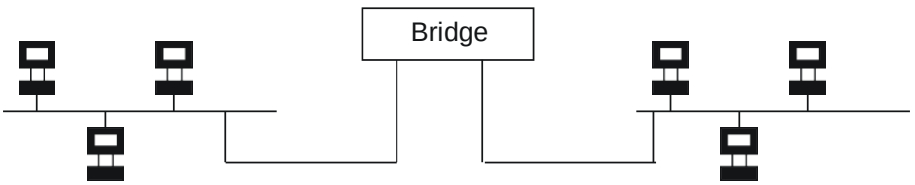


Fig. 4.24 *Bridged LAN Network*

From the architectural point of view, bridges are protocol independent devices and are very simple. No complex processes, such as the evaluation of the network as a whole in making decisions on end-to-end routing, are carried out on the data packets that travel through them. They only read the destination address in the data packet before forwarding it to the next link. Therefore, these devices are inexpensive and fast. There are bridges called cascading bridges that are used to support multiple LANs which are connected by multiple media.

Dissimilar LANs can also be connected with the help of a bridge known as encapsulating bridge. Ethernet-to-token ring is an example of dissimilar LANs. The function of encapsulating bridge is also very simple. It encapsulates the originating LAN data along with the control information of the end user LAN.

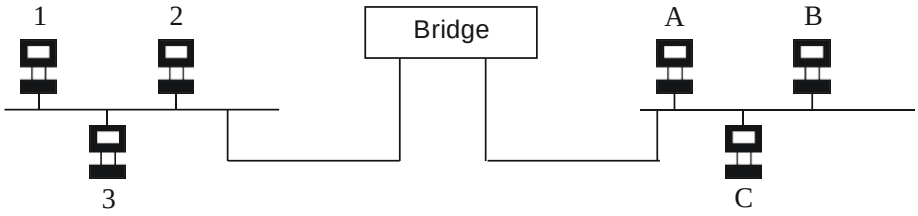


Fig. 4.25 *Filtering and Forwarding in Bridged Network*

Computer 1 in the Figure 4.25 wishes to talk to computer 3 on the same network. The packet sent by computer 1 will contain the physical address of computer 3 which will also be received by the bridge device connecting the two LAN segments. The bridge will read the physical address contained in the packet and observe that this address belongs to the computer on the same LAN segment. Hence, a bridge will filter this packet and will not allow it to be transmitted to the other side of the network. In case Computer 1 wishes to talk with computer C on the other segment, the bridge will know from its table of addresses that this address belongs to the computer attached to the other segment of the network. In this case, the packet will be forwarded to the other segment of the LAN. The bridge learns the location of computers attached to the network by watching frames. Note that in case of broadcast and multicast packets, bridges forward these packets to all the computers that are attached to the segment on both the sides.

Media Access Control (MAC) Bridge

This is used to connect dissimilar LANs. Ethernet-to-token ring are dissimilar LANS that use encapsulation or translation. This bridge translates the original packet format from the requesting LAN segment. For this, control data that are specific to the protocol of the destination LAN segment are encapsulated.

Address table

As explained above, each bridge should have an address table that indicates the location of different computers or nodes on the LAN segments. More specifically, it indicates the connection between nodes and ports. When a bridge is booted for the first time, this table is found to be blank. How this table is filled with appropriate addresses of the different nodes that are attached to the ports is a pertinent question. Most of the bridges are called adaptive or self-leaning bridges because they learn the location of the node and associated port themselves and make a list of the nodes attached to each segment.

When a data packet is received by a bridge from a computer, it copies the physical address of that computer contained in the packet to its list. Afterward, the bridge determines whether this packet should be forwarded or not. In other words, the bridge learns the location of the computer on the network as soon as the computer on the network sends some packet.

If a computer does not send a packet, the bridge will never be able to determine its position and unnecessarily forwards the packet on the network. Fortunately, this cannot happen because a computer with network software attached to a network

transmits at least one frame when the system first boots itself. Furthermore, computer communication is bi-directional, there is always an acknowledgement for each received packet.

Bridge Protocols

There are three bridge protocols: spanning tree protocol, source routing transparent protocol and source routing protocol.

Spanning tree protocol (STP) bridge

These are adaptive or self-learning bridges. They are defined in standard IEEE 802.1. Ideally, in a bridged network, only one link is provided in the network tree of the bridge for each LAN-to-LAN connection and, therefore, no network which has bridges can form a loop. Sometimes looping can occur. This can be explained with the help of Figure 4.26.

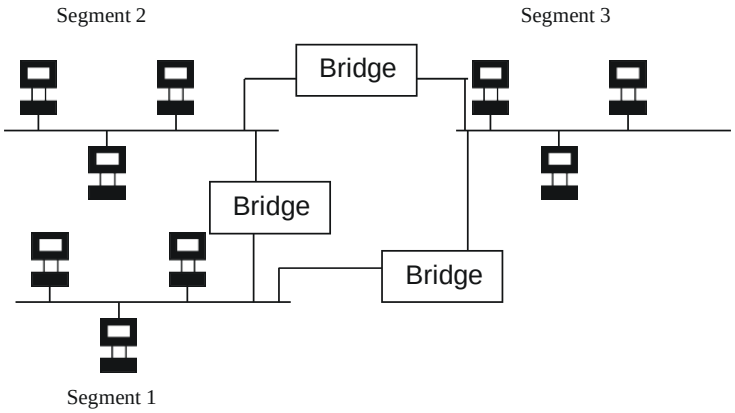


Fig. 4.26 *Loop in a Bridged Network*

A broadcast data packet sent by the computer attached on segment 1 can reach all computers attached on segment 2 and 3 without a connection between segment 1 and 3 as shown in Figure 4.26. Sometimes, the bridge connection between segment 1 and 3 or like is provided to give the network more redundancy. Now in this case the same broadcast packet sent by segment 1 will reach segment 3 through two routes, i.e., from segment 1 to 2 to 3 and another by segment 1 to 3. In this manner the computers on segment 3 will receive duplicate packets. In case of large networks some segments may receive many packets and thus cause looping.

A loop, therefore, can cause a broadcast packet or a packet with an unknown destination to circulate through it, thus rendering the network inoperable. This condition is avoided by making some bridges not forward frames. An algorithm known as Distributed Spanning Tree (DST) accomplishes this task. This algorithm decides which bridge should forward the packets in the network. Under this scheme bridges exchange a control message known as a hello message to select a single transmission route. Remaining bridges maintain a standby position and provide an alternate path in case some bridge fails in the selected transmission path. In Figure 4.26 the bridge connecting segment 1 and 3 will be active only if the bridge connecting segment 2 and 3 fails; otherwise it acts as a standby bridge for the network. In other words, bridges with spanning tree algorithm are capable of reconfiguring themselves automatically for alternate paths if a network segment fails. This improves its overall reliability.

IBM Source routing protocol (SRP) bridge

These are programmed and have specific routes for every packet. This routing is based on factors like number of bridges and the physical location of the nodes.

Source routing transparent (SRT)

The standard IEEE 802.1 has defined SRT. It combines STP and SRP. SRT router connects LANs as programmed and can use either method.

Classification of Bridges

Bridges are classified into three types, local, remote bridges and wireless bridges.

- Local brides are ordinary bridges
- Remote bridges are used to connect networks that are far from each other. A WAN is generally provided between two bridges.
- Wireless bridges are used to join LANs as well as to connect remote stations to LANs.

Figure 4.27 shows the local and remote bridge connection.

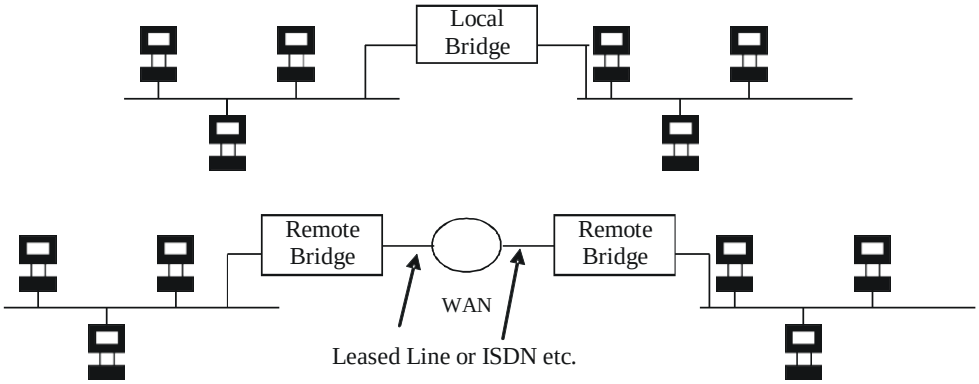


Fig. 4.27 *Local and Remote Bridge*

Multiplexer

A multiplexer or mux is an electronic device which performs multiplexing by selecting one out of many input signals (analogue or digital) and forwarding the selected input into a single line. This process is repeated till all the input signals are forwarded. Hence, an electronic multiplexer allows several signals to share one common device or resource. On the receiving end, a multiplexer can have a complementary demultiplexer. A demultiplexer or demux is also an electronic device that takes a single input signal and selects one out of many data-output-lines connected to the single input. Basically, an electronic multiplexer is a multiple-input, single-output switch, and an electronic demultiplexer is a single-input, multiple-output switch. A multiplexer is represented symbolically with the help of an isosceles trapezoid in which the longer parallel side contains the input pins and the short parallel side contains the output pin. The following is the schematic symbol of a 2-to-1 multiplexer. A wire, called the sel wire is used to connect the desired input to the required output.

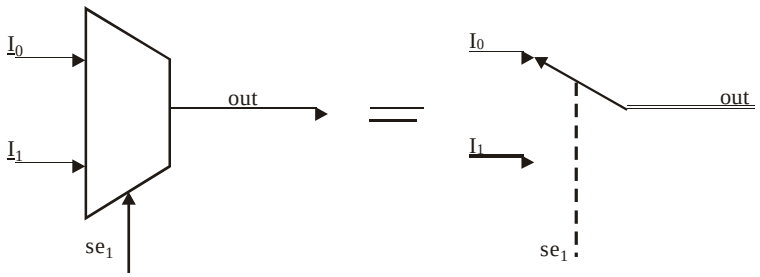


Fig. 4.28 *2-to-1 Multiplexer*

The multiplexer is very important in telecommunications and is used to combine several input signals into one output signal that carries a number of communication channels using the multiplex technique. Similarly, a demultiplexer is also used in telecommunications to separate and take a single input signal out of multiple output signals.

Fig. 4.29 *Multiplexer and Demultiplexer*

Function of a Multiplexer

The basic function of a multiplexer is to combine multiple inputs into one single data stream. At the receiving end a demultiplexer is used to split the received single data stream into multiple original signals. Generally, both multiplexer and demultiplexer are combined into a single equipment and are termed as multiplexer. This combined single piece equipment is set at both the ends of the transmission link, because the communication systems transmit data streams for sending and receiving operations.

Types of Multiplexers

(a) **Analog Time Division Multiplexer:** An *analogue time division multiplexer* (TDM MUX) is used in signal processing and telecommunications to select various types of analogue signals and then combine them into one pulse amplitude modulated (PAM) wide-band analogue signal. On the other hand, a digital TDM multiplexer is used to combine only a specific number of constant bit rate digital data streams into one single data stream of higher data rate by creating data frames of one time slot per channel.

(b) **Statistical Multiplexer:** A statistical multiplexer is used in telecommunications, computer networks and digital video to combine different variable bit rate data streams into a single constant bandwidth signal. This is used to share communication links and is the same as Dynamic Bandwidth Allocation (DBA). Using statistical multiplexing you can divide a communication channel into an arbitrary number of variable bit-rate digital channels or data streams. Adaption of link sharing is performed as per the instant traffic demands of the data streams being transferred over each channel. On successful performance, the

statistical multiplexing is further improved to provide link utilities and is termed as statistical multiplexing gain.

(c) **Inverse Multiplexer:** An inverse multiplexer or inverse mux or imux helps to break a data stream into multiple lower data rate communication links. It is used to transfer one signal by utilizing various communication channels. For example, a number of ISDN channels can be combined together in one single high rate circuit, when the Data Terminal Equipment (DTE) requires a higher rate connection than that which is currently produced by a single ISDN connection. It is very useful in areas when higher rate circuits are missing.

(d) **Digital Multiplexers:** Digital multiplexers are used in digital circuit design where the selector wires have digital values. For a 2-to-1 multiplexer, a logic value of 0 is required to connect I_0 to the output and a logic value of 1 will connect I_1 to the output. In the case of advanced and large multiplexers, the number of selector pins must be equal to élog$_2$ (n) ù where n is the total number of inputs. For example, 9 to 16 inputs will need a minimum of 4 selector pins and 17 to 32 inputs will need a minimum of 5 selector pins. The selected input pins are determined on the basis of the binary value expressed on these selector pins.

(e) **Chaining Multiplexers:** Small multiplexers are chained together to design and construct large multiplexers. For example, an 8-to-1 multiplexer can be constructed using two 4-to-1 and one 2-to-1 multiplexers. Here, the outputs of two 4-to-1 multiplexers are fed into the one 2-to-1 multiplexer with the help of selector pins put in parallel on the 4-to-1 multiplexers giving a total number of selector inputs as 3, which is equivalent to an 8-to-1 multiplexer. This is termed as chaining multiplexers.

(f) **Digital Subscriber Line Access Multiplexer:** A Digital Subscriber Line Access Multiplexer (DSLAM) helps in making faster connections to the Internet using telephone lines. It is a basic network device and is placed in the telephone exchanges of the service providers. With the help of multiplexing techniques it connects multiple customer Digital Subscriber Lines (DSLs) to a high-speed Internet backbone line. The telephone companies provide DSL service to locations which are beyond the effective range of the telephone exchange by placing remote DSLAMs.

(g) **Video Multiplexer:** A multiplexer is a device which structures the transmission channels on a single medium and also provides the rights to share these resources so that a more efficient bandwidth can be allocated. Basically, video equipments utilize complex video inputs or outputs. For example, cable TV and broadcast TV are the major sources of complex video that generate compound video outputs. Video devices such as VCRs, digital camcorders, video cameras and TV monitors receive compound video and process it for recording or playing video data. Video multiplexer is used in multiple video systems to control and access the plurality of video signals.

Multiplexing is the process where by multiple channels are combined for transmission over a common transmission path. Multiplexing can be done in the following ways:

- Frequency Division Multiplexing (FDM)
- Time Division Multiplexing (TDM)
- Code Division Multiplexing (CDM)
- Wavelength Division Multiplexing (WDM)

Router

Routers are used to connect both similar and dissimilar LANs, as shown in Figure 4.30. Router operates on the network layer of OSI model using the physical layer, data link layer and network layer to provide connectivity, addressing and switching as shown in Figure 4.31. These are highly intelligent devices. In case of TCP/IP network, Internet Protocol (IP) is used as addresses for network. TCP/IP is the router that interprets the IP address and delivers the packet reliably. A router transmits the network layer data. It, therefore, provides transmission of data between LANs that use different data link protocols. Itself the router uses the same network layer protocol. Because of this Ethernet can be connected with token ring network using routers. Additionally, routers provide connectivity to MAN (SMDS) and WAN (X.25, Frame Relay and ATM). Routers are protocol sensitive, typically supporting multiple protocols and large and varying packet sizes such as might be involved in supporting both Ethernet and Token Ring.

A network consisting of routers can have multiple paths unlike bridges. Normally, the shortest of all paths in the network is used to transfer packets.

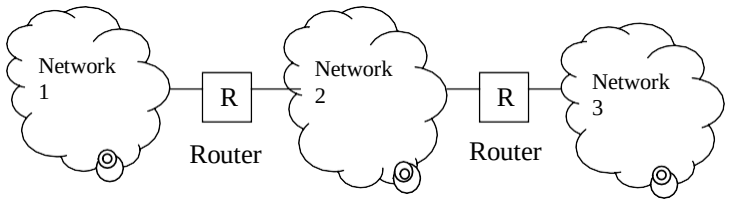


Fig. 4.30 *Router Network*

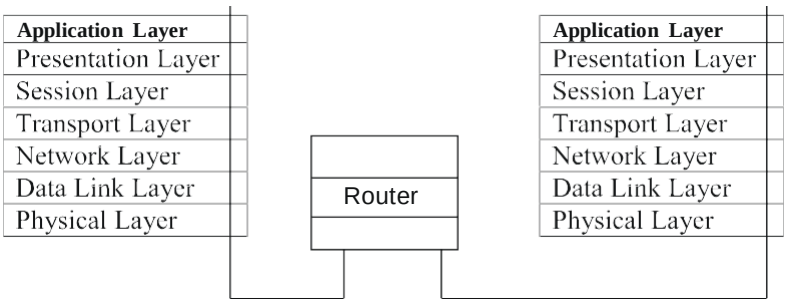


Fig. 4.31 *OSI Correspondence in case of Routers*

The communication via routers can be understood from Figure 4.32.

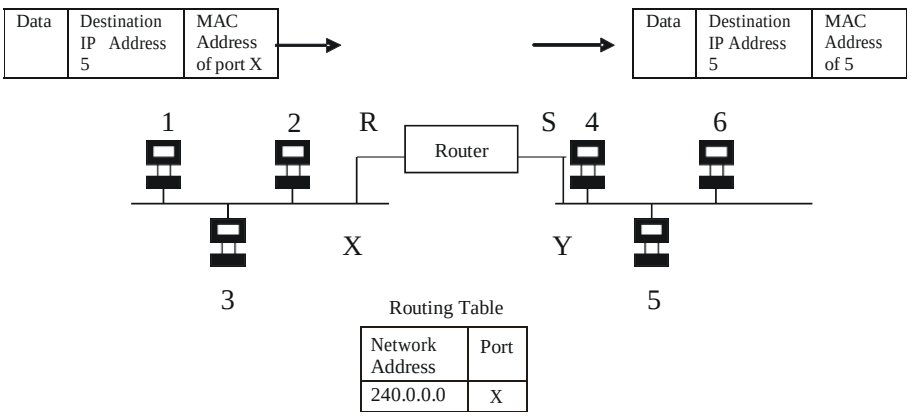


Fig. 4.32 *Communication via Router*

Consider a case for data transmission from Computer 1 to Computer 5 on the network shown in Figure 4.32. When Computer 1 starts sending data, it compares its IP address with that of Computer 5, i.e., the destination computer addresses to know whether Computer 5 lies on its own network or not. When Computer 1 finds that Computer 5 is not on its network it transmits a data packet that contains the MAC address R of the router. When the router receives this packet it sets the MAC address of Computer 5 and sends the packet to the port which has the same IP destination address as given in the data packet. In this manner Computer 5 receives the data packet.

Characteristics of Routers

- Routers are multiport devices with high-speed backbones.
- Like bridges, routers also support filtering and encapsulation.
- Like bridges routers are also capable self-learning, as they can communicate their existence to other devices and can learn of the existence of new routers, nodes and LAN segments.
- Routers route traffic by considering the network as a whole. It shows that they use a high level of intelligence to accomplish this task. This characteristic makes them superior to hubs and bridges because hubs and bridges simply view the network on a link-by-link basis.
- The packet handled by a router may include the destination address, packet priority level, least-cost route, minimum route delay, minimum route distance, and the route congestion level.
- Routers constantly monitor the condition of the network, so as to dynamically adapt to the changes in the condition of the network.
- Routers typically provide some level of redundancy so that they are less susceptible to catastrophic failures.

Router Protocols

These protocols consist of both bridging and routing protocols listed as follows:

(a) **Inter-router protocols:** These are router-to-router protocols that can operate over dissimilar networks. This protocol routes information and stores data packets during periods of idleness.

(b) **Serial line protocols:** This protocol is widely used over serial or dialup links and connects unlike routers. Examples include HDLC, SLIP (Serial Line Interface Protocol), and PPP (Point-to-Point Protocol).

(c) **Protocol Stack Routing and Bridging Protocols:** This advises the router about packets that should be routed and those that should be bridged.

Brouter

Brouters are network devices that perform the function of both a bridge as well as a router. It routes packets for known protocols. As a bridge it simply forwards packets.

Brouters operate both at the network layer and the data link layer. It operates for routable protocols at the network layer and for non-routable protocols at the data link layer. The growth of network has given rise to more and more complexities. A need for a device which combines the features of routable and non-routable protocols was felt. This gave birth to brouters. In bridged protocols, techniques for filtering and learning are used to reduce congestion which is a potential problem in transmitting frames.

A brouter is pronounced as **BRAU-tuhr** or **BEE-rau-tuhr**, and it has the combined features of a network bridge as well as a router in a single device. A bridge connects LANs using the same protocol. Ethernet and Token Ring are examples of LAN. If a data unit is being sent from one LAN to another interconnected LAN, the data unit is forwarded by the bridge; else it passes the data unit to the same LAN. A bridge normally offers a single path to an interconnected LAN. On the contrary, a router connects a network to other networks that are part of a WAN and offers many paths to destinations on these networks. A router, thus, requires more information regarding the interconnected networks as compared to a bridge. There is a routing table in which this information is kept for access. A packet containing a data unit from a sending computer may be destined for a computer either on the local LAN, an interconnected LAN, or a WAN. Therefore, it advisable to have a device which is capable of examining data units, both routable and non-routable, to forward them to their correct destination on the network.

Manufacturer: **Zhone Technologies (Paradyne)**

Brouter

The product 6200 ADSL2+ family endpoints are a series of brouters. These are used in residential buildings, business houses, in hotels/motels, in temporary housing, etc., to access the Internet at a high-speed. It is also used to provide video-on-demand. The products are easily installable. Web-based user interface is embedded to make deployment of ADSL quite simple. These products provide an auto sensing Ethernet connection and a user need not worry about the cable type that has to be used for the connection. It may be a straight-through or a crossover. There is a feature known as DELT which stands for Dual End Loop Test which is used in reactive loop testing of a modem. Default settings and those features that can be quickly and easily installed require no configuration. As a router, it supports NAPT, RIP and DHCP Server/ Relay/Client. Apart from this it supports static routing, dynamic routing and port forwarding. It also has a provision to support firewall functions and PAP/CHAP authentication including IP filtering to provide security.

Its main parts of specification are as follows:

- **Connectivity Technology** : Wired
- **Data Link Protocol** : ATM, Ethernet, Fast Ethernet
- **Network / Transport Protocol** : PPPoA, PPPoE
- **Remote Management Protocol** : HTTP, Telnet
- **Routing Protocol** : RIP-1, RIP-2, Static IP routing
- **Features** : DMZ port, DHCP support, Firewall protection, MAC address filtering, Quality of Service (QoS)
- **Compliant Standards** : ANSI T1.413, IEEE

Manufacturer: Cisco Systems Inc.

Brouter

Cisco has offered a wide variety of products that provide connectivity and expansion and upgrade modules for a wide range of applications as per customer needs. Customers can choose a connectivity solution as suited to their requirements. They provide modular structure for components. These are field-upgradeable and can cater to the changed needs of the customers. Cisco 1600 series routers are small desktop routers that link small-to-medium remote Ethernet LANs to regional and central offices over multiple WAN connections.

Its main parts of specification are as follows:

- **Connectivity Technology** : Wired
- **Data Link Protocol** : ISDN, Ethernet
- **Switching Protocol** : PPP, SMDS, X.25, Ethernet, Frame Relay
- **Network / Transport Protocol** : TCP/IP, IPX/SPX, AppleTalk
- **Communication Mode** : Full-duplex
- **Remote Management Protocol** : SNMP
- **Status Indicators** : Power, Port status, Link activity
- **Features** : Manageable, Firewall protection
- **Compliant Standards** : IEEE 802.3

Manufacturer: ADC Telecommunications

Brouter

The Campus-RS REX2 (Remote Ethernet eXpress) is a module that acts as an interface that has been installed into such remote devices as Campus-RS or Campus-RS Star concentrator to provide interconnectivity to LANs that are located at different geographical locations in private networks. This product does the work of a full-bandwidth Ethernet remote bridge or a static or dynamic IP router. It uses copper connectivity as a transmission medium. The connectivity provided by it is of the speed of 4.6 Mbps. Its architecture is so robust that it does not require other bridges routers and repeaters. An auto sensing port along with an SNMP agent and a transparent MAC-layer Bridge which conforms to the IEEE 802.1d standard is embedded into it. This modem is interoperable with other internetworking devices due to options like

encapsulation of HDLC and PPP and Virtual LAN (VLAN) on IP routing. These products are useful as it extends the subnetworks to remote sites of the private network.

Its main parts of specification are as follows:

- **Connectivity Technology** : Wired
- **Data Link Protocol** : HDLC, Ethernet, Fast Ethernet
- **Switching Protocol** : Ethernet
- **Remote Management Protocol** : Telnet
- **Routing Protocol** : RIP, RIP-2, Static IP routing
- **Features** : IP-routing, VLAN support, Auto-sensing per device
- **Compliant Standards** : IEEE 802.1D

Gateway

Gateway routers are used to connect dissimilar LANs and to perform the functions of bridges and routers. It operates at all seven layers of the OSI Reference Model as shown in Figure 4.33. These are actually predecessors of the routers that are in existence today and are technology wise more expensive and highly functional. In general, they consist of software which resides in a host computer, such as a midrange or a mainframe as shown in Figure 4.34.

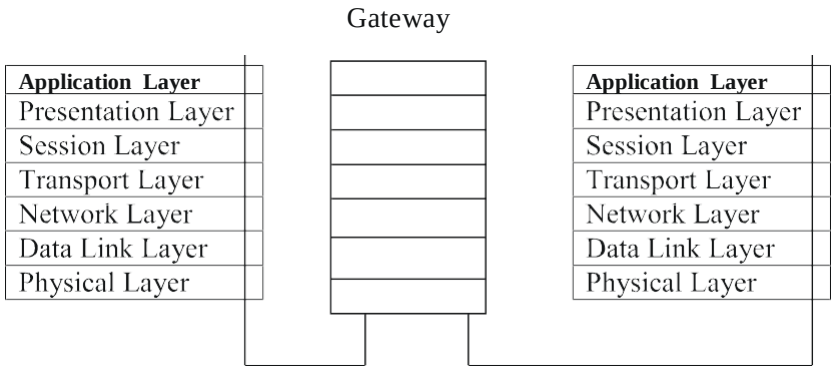


Fig. 4.33 *OSI Correspondence of Gateways*

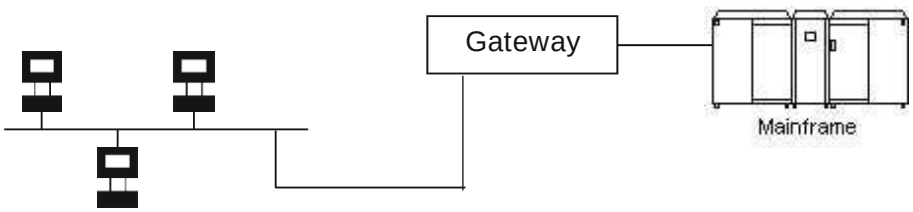


Fig. 4.34 *Interconnection between Ethernet and Mainframe using Gateway*

A gateway contains things like protocol translators, devices for impedance matching, fault isolators, rate converters, or signal translators as devices that are necessary for system interoperability. A set of mutually acceptable protocols are also required as administrative procedures between both the networks.

A gateway is a point in the network acting as an entrance gate to another network. Gateway functions in a much more complicated way than a router or a switch. A gateway must be able to convert one protocol stack into another.

A node on the Internet can be either a gateway or a host node. Users' computers on the Internet and computers acting as page-servers for users are considered host nodes but nodes connecting networks, in between, are gateways. For example, computers controlling traffic between networks of a company or those used by the Internet Service Providers (ISPs) for connecting users to Internet, are gateway nodes.

A computer server that is kept in the network of an enterprise acts as a gateway node. It also acts as a proxy server and a firewall server. A gateway functions both as a router and a switch. It acts like a router since it knows the destination of a given packet of data arriving at the gateway. It acts as a switch since it furnishes the actual path to and from the gateway for a given packet.

A gateway forwards an IP packet to another network for communication. A subnet mask is the IP range of a network. For example, we take a network having the base IP address of 192.169.0.0 with a subnet mask of 255.255.255.0. Any data to an IP address that falls outside of 192.169.0.X will be diverted to that network's gateway. The gate way may not perform the job of Network Address Translation while sending an IP packet to another network.

A gateway may be either hardware or software. A node on the Internet can be either a gateway or a host. So is the case with a router. Computers controlling and managing traffic and bandwidth within the network of an enterprise or those at the ISP end are gateway nodes. In the network of an enterprise the gateway node does the function of a proxy server and a firewall.

Characteristics of Gateways

The characteristics of gateways are as follows:

- Gateways provide full protocol conversion from one proprietary LAN technology to another, i.e., Ethernet to token ring or FDDI or to any other standard or protocol rather than encapsulation.
- It uses higher layers of the OSI model, perhaps through layer 7, the application layer. IBM SNA, DECnet, Internet TCP/IP and other protocols can be converted from network-to-network.
- Unlike bridges and routers, gateways operate slowly because of protocol conversion. Consequently, they may create bottlenecks of congestion during periods of peak usage.

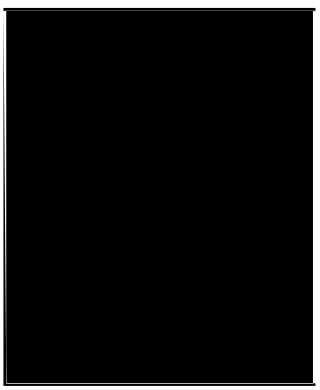
Default Gateway

A default gateway is a device that allows traffic to pass from devices on a local subnet to those on a other subnets. This connects a local network to the Internet, even though there exists internal gateways for local networks.

Such gateways are either of the following types:

- Small networks, for home or a small office, that has a broadband router for sharing the Internet connection, home router is the default gateway.
- Small networks for home or a small office without a router with dialup facilities for accessing the Internet, a router located with the Internet Service Provider is the default gateway.

A proxy server passing requests and giving unmodified replies is also a gateway. It is also called tunnelling proxy.



LAN, MAN AND WAN

Earlier, a computer network consisted of mainframes in an enclosure. One could see an input in the form of a punch card. These were read by card readers and the output was in the form of printed results via local printers. Local terminals were mostly used for control and programming input. Instead of being interactive all processing was on a batch basis. In other words, the input was transmitted in a batch from a card reader over a short circuit to the processor. The processor processed the programme in a batch and the output to the printer was in a batch. The first true mainframe was the IBM 360, introduced in 1964. Over time, input to the mainframe was extended to multiple users at dumb terminals that connected to ports on the mainframe through terminal controllers, or cluster controllers.

The development of data networking took place parallely with the development of computers. Computers became more powerful as processor speeds increased with the development of faster microprocessors using silicon chips. Memory became more available as chip technology and hard drive technology improved. Additionally, computers became smaller and less expensive, to the point that the typical desktop PC became equivalent to an early mainframe that would have filled a moderate-size office building. As a result, the computing power and storage capability of all these desktops for them lead to a need already implemented to network with the devices within the workplace. It has been estimated that a majority of data transfer is confined to the workplace, while only a small percentage travels to remote places. Hence, it is clear that PC users need to share access to hosts, databases, printers, etc. LANs provide a solution to that requirement.

Robert M. Metcalfe and his associates at the Xerox Palo Alto Research Centre (Xerox PARC) first conceived LAN technology. Later on, Xerox commercialized the technology and named it The Xerox Wire. When Digital Equipment Corporation (DEC), Intel and Xerox corporation decided to standardize the technology in 1979, they named it Ethernet. Ethernet quickly became a de facto standard. Ethernet and LANs were officially recognized when the IEEE established Project 802 at the request of its members. By the end of 1982, the first standard was published and circulated. Ethernet, clearly, is still the most popular LAN standard.

Computers are connected through many different technologies. A network is an interconnection between two or more computers in a peer-to-peer or client to server manner or fashion usually over a shared and virtual connection. In other words, networks provide the connection between computer resources in order to accommodate the flow of information. This is just the opposite of the old terminal-to-host hardwired connection. Although a network can support terminal-to-host connections through terminal emulators or terminal servers, it offers a lot more flexibility in switching connections. The disadvantage of this explosion in terms of sharing information arises when one computer wishes to share its information system with another which has different network protocols and a different network technology. As a result, even if one could agree on a type of network technology to physically interconnect the two computers at different locations, the applications still would not be able to communicate with each other because of the difference protocols.

A very basic question arises about the requirement of networks. This may be justified with the help of the following points:

- Sharing of resources can be done easily.

- Reliability — There is no central computer, so if one breaks down other computers can be used.
- Networks allow us to be mobile.

The term networking applies to the following:

- The exchange of information among individuals, groups, or institutions.
- The process of electronic voice or data communications.

Communication networks are broadly categorized into the following three categories:

Local Area Network (LAN)

LAN technology connects people and machines within a site. A LAN is a network that is restricted to a relatively small area as shown in Figure 4.35. LANs can be defined as privately owned networks offering reliable-high-speed communication channels that are optimized to connect information processing equipment in a small and restricted geographical area, namely, an office, a building, a complex of buildings, a school or a campus.

A LAN is a form of local (limited-distance), shared packet network for computer communications. LANs interconnect computers and peripherals over a common medium so that users are able to share access to host computers, databases, files, applications, and peripherals. They can also provide a connection to other networks either through a computer, which is attached to both networks, or through a dedicated device called a gateway.

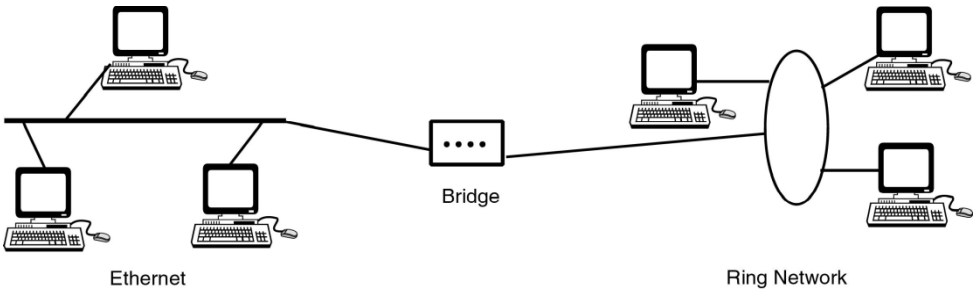


Fig. 4.35 *Local Area Network (LAN)*

The components used by LANs can be categorized into hardware, cabling standards and protocols. The various LAN protocols are Ethernet, Token Ring, TCP/IP, SMB, NetBIOS and NetBeui, IPX/SPX, Fibre Distributed Data Interchange (FDDI) and Asynchronous Transfer Mode (ATM).

Metropolitan Area Network (MAN)

A MAN covers large geographic areas such as towns, cities or districts. By linking or interconnecting smaller networks within a large geographic area, information is conveniently distributed throughout the network. Local libraries and government agencies often use a MAN to establish a link with private industries and citizens. A MAN may also connect many MANs together within an area that is than that covered by a LAN. The geographical limit of a MAN may span a city. Figure 4.36 depicts how a MAN may be available within a city.

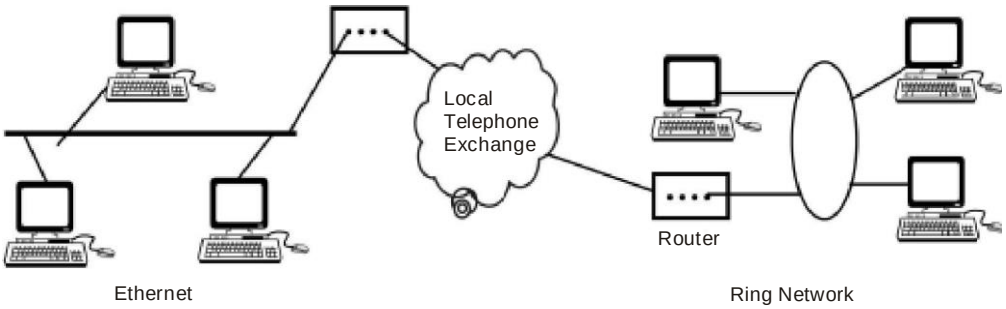


Fig. 4.36 *Metropolitan Area Network (MAN)*

In MAN, different LANs are connected through a local telephone exchange. Some of the widely used protocols for MAN are RS-232, X.25, Frame Relay, Asynchronous Transfer Mode (ATM), ISDN (Integrated Services Digital Network), OC-3 lines (155 Mbps), ADSL (Asymmetrical Digital Subscriber Line) etc. These protocols are quite different from those used for LANs.

Wide Area Network (WAN)

This technology connects sites that exist in diverse locations. WANs connect larger geographic areas, such as New Delhi, in India, with other parts of the world. The geographical limit of a WAN is unlimited. Dedicated transoceanic cabling or satellite uplinks may be used to connect this type of network. Hence, a WAN may be defined as a data communications network covering a relatively broad geographical area to connect LANs together between different cities with the help of transmission facilities provided by such common carriers as telephone companies. WAN technologies operate at the lower three layers of the OSI reference model. These are the physical data link and network layers.

Figure 4.37 explains the WAN, which connects many LANs together. It also uses the switching technology provided by local exchange and long distance carriers.

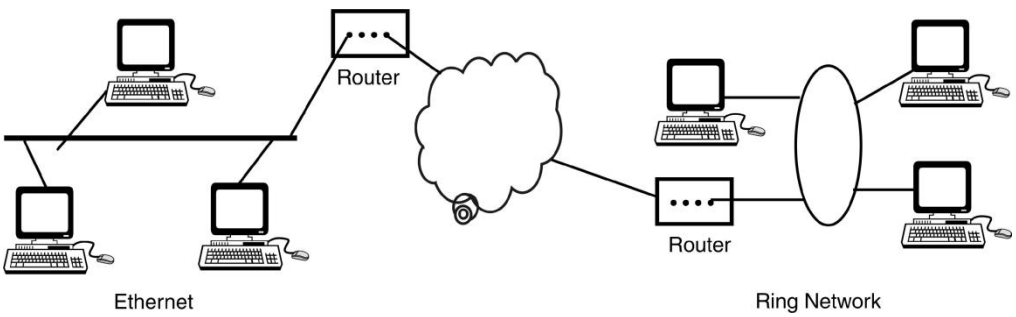


Fig. 4.37 *Wide Area Network (WAN)*

Packet switching technologies such as Asynchronous Transfer Mode (ATM), Switched Multimegabit Data Service (SMDS), Frame Relay and X.25 are used to implement WAN along with statistical multiplexing to allow devices to use and share these circuits.

The difference between MAN and WAN may be understood only from the services that they use. WAN uses both the local and long distance carrier while MAN uses only a local carrier. Hardware and protocols are the same for both.

There is a lot of confusion between LAN technology and WAN technology. The answer lies in how data is switched. It is the LAN/WAN integration that makes the

network functional. After all, people and machines not only need to be accessible locally, but from different sites as well.

A network is formed and completed using the following basic components:

- Hardware
- Applications (useful software)

Each of these is comprised of several layers. The concept of layers is an important one in networking as well as computer designs. Each layer provides protection to the layer above from the layer below so that one layer can change without affecting the upper layers too much. In some cases, the protection provided is so good that an application may never become aware that it is functioning on a different hardware. The OSI reference model defines seven layers.

The role of computer networks in development has many facets. Computers along with the necessary networking infrastructure required have to be connected with either a LAN or a WAN or the Internet or all, depending on their needs. Computers play a great role in e-governance, telemedicine, e-education, e-business, etc. Acomputer with Internet (internetworking) has become a potent tool for education, productivity and enlightenment. The Internet can improve life at a relatively low cost. The Government of India set up ERNET in 1986 to provide TCP/IP connections to education and research communities in India. ERNET established the first TCP/IP computer network in India and it offers services like e-mail, surfing Internet, FTP, Telnet, and database access, gopher, Archie, WAIS and WWW. Subsequently, the Government of India liberalized the policies relating to the Internet. The liberalized policies initiated by it encouraged many private players like DISHNET, Mantra online, JAIN TV, etc., and other government organizations like NIC, VSNL and MTNL to enter in this field and make the Internet available to the common people.

The major network infrastructure available in the country has two types of WAN which are as follows:

- Terrestrial WAN
- VSAT WAN

The different options available to the major network infrastructure with terrestrial WAN and VSAT WAN to set up Intranet, education portal, e-commerce, etc., are as follows:

- Leased line
- Dialup connection
- VSAT
- RADIO LINK

The role of Internet can be seen in the area of education, economic productivity, healthcare, democracy and human rights and quality of life, etc. There are several more areas where the Internet can make contributions. In the area of education, the Internet can contribute by way of shared databases, organization of conferences, circulation of papers and discussion, collaborative research and writing undertaken, web-based registration, online digital library privileges, other online learning facilities like virtual classrooms and information regarding courses and so forth. Economic productivity may be enhanced as the Internet that runs over telephone infrastructure at a relatively marginal cost, provides more economic advantage. The Internet enables global communication with suppliers and customers, etc. This can open global markets to the developing countries. In this manner, the Internet has facilitated the opening of

e-commerce. The Internet is being effectively utilized in the health sector. The rapid growth of the Internet and its related areas like switched leased lines, terrestrial and satellite packet radio and videoconferencing, etc., has lead to the development of telemedicine. The Internet is expected to encourage democracy by providing those suffering dictatorship with external information and new ideas. This exposure to information allows people to share ideas and coordinate political activity within their countries. The internet may force transparency in the administration and therefore, may be considered as a catalyst to encourage human rights in a wider sense. The environment is under a lot of presure everywhere. We have pollution and there are limited resources for energy. The Internet may enable us to substitute communication for transportation and therefore, will reduce pollution and save energy and time in the larger interest of mankind.

INTERNET

The Internet is a '**network of networks**' that links computer systems around the world. It allows communication across networks, i.e., communication can take place between one network and another. This allows people to have access to information anytime and from anywhere. It virtually makes accessible a sea of information and a nearly worldwide audience at the click of a button.

It was the Sputnik's launch and the subsequent cold war, space race and the development of ARPANET (Advanced Research Projects Agency Network) in 1950 that led to the establishment of the Internet. However, it actually gained momentum in the 1980s when ARPANET was used by the National Science Foundation to connect the five supercomputers at its regional centres. Thus, emerged a high-speed Internet service that enabled access to many universities, networks, bulletin board systems, commercial online services and institutions. The decade closed with the coming into being of the World Wide Web (WWW), which proclaimed the emergence of an independent platform of communication that was further augmented by a relatively easy-to-use and pleasant graphical interface.

Important Features

Some of the facilities that are available on the Internet are as follows:

- **World Wide Web:** The Internet application that is currently drawing maximum attention is the World Wide Web. It has dramatically influenced the online world and continues to grow in popularity.
- **Direct Communication:** Through e-mail (electronic mail), messages can be sent to or received from any part of the world within a few minutes.
- **Round-the-Clock Availability:** Information on the Internet is available to users 24 hours a day.
- **Central Repository of Data:** The Internet is like a huge central warehouse of data that people from all over the world can access.
- **Search Engines:** These are like directories which help get any kind of information from the world over within a few seconds.
- **Advertisement:** A company can advertise its products/services through the Internet.
- **E-Commerce:** The Internet is increasingly being used for conducting monetary transactions. Through the Internet, you can shop and pay through your credit

Check Your Progress

9. Define LAN.
10. Name the three main categories of communication networks.

card or ask your bank to transfer your money to a different account, without even leaving your desk.

- **Distance Learning:** Several online distance learning courses are now being offered by Indian and foreign universities on the Internet.
- **BBS and New Services:** The Internet is perhaps the cheapest medium for online help. BBS services are available on the Internet through which you can ask questions and get immediate troubleshooting assistance.
- **Wide Area Networks:** Using the Internet, organizations can collect and compile information from offices spread over large geographical areas.
- **Shareware Software:** The Internet is also a great medium for downloading free software. You can get a truckload of free games, utilities and trial versions of software through the Internet.

Key Concept

The Internet has made things simpler. It can serve the following purposes:

- **Direct Communication:** You can send messages to family and friends, business associates and acquaintances using the electronic mail facility. Using electronic mail, you can send and receive messages within a few seconds anywhere in the world. Using the Internet Relay Chat (IRC), you can communicate online with people over the Internet. You can log into a chat room and converse with others by typing messages that are instantly delivered. With the improvement of network technologies and increase in broadband, not only can you use text messages but also graphics, audio and video for communication with other people.
- **Online Shopping:** Logically, the Internet has removed all barriers of distance and nationality. You can shop for products and services across the world by logging on to a Web portal. You can also pay your bills online using credit and debit cards. You can also transfer money between different accounts with the click of a mouse.
- **Distance Education:** The Internet provides a perfect medium for knowledge sharing and information dissemination. Courses are available on the Internet. You can register and pay online, and complete a course on different interest areas. You can also pursue specialized higher studies now in the comfort of your own office or home.
- **Knowledge Base:** The Internet provides a rich information base that people from across the globe can access. In fact, it is one of the richest information bases that can be accessed at the click of a mouse. Using search engines, you can search for detailed information on any topic of your interest.
- **Banking:** Banks are using information technology to provide online banking facilities to their customers. Using the Internet, you can now view your account details, get drafts made, request for chequebooks and transfer money from one account to another. The use of Automated Teller Machines or ATMs has shifted the mundane back-office work to the customer himself. Instead of hiring an army of bank clerks, banks can now uses ATMs to considerably reduce time and operational costs.
- **Travel:** Using the Internet, travel agencies can publish their services on the Web along with the latest discounts, packages and availability details, so that customers can compare rates, make online bookings and avail discounts without having to run around multiple offices.

- **Bill Payments:** The government sector has also realized the benefits of IT. Now you can make online payments for public utilities, such as water, electricity and phones, using credit cards as the payment medium.

Working of the Internet

You can use following options for connecting to the Internet.

Direct Connection

Through a direct connection, a machine is directly connected to the Internet backbone and acts as a gateway. Though a direct connection provides complete access to all the Internet services, it is very expensive to implement and maintain. Direct connections are suitable only for very large organizations or companies.

Through Internet Service Provider (ISP)

You can also connect to the Internet through the gateways provided by ISPs. The range of Internet services varies depending on the ISPs. Therefore, you should use the Internet services of the ISP that is best suitable for your requirements. You can connect to your ISP using two methods:

Remote Dial-Up Connection

A dial-up connection (see Figure 4.38) enables you to connect to your ISP using a modem. A modem converts the computer bits or digital signals to modulated or analogueue signals that the phone lines can transmit and vice versa. Dial-up connections user either SLIP (Serial Line Internet Protocol) or PPP (Point-to-Point Protocol) for transferring information over the Internet.

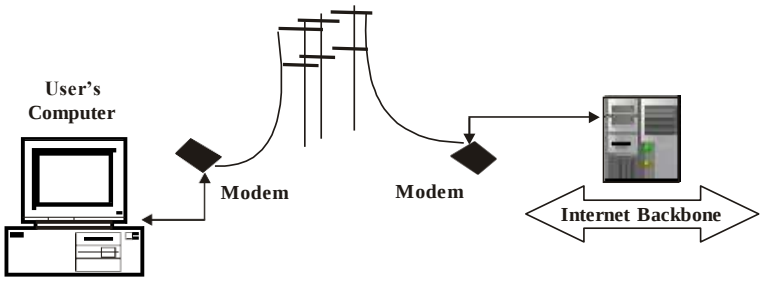


Fig. 4.38 *Remote Dial-Up Connection*

For dial-up connections, regular telephone lines are used. Therefore, the quality of the connection may not always be very good.

Permanent Dedicated Connection

You can also have a dedicated Internet connection that typically connects you to ISP through a dedicated phone line. Adedicated Internet connection is a permanent telephone connection between two points. Computer networks that are physically separated are often connected using leased or dedicated lines. These lines are preferred because they are always open for communication traffic unlike the regular telephone lines that require a dialling sequence to be activated. Often, this line is an ISDN (Integrated Services Digital Network) line that allows transmission of data, voice, video and graphics at very high speeds. ISDN applications have revolutionized the way businesses communicate. ISDN lines support upward scalability, which means that you can transparently add more lines to get faster speeds, going up to 1.28 Mbps (Mega bits per second).

T1 and T3 are the two other types of commonly used dedicated line types for The Internet connections. Dedicated lines are becoming popular because of their faster data transfer rates. Dedicated lines are cost-effective for businesses that use Internet services extensively.

History of the Internet

The Internet, World Wide Web or WWW and Information Super Highway are terms which have the lives of millions of people all over the world. The widespread impact of Internet across the globe could not be possible without the development of Transmission Control Protocol/Internet Protocol (TCP/IP). This protocol suite is developed specifically for the Internet. The Information Technology revolution could not have been achieved without this boundless chain of networks. It has become a fundamental part of the lives of millions of people all over the world. All the aforesaid services, provide us the necessary backbone for information sharing in organizations and within common interest groups. That information may be in several forms. It can be notes and documents, data to be processed by another computer, files sent to colleagues, and even more exotic forms of data.

During late 60s and 70s, organizations were inundated with many different LAN and WAN technologies such as packet switching technology, collision-detection local area networks, hierarchical enterprise networks, and many other excellent technologies. The major drawbacks of all these technologies were that they could not communicate with each other without expensive deployment of communications devices. These were not only expensive but also put users at the mercy of the monopoly of the vendor they were dealing with. Consequently, multiple networking models were available as a result of the research and development efforts made by many interest groups. This paved the way for development of another aspect of networking known as protocol layering. This allows applications to communicate with each other. A complete range of architectural models were proposed and implemented by various research teams and computer manufacturers. The result of this know-how is that today any group of users can find a physical network and an architectural model suitable for their specific needs. This includes cheap asynchronous lines with no other error recoverythan a bit-per-bit parity function, through full-function wide area networks (public or private) with reliable protocols such as public packet switching networks or private SNA networks, to high-speed but limited-distance local area networks.

It is now evident that organizations or users are using different network technologies to connect computers over the network. The desire of sharing more and more information among homogeneous or heterogeneous interest groups motivated the researcher to device a technology whereby one group of users could extend its information system to another group who had a different network technology and different network protocols. This necessity was recognized in early 70s by a group of researchers in the United States of America (USA) who hit upon a new principle popularly known as Internetworking. Other organizations also became involved in this area of interconnecting networks, such as Telecommunication Standardization Sector or ITU-T (formerly International Telegraph and Telephone consultative Committee or CCITT) and ISO. All were trying to define a set of protocols, layered in a well-defined suite, so that applications would be able to communicate with each other, regardless of the underlying network technology and the operating systems where those applications run.

Internetworks

The availability of different operating systems, hardware platforms and the geographical dispersion of computing resources necessitated the need of networking in such a manner that computers of all sizes could communicate with each other, regardless of the vendor, the operating system, the hardware platform, or geographical proximity. Therefore, we may say that *Internetworking* is a scheme for interconnecting multiple networks of dissimilar technologies. To interconnect multiple networks of dissimilar technologies use both additional hardware and software. This additional hardware is positioned between networks and software on each attached computer. This system of interconnected networks is called an *Internetwork* or the *Internet*.

To develop standards for Internetworking, Defense Advanced Research Projects Agency (DARPA) funded research projects. The Advanced Research Projects Agency Network or ARPANET, a project of DARPA, introduced the world of networking with protocol suite concepts such as layering, well before ISO's initiative in this direction. DARPA continued its research for an Internetworking protocol suite. This may be seen in the early NCP (Network Control Programme) host-to-host protocol to the TCP/IP protocol suite, which took its current form around 1978. DARPA was well-known for its pioneering of packet switching over radio networks and satellite channels and ARPANET was declared an operational network with responsibility of administering it to Defense Communications Agency (DCA) in 1975. TCP/IP had not yet been developed.

ARPANET was basically a network based on leased lines connected by special switching nodes, known as Internet Message Processors (IMP). Many researchers were involved in TCP/IP research by 1979. This motivated DARPA to form an informal committee to coordinate and guide the design of the communication protocols and architecture. The committee was called the Internet Control and Configuration Board (ICCB).

The first real implementation of the Internet was when DARPA converted the machines of its research network ARPANET to use the new TCP/IP protocols. After this transition which started in 1980 and finished in 1983, DARPA demanded that all computers willing to connect to its ARPANET must use TCP/IP. The US military adopted TCP/IP as standard protocol in 1983 and recommended that all networks connected to the ARPANET conform to the new standards.

The success of ARPANET was more than the expectations of its own founders and TCP/IP Internetworking became widespread. As a result, new Wide Area Networks (WAN) were created in the USA and connected to ARPANET using TCP/IP protocol. In turn, other networks in the rest of the world, not necessarily based on the TCP/IP protocols, were added to the set of interconnected networks. Computing facilities all over North America, Europe, Japan and other parts of the world are currently connected to the Internet via their own sub-networks, constituting the world's largest network. In 1990, ARPANET was eliminated, and the Internet was declared as the formal global network.

DARPA also funded a project to develop TCP/IP protocols for Berkeley UNIX on the VAX and to distribute the developed codes free of charge with their UNIX operating system. The first release of the Berkeley Software Distribution (BSD) to include the TCP/IP protocol set was made available in 1983 (4.2BSD). This led to the spread of TCP/IP among universities and research centers and has become the standard

communications subsystem for all UNIX connectivity. There are many updated versions of BSD code available. These are 4.3BSD (1986), 4.3BSD Tahoe (1988), 4.3BSD Reno (1990) and 4.4BSD (1994).

Some examples of the different networks that have played key roles in this development are described as follows:

The Internet

The word Internet is a short form of a complete word Internetwork or interconnected network. Therefore, it can be said that the Internet is not a single network, but a collection of networks. The commonality between them in order to communicate with each other is TCP/IP. The Internet consists of the following groups of networks:

- **Backbones:** These are large networks that exist primarily to interconnect other networks. Some examples of backbones are NSFNET in the USA, EBONE in Europe and large commercial backbones.
- **Regional Networks:** These connect, for example, universities and colleges. ERNET (Education and Research NETwork) is an example in the Indian context.
- **Commercial Networks:** They provide access to the backbones to subscribers, and networks owned by commercial organizations for internal use and also have connections to the Internet. Mainly, Internet Service Providers come into this category.
- **Local Networks:** These are campus wide university networks.

The networks connect users to the Internet using special devices that are called gateways or routers. These devices provide connection and protocol conversion of dissimilar networks to the Internet. Gateways or routers are responsible for routing data around the global network until they reach their ultimate destination as shown in Figure 4.39. The delivery of data to its final destination takes place based on some routing table maintained by router or gateways. These are the fundamental devices to connect similar or dissimilar networks together.

Over time, TCP/IP defined several protocol sets for the exchange of routing information. Each set pertains to a different historic phase in the evolution of architecture of the Internet backbone.

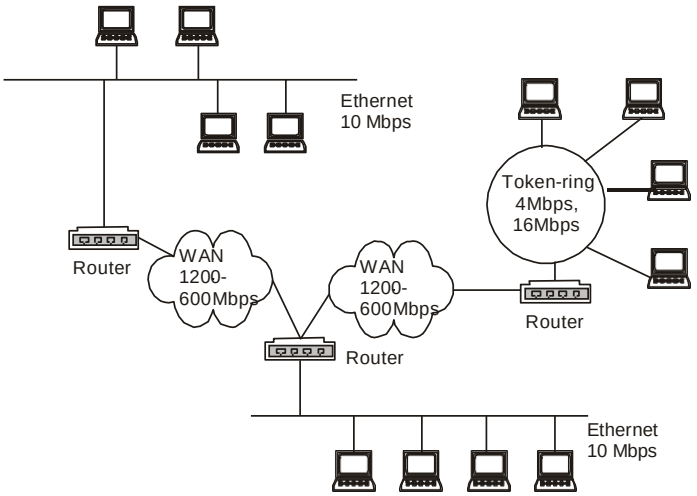


Fig. 4.39 *Local Area Networks Connected to the Internet via Gateways or Routers*

Arpanet

ARPANET was built by DARPA as described earlier. This initiated the packet switching technology in the world of networking and, therefore, is sometimes referred to as the 'grand-daddy of packet networks'. The ARPANET was established in the late 60s for Department of Defense to accommodate research equipment on packet switching technology besides allowing resource sharing for the Department's contractors. This network includes research centres, some military bases and government locations. It soon became popular with researchers for collaboration through electronic mail and other services. ARPANET marks the beginning of the Internet.

ARPANET provided interconnection of various Packet Switching Nodes (PSN) located across continental USA and Western Europe using 56 Kbps leased lines. ARPANET provided connection to minicomputers running a protocol known as 1822 (after the number of a report describing it) and dedicated it to the packet switching task. Each PSN had at least two connections to other PSNs (to allow alternate routing in case of circuit failure) and up to 22 ports for user computer connections. Later on, DARPA replaced the 1822 packet switching technology with the CCITT X.25 standard. The increase in data traffic made 56 Kbps capacity of the lines insufficient. ARPANET has now been replaced with new technologies as backbone for the research side of the connected Internet.

PROTOCOLS OF INTERNET

TCP/IP stands for Transmission Control Protocol/Internet Protocol. It was developed with the objective to specify a suite of protocols capable of providing transparent communications interoperability services between computers of all sizes, regardless of the hardware or operating system platforms supporting them. Over the years, TCP/IP has become the most widespread of today's protocols. One reason for TCP/IP's popularity is the public availability of its protocols' specifications. In this sense, TCP/IP can justifiably be considered an open system. Most users rely on TCP/IP for the purpose of file transfers, electronic mail (e-mail), and remote login services.

LAN Protocol and OSI

There are a variety of LAN standards. These standards define physical transmission media and how these media should be used. These standards correspond to the protocols defined in the physical and data link layers of the OSI reference model as shown in Figure 4.40. Among the protocols defined in the layers above the data link layer, TCP/IP, IPX/SPX and NetBIOS are well known. Of these protocols, TCP/IP is the most popular and is employed for UNIX and the Internet. IPX/SPX is used for Novel's NetWare. NetBIOS was developed by IBM for small size LANs and is employed in Windows 95 or Windows NT environment.

Check Your Progress

11. Mention the facilities available through the use of the Internet.
12. What are commercial networks?

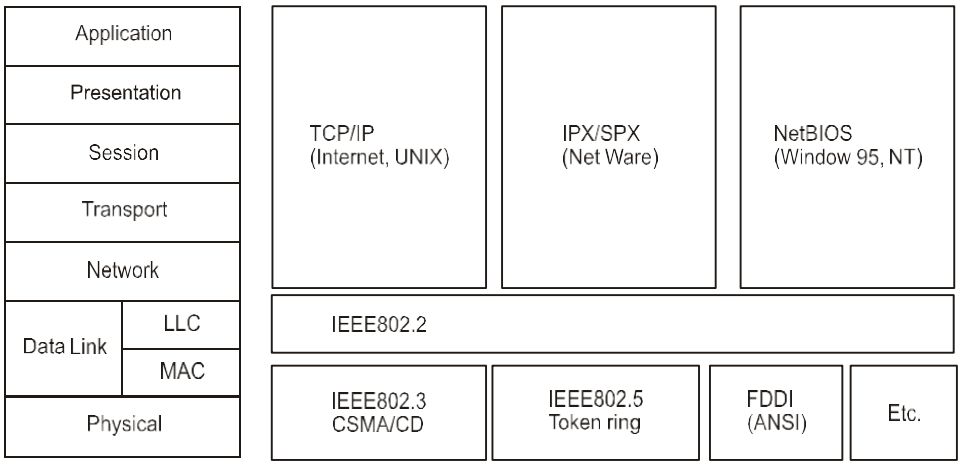


Fig. 4.40 *LAN Standards in Physical and Data Link Layers*

4.6.1 TCP/IP Suite

TCP corresponds to the fourth layer of OSI reference model. IP corresponds to the third layer of the same model. Each of these protocols has the following features:

TCP – It provides a connection type service. That is, a logical connection must be established prior to communication. With this a continuous transmission of large amount of data is possible. It ensures a highly reliable data transmission for upper layers using IP protocol. This is possible because TCP uses positive acknowledgement to confirm the sender about the proper reception of data. The sender sends data at constant intervals until it receives a positive acknowledgement.

A negative acknowledgement implies that the failed data segment needs to be retransmitted.

What happens when a packet is lost on the network and fails to reach its ultimate destination? When host A sends data, it starts a countdown timer. If the timer expires without receiving an acknowledgement, host A assumes that the data segment was lost. Consequently, host A retransmits a duplicate of the failing segment.

Its other functions include sequence control, error recovery and control, flow control and identification of port number.

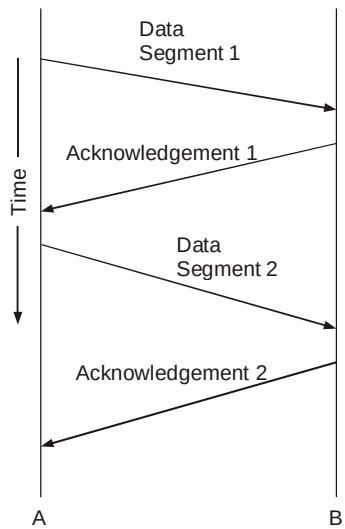


Fig. 4.41 *TCP DEstablishes Virtual Circuits*

Figure 4.41 shows the format of the TCP data segment. The TCP header includes both source and destination port fields for identifying the applications for which the connection is established. The sequence and acknowledgement number fields underlie the positive acknowledgment and retransmission technique. Integrity checks are accommodated using the checksum field.

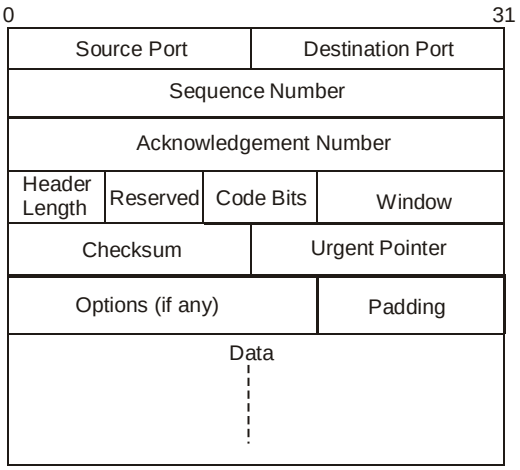


Fig. 4.42 *Data segment format of the TCP protocol*

IP – In contrast to TCP, it is a connectionless type service and operates at third layer of OSI reference model. That is, prior to transmission of data, no logical connection is needed. This type of protocol is suitable for the sporadic transmission of data to a number of destinations. It does not have such functions as sequence control, error recovery and control, flow control but it identifies the connection with port number.

From the above it seems that TCP/IP may be considered as two separate protocols i.e. TCP and IP. However, TCP actually refers to multiple protocols employed for communications using IP. Therefore, TCP/IP is also referred to as the TCP/IP protocol suit. Figure 4.43 shows the relationship between TCP/IP and the OSI reference model.

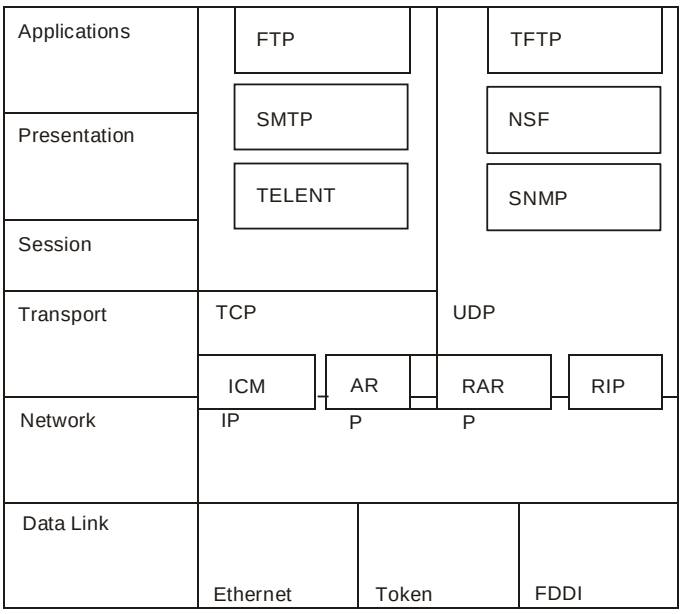


Fig. 4.43 *Correspondence between the TCP/IP model and the OSI model*

The applications shown for layers 5, 6 and 7 will be discussed in the upcoming sections.

TCP/IP Layers and Protocols

TCP/IP defines a suite of communications and applications protocols in layer structure, with each layer handling distinct communication services. TCP/IP defines a four-layer model as shown in Figure 4.44 consisting of Application, Host-to-Host, Internet, and Network Access layers. This architecture is based on three sets of interdependent processes, namely, application-specific processes, host-specific processes, and network-specific processes.

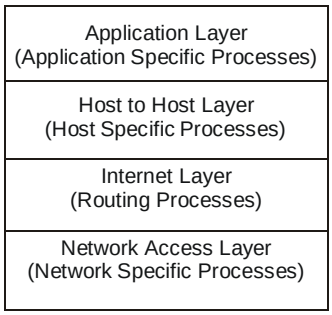


Fig. 4.44 *TCP/IP communication architecture*

Following are examples of concerns that each of these processes should handle:

Application-specific processes – TCP/IP defines the External Data Representation (XDR) protocol to provide an agreement between the data syntax running between the different platforms.

Host-specific processes – It is the responsibility of the host-specific process to establish, maintain, and release a connection on behalf of an application without losing track of other logical connections on multi-user/multitasking operating systems. Therefore, it ensures that data integrity is maintained without confusing the identity of the communicating applications.

Network-specific processes – These are processes that concerns with the delivery of data to the transmission medium and route data across networks until it reaches its ultimate destination.

Data Transmission by TCP and Ethernet

TCP/IP encapsulate upper layers using headers for the purpose of exchanging control and status information about the progress of the communication because its protocols also engage in peer talk by encapsulating data with protocol headers before submitting it to the underlying layer for subsequent delivery to the network. Figure 4.45 represents the data communication using TCP/IP and Ethernet as it is passed down the layers by an application on node X to node Y across the network.

A header is added to the data at each layer before being sent to the receiving node. The same header is removed at the receiving end in the reverse order as shown in Figure 4.45. Here, when a node wishes to transmit a data the application layer of TCP/IP architecture adds a header as TCP header which is again complemented by IP header and Ethernet header in the lower layers.

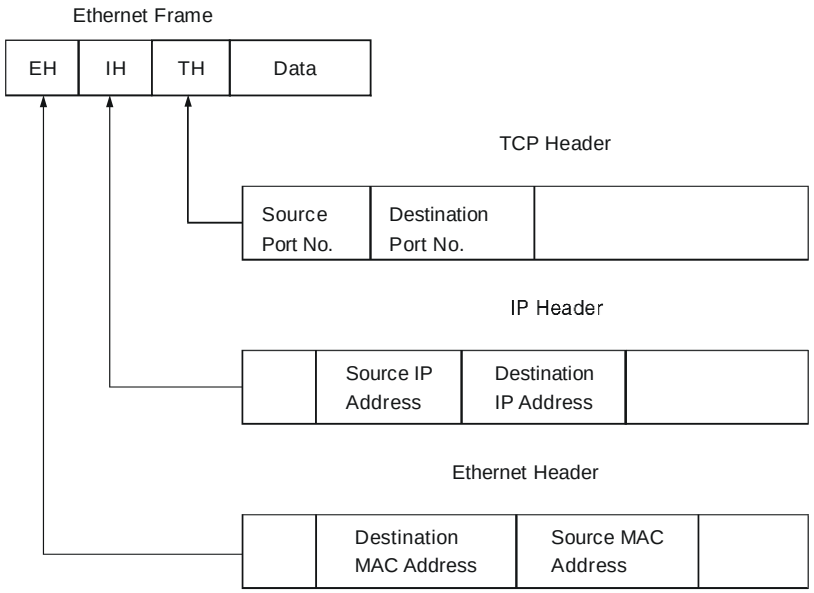


Fig. 4.45 *TCP/IP data encapsulation*

Figure 4.46 shows the configuration of each header. The addresses included in the TCP, IP and Ethernet headers are port numbers, IP addresses, and MAC addresses respectively.

At the transport layer, the header includes destination and source port numbers. For example, port number 25 identifies a SMTP session, whereas port number 80 the HTTP session. Therefore, upon receiving data from the Internet layer, the transport layer fetches its own header for the destination port number to identify the application that it is supposed to deliver the data to. This mechanism helps the transport layer establish connections on behalf of multiple applications without confusing the data exchange process. The protocol data unit thus formed at this layer is normally referred to as a data segment.

At the Internet layer, the header contains information to identify the IP addresses of the ultimate communicating hosts and intervening routers.

At the network access layer, the header includes the MAC addresses of the source and destination devices communicating on the same physical network. A frame check sequence is also included to assist the network access layer in checking the integrity of the received data. The protocol data unit thus formed at this layer is normally referred to as a data frame.

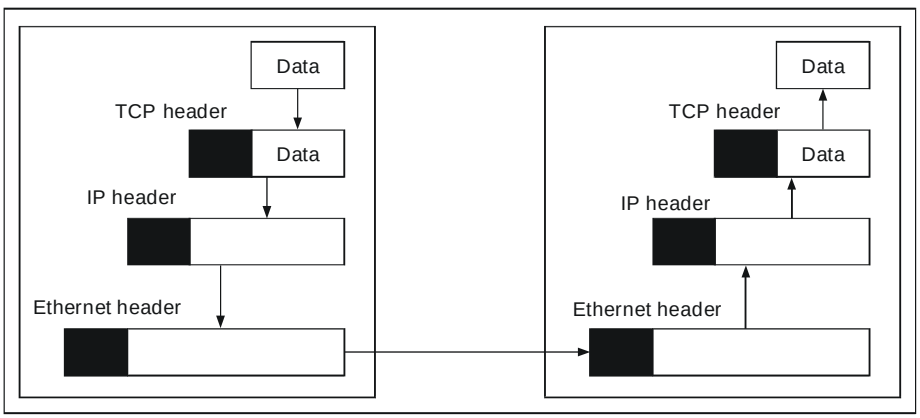


Fig. 4.46 *Configuration of TCP, IP and Ethernet header*

Data Encapsulation

Data encapsulation simply means adding the IP header to the (Figure 4.18) data. As shown in Figure 4.47, the IP header consists of five or six 32-bit words; the sixth word is attributed to the IP options field.

Internet Header Length (IHL): IP determines the length of the header by the contents of the IHL.

The version field: It refers to the version of the IP protocol in use. The current version of IP is 4.

The service type field: It refers to any of the type of services that IP supports. Desired service type is normally specified by user-level applications. Examples of service type include minimum and maximum throughput, requested by applications such as the File Transfer Protocol (FTP) and Simple Mail Transfer Protocol (SMTP).

The total length field: If it is subtracted from the IHL field, it indicates to IP the actual length of the data field.

The identification and the fragment fields: These provide the necessary elements on which IP's capability to fragment and reassemble data depend.

Header checksum field: IP supports a header checksum field in its header though it is an unreliable protocol. IP uses this field to check the integrity of its own header only. If it does not pass the integrity check, the entire datagram is discarded. It is worth noting that IP does not report such failures to the protocol service users. Instead, it is the responsibility of the latter to detect them mainly by employing a suitable timeout mechanism.

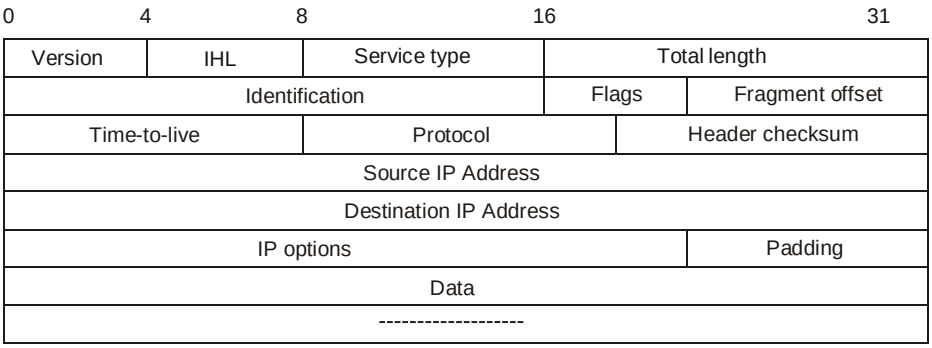


Fig. 4.47 *IP header configuration*

The Time-To-Live (TTL) field: – TTL is employed by IP to prevent a lost datagram from endlessly looping around the network. IP achieves this objective by initializing the TTL field to the maximum number of routers that the packet can traverse on the network. Every time the datagram traverses a router, IP decrements the TTL field by 1.

The source and destination IP addresses: These provide the identification for the receiving and communicating hosts across the inter-network.

IP Options field: On its presence, it includes optional control information. An example of optional information includes the route record, which includes a record of every router that the datagram traversed during its trip around the network.

Data Routing

Routing refers to the process of selecting the shortest and most reliable path intelligently over which to send data to its ultimate destination. IP routing protocol makes the distinction between hosts and gateways. A host is the end system to which data is

ultimately delivered. An IP gateway, on the other hand, is the router that accomplishes the act of routing data between two networks. A router can be a specialized device supporting multiple interfaces, while being connected to a different network as shown in Figure 4.20 or a computer multiple interfaces (commonly called a multihomed host) with routing services running in that computer.

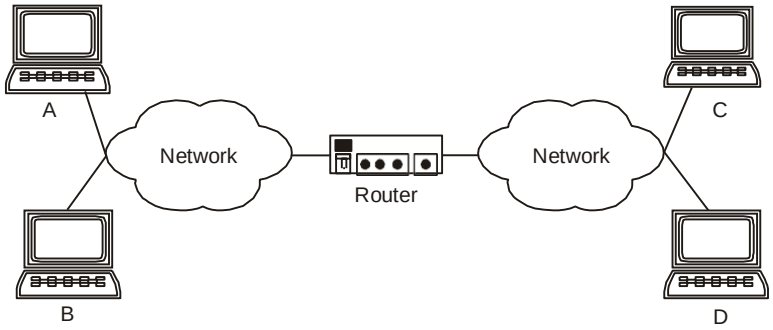


Fig. 4.48 *IP router providing services between two networks*

By OSI norms and standards, a gateway is not only a router but also a connectivity device that provides translation services between two completely hybrid networks. For example, a gateway (not a router) is needed to connect a TCP/IP network to an AppleTalk network.

It is important to know that both hosts and IP routers (gateway) perform routing functions and therefore, compatible implementations of the IP protocol are necessary at both ends. In other words, datagrams are submitted either to a host that shares the same physical network with the originating host or to a default gateway for further routing across the network. As such, IP on a host is responsible for routing packets that originate on this host only, fulfilling local needs for routing. A gateway, on the other hand, is responsible for routing all traffic regardless of its originator (as long as the TTL field is valid).

A default gateway is a router that a host is configured to trust for routing traffic to remote systems across the network. However, the trusted router must be attached to the same network as the trusting host. A router on a remote network cannot be used for providing the functionality of the default gateway.

An Error Reporting Mechanism — The Internet Control Message Protocol (ICMP)

The Internet Control Message Protocol (ICMP), an error reporting protocol is an integral part of the IP protocol. ICMP communicate control data, information data, and error recovery data across the network. Problems that are less severe than transmission errors result in error conditions that can be reported. For example, suppose some of the physical paths in Internet fail, causing the Internet to be partitioned into two sets of networks with no path between the sets, a datagram sent from a host in one set to a host in other cannot be delivered.

The TCP/IP suite includes a protocol called ICMP that IP uses to send error messages when conditions such as the one described above arises. The protocol is required for a standard implementation of IP. We will see that the two protocols are co-dependent. IP uses ICMP when it sends an error message, and ICMP uses IP to transport messages.

The following is a brief description of some of the error messages defined by ICMP protocol:

- **Source Quench:** A router or host whose receive communication buffers are nearly full normally triggers this message. A source quench message is sent to the sending host; the receiver is simply requesting the sending host to reduce the rate at which it is transmitting until advised otherwise.
- **Time Exceeded:** A time-exceeded message is sent in two cases. Whenever a router reduces the TTL field in a datagram to zero the router discards the datagram and sends a time exceeded message. In addition, a time exceeded message is sent by a host if the reassembly timer expires before all fragments from a given datagram arrive.
- **Route Redirect:** A router sends this message to a host that is requesting its routing services. When a host creates a datagram destined for a network, it sends the datagram to a router, which forwards the datagram to its destination. If a router determines that a host has incorrectly sent a datagram that should be sent to a different router, the router uses route redirect message to cause the host to change its route. In this manner, a route redirect message improves the efficiency of the routing process by informing the requesting host of a shorter path to the desired destination.
- **Host unreachable:** Whenever a gateway or a router determines that a datagram cannot be delivered to its final destination (due to link failure or bandwidth congestion), an ICMP host unreachable message is sent to the originating node on the network. Normally the message includes the reason the host cannot be reached.
- **Fragmentation and Reassembly:** The largest datagram the IP protocol can handle is 64kb.. The maximum datagram size is dictated by the width of the total length field in the IP header as shown in Figure 4.16. Realistically, most underlying data link technologies cannot accommodate this data size. For example, the maximum size of the data frame supported by Ethernet is 1,514 (Kilo) bytes. Unless rectified, IP has to discard data that is delivered to it from upper-layer protocols with sizes exceeding the maximum tolerable size by the data link layer. To circumvent this difficulty, IP is built to provide data fragmentation and reassembly.

  Whenever an upper-layer protocol delivers data segments whose sizes exceed the limit allowed by the underlying network, IP breaks the data into smaller pieces that are manageable within the allowed limit. The small datagrams are then sent to the target host, which reassembles them for subsequent delivery to an upper-layer protocol.

  Although all data fragments are normally delivered using the same route, in some situations a few of them might traverse alternative routes. Fragments following different routes, however, stand the chance of reaching their destination out of the order in which they were sent. To allow for recovery from such behaviour, IP employs the fragmentation-offset field in its header. The fragmentation-offset field includes sequencing information that the remote IP host uses to recover the sequence in which the datagrams were sent. IP also uses the information in the fragmentation-offset field to detect missing fragments. Data is not passed to the protocol described in the protocol field unless all related fragments are duly received and reordered. This process of fragment recovery and re-sequencing is called data reassembly.

Fragments belonging to two or more independent large data can be differentiated by IP using identification fields. Fragments belonging to the same datagram are uniquely assigned in the identification field. The receiving host uses this number to recover the IP fragments to their respective datagrams.

A host that creates a datagram can set a bit in the flag field to specify the fragmentation. Among other bits, the flag field includes a more fragments bit, which is set to 1 in all fragments belonging to a datagram except for the final fragment. This ensures that all fragments of a datagram are received.

- **Echo request/Echo reply:** These two ICMP messages are exchanged between ICMP software on any two hosts in a bid to check connectivity between them. The ping command is an example of a diagnostic command commonly used by network users to check for the reachability of a certain host. Whenever ping is invoked at the command line, ICMP echo request message is sent to the target host. If the target host is operational and connected to the network, it responds with an echo reply message as proof of reachability. In other words, the reply carries the same data as the request.
- **Address Mask Request/Reply:** A host broadcasts an address mask request when it boots, and routers that receive the request send an address mask reply that contains the correct 32-bit subnet mask being used on the network.

INTERNET SERVICES

The Internet is becoming a necessary tool rather than a convenient tool in society. It proves its utility in improving the productivity in all walks of life whether it be education, social, political or individual. This is being witnessed because of the presence of widespread networks with wide information sources, commercial vehicles and getting connected together to form the Internet and providing application and information to carry out useful tasks. Users connecting daily to the Internet are allowed to access these applications to reach other users, which were not possible few years ago. All these may be obtained on his/her terminal in a very short time. Moreover, they are not required to know the details of the technology underlying the Internet. This is the major reason behind the popularity of the Internet among laymen also. The information available on the Internet is making them more aware about their area of working and without which they feel the productivity and the profitability of their businesses would be seriously affected.

The following is a summary of the most widespread applications on the Internet today.

World Wide Web (WWW)

The World Wide Web is also known as the Web, WWW or W3. It is a global system of hypertext and multimedia services. WWW is a client-server model based on TCP/IP protocols and consists of browsers as clients and web servers as servers. Web servers use http (HyperText Transmission Protocol) and html (HyperText Markup Language) to make the www hypertext and multimedia services available to clients over the Internet. WWW supports hypertext to access several Internet protocols on a single interface. Hypertext or Hypermedia system allows interactive access to collections of documents. These documents can hold text (hypertext), graphics, sound, animations and video. These documents are linked together and may be seen as non-

Check Your Progress

13. What was the main objective of developing TCP/IP?
14. Define routing.

distributed and distributed, In non-distributed, all documents are stored locally (like CD-ROM). In distributed, all documents are stored on remote servers.

The Internet supports various protocols and network services. This includes e-mail, FTP, Gopher, Telnet, Usenet News. In addition to these, the world wide web has its own protocol.

The www provides a single interface for accessing all these protocols. This creates a convenient and user-friendly environment. It is no longer necessary to be conversant in these protocols. The Web gathers together these protocols into a single system. Because of this feature, and the Web's ability to work with multimedia and advanced programming languages, the WWW is the fastest-growing component of the Internet.

The operation of the Web relies primarily on HyperText — HyperText is a document that contains links (pointers) to other documents. A button represents these links. A single hypertext document can contain links to many documents. In the context of the Web, button or graphics may serve as links to other documents, images, video and sound.

A page represents each document. The initial page for individual or organization is called a home page**.** The Page can contain many different types of information and must specify content, type of content, location and links. These pages are formatted with a markup language called html (HyperText Markup Language) rather than fixed WYSIWYG (What You See Is What You Get) representation (e.g., Word). With html, tags are placed within the text to accomplish document formatting, visual features such as font size, italics and bold, and the creation of hypertext links. Graphics may also be incorporated into an html document. The html is an evolving language, with new tags being added as each upgrade of the language is developed and released.

The Web provides a vast array of experiences including multimedia presentations, real-time collaboration, interactive pages, radio and television broadcasts, and the automatic push of information to a client computer. Newer programming languages such as Java and JavaScript are extending the capabilities of the Web.

E-mail

Electronic mail, or e-mail, allows computer users locally and worldwide to exchange messages. E-mail users have an electronic mailbox into which incoming mail is dropped. Messages sent through e-mail arrive within a matter of seconds. User accesses these mails with a mail reader programme, called mail user interface that is usually associated with computer account. One user may have different electronic mailboxes. Electronic mailbox is identified by an e-mail address and is given a user's account ID. This is not always true because on non-networked multi-user computer, e-mail address is just account ID.

Mail delivery among networked computers is more complicated. In this case, a mail must identify the computer as well as the mailbox. Syntactically, e-mail address is composed of computer name and mailbox name; for example, user_id@domain.

E-mail message format contains header and body. Header includes delivery information and body carries message part. The header and body are separated by blank line. An e-mail message can only be transmitted in the form of 7-bit ASCII (American Standard Code for Information Interchange) data. ASCII is a 7-bit code, resulting in a maximum of 128 characters. The data in e-mail could not contain arbitrary binary values, e.g., executable programme. There are techniques for encoding binary data so that binary data may be transported.

A powerful aspect of e-mail is the option to send electronic files to a person's e-mail address. Non-ASCII files, known as binary files, may be attached to e-mail messages. These files are referred to as MIME (Multi-purpose Internet Mail Extensions) attachments. MIME extends and automates encoding mechanisms and was developed to help e-mail software handle a variety of file types. It allows inclusion of separate components, i.e., programmes, pictures, audio clips in a single mail message. The sending programme identifies the components so that the receiving programme can automatically extract and inform mail recipient. Many e-mail programmes, including Eudora and Netscape Messenger, offer the ability to read files written in html, which is itself of MIME type.

E-mail communication is actually a two-part process. The user composes mail with an e-mail interface programme. This mail transfer programme delivers the mail to the destination and waits for the mail to be placed in outgoing message queues. SMTP (Simple Mail Transfer Protocol) is the standard application protocol for delivery of mail from source to destination. It provides reliable delivery of messages using TCP and message exchange between client and server including e-mail address lookup and e-mail address verification.

The e-mail can be considered as an electronic version of paper-based office memo, which is quick and much cheaper than a written communication. Because e-mail is encoded in an electronic medium, therefore fast, automatic processing in the form of sorting and reply is possible. It allows quick, asynchronous communication across the entire Internet. Asynchronous communication consists of asynchronous characters which gives output at a rate that is independently generated by the transmitter. The asynchronous characters are actually self-synchronized because they are framed by Start and Stop bits that delineate the character. E-mail is the most widely used the Internet service. The best feature of the mail is its quick and reliable delivery of messages.

Telnet

A popular utility provided by TCP/IP is the TELNET. Telnet is a virtual terminal emulation facility that allows a user to connect to a remote system as if the user's terminal was hard-wired to that remote system. This works on client server architecture. A single telnet server hosts various files and databases to share a client machine that accesses these resources. Telnet is a programme that allows logging into computers on the Internet and using online databases, library catalogs, chat services, and more. The basic need to telnet to a computer is that its address should be known. This can consist of word (rag.gov.in) or numbers (140.147.254.3). The operation of this service is very simple. This requires just typing of the word telnet and then the address. Telnet is available on the www. Probably the most common web-based resources available through telnet are library catalogs. A link to a telnet resource may look like any other link, but it will launch a telnet session to make the connection. A telnet programme must be installed on local computer and configured to web browser in order to work.

FTP

File transfer facilities are implementations usually provided for by a mechanism known as the File Transfer Protocol (FTP). It is a simple featured file moving utility that allows a record-oriented (one record at a time) transfer, a block transfer (which moves chunk of a file) or an image transfer. To transfer a file, the user invokes the host, FTP utility specifies file name, type (if necessary) and remote destination.

This is both a programme and the method used to transfer files between computers on the Internet. Anonymous FTP is an option that allows users to transfer files from thousands of host computers on the Internet to their personal computer account. File transfer is quite rapid. FTP sites contain books, articles, software, games, images, sounds, multimedia, course work, data sets, and more.

INTERNET APPLICATIONS

The railroad industry is an important driver of a country's economic growth. An efficient rail network means transportation of goods and people at low cost and in time and, thereby, it facilitates economic growth. However, the size and complexity of problems which the railways face are also unique. Let us, for instance, consider Indian Railways, which is one of the largest rail networks in the world. It runs around 11,000 trains everyday, out of which 7000 are passenger trains. It has over 7500 locomotives, 37,000 coaches and over 2 lakh freight wagons. It operates from over 6800 railway stations and employs over 1.5 million people. The sheer scale of the operations poses numerous management and operational problems. Fortunately, the key decision makers in railways saw the tremendous potential of IT in solving some of these problems and embarked upon a major computerization initiative. Some of these are as follows:

- **All India centralized reservations system:** One of the most successful examples of computerization in the country; the computerized reservations mean that anybody, even in a small town, can book tickets for any destination.
- **Internet booking:** An online ticketing facility has been launched by IRCTC which can be accessed through the Website irctc.co.in. Currently, people can avail these facilities from 758 locations in the country. Computerized enquiries related to reservation like train schedule, passenger status and trains between pairs of stations are also provided on this site. Anybody with a credit card can book a ticket on any train through this Website The site levies a small service fee and delivers the ticket to the passenger's home through courier within 24 hours. Timetables, network maps, freight information, fares and tariff are also available on the Indian Railways homepage.
- **Computerized unreserved ticketing:** Nearly 12 million unreserved passengers travel everyday on Indian Railways. For catering to this large segment, a computerized system of ticketing has been launched recently. Unreserved tickets can now be bought even from other locations, not only from the boarding station, reducing long queues at booking offices and stations.
- **Season tickets:** A pilot project to issue monthly and quarterly season tickets through ATM has been successfully launched in Mumbai. Another pilot project to purchase tickets (including monthly and quarterly season tickets) using Smart Cards has also been launched.
- **National train enquiry system:** This system has been introduced for providing better passenger information and enquiries. This system provides real-time position of running trains using several output devices like interactive voice response system (IVRS) at major railway stations. This project has been put into action at 98 stations so far.
- **Railnet:** Railways have established their own intranet called 'Railnet'. It provides networking between railway board, zonal headquarters, divisional headquarters, training centres, production units, etc. to facilitate inter and intra-departmental communication and coordination.

Check Your Progress

15. What is a Telnet?
16. What is FTP?

Airlines

The air travel industry is one of the biggest users of information technology. There is hardly any aspect of the airline business in which computer systems have not been deployed for increasing revenues, reducing costs and enhancing customer satisfaction.

It is now almost inconceivable to book a ticket or get a seat confirmed across multiple sales counters (airline offices, travel agents, etc.) spread over numerous cities, without using computerized databases and e- networking. Like most other industries, the use of computerized systems in the air travel industry started with the front office and sales desk with back office operations playing a oracial role in delivering a quality experience to consumers. What typically started as airlines Intranet systems have now blossomed into a vast Web-based online systems which can be accessed by anybody from anywhere in the world.

Some of the interesting areas where IT has been used successfully are as follows:

- **Online ticket reservation through Internet:** Today, most leading airlines like United Airlines, Delta, British Airways, etc. sell tickets through their Websites. You can book the ticket through the Internet, pay online by giving your international credit card details and then collect the ticket (on the day of journey) and boarding pass from e-ticket kiosks at the airport by simply furnishing your booking reference details.
- **Flight and seats availability:** If you wish to travel from New Delhi to New York and do not know what your flight options are, simply log onto the airline site (or better still a travel site like 'msn', which offers information and tickets from many airlines and can, therefore, give you more options than a single airline's Website), specify the cities of travel origin and destination along with preferred journey dates and the database would yield all the possible options. Once you have selected the flights, you could even go a step further (possible in the case of a few airlines) and book a specific seat number in that flight along with the choice of meal.
- **Last minute deals and auctions:** A seat is a perishable commodity. An unsold seat means a revenue opportunity lost forever. Therefore, most airlines, including Indian Airlines (and some specialized ticket auction sites like Razorfinish.com) have now started a facility on their Website where potential customers can bid for last minute tickets in online auctions. Cases of people buying a ticket worth $1000 for as low as $100 are not uncommon. This is a win-win case by effective use of IT—the passenger is happy with getting the ticket at a fraction of its normal cost, and the airline is able to recover something from what might otherwise have been an unsold seat.

All these facilities/opportunities would have been impossible without integrated online computer systems.

Banking

In the 1960s and 1970s, the banking industry was losing the battle of providing good customer services because of impossibly heavy workloads. All major banks already had branches in most major locations and they simply had to recruit more and more staff to cope with the increasing number of customers. The accepted wisdom was that cost was the main basis for competition and so the banks made strenuous efforts

to reduce operational costs, kicking off the process by computerizing customer accounts. Computerization did lead to cost reductions by saving a lot of back office work, but banks still needed to employ a large number of front office staff to deal with customers. To overcome this problem, one of the UK banks adopted a radical solution. Why not get the customers to do the clerical work? This idea—not unlike that behind the airline reservation systems—led to the development of ATMs which allowed customers to take advantage of specific banking services 24 7 , without entering the bank. ATMs made it easy to deposit and withdraw money, check balances, request statements, etc. and coupled with the added advantage of round the clock availability, they not only reduced staff workloads but also gave their customers a new experience of hassle-free banking.

The banking sector has come a long way since then. It is now one of the largest users of information technology. Some of the areas where banks typically use IT are as follows:

- **Back office computerization:** Nowadays, almost all Indian and international banks run on fully integrated and online systems where all back office operations like accounts posting, reconciliation, clearing house operations, etc. are completely automated.
- **Front office computerization:** All banks provide facilities like instant account statement, making fixed deposits, electronic funds transfer, direct debit facility, etc. to their customers. None of these would be possible without the low transaction costs and efficiency offered by computerized systems.
- **Automated teller machines (ATMs):** These computerized machines enable customers to do their regular bank transactions (like depositing and withdrawing money, ascertaining current account balance, etc.) without visiting a bank branch. ATMs considerably reduce costs for banks (employee cost, space cost, etc.) and provide better level of service to customers (by enabling 24 hour banking access at numerous locations).
- **Internet banking:** Most banks like HSBC, Standard Chartered, HDFC, ICICI etc. have extremely user-friendly Websites where the typical banking transactions (like making request for cash and cheque pickup, cash delivery, generating account statements, requests for cheque books and drafts, etc.) can be carried out online without visiting the bank. This innovative use of IT means that, effectively, customers have no need to physically visit the bank for most routine banking transactions, which is an enormous convenience.
- **Credit card operations:** In a typical credit card operation, you purchase an article or a service and give your credit card to the vendor/service provider at the time of clearing the bill. The vendor (called 'Merchant' in banking language) swipes your credit card on a point of sale (POS) machine that instantly dials into the bank database to verify the authenticity and credit worthiness of the card. If both are satisfactory (in other words the transaction is covered by your credit card limit agreed between you and the bank), the POS prints an authentication receipt that authorizes the merchant to collect the transaction amount from the bank instead from the customers. Credit cards obviate the necessity of having to carry huge amounts of cash and an option of spending more than one's current cash status. On the other hand, banks earn money by charging a transaction fee from the merchant and interest on the credit facility. This entire operation is critically dependent on IT and would not have been possible otherwise.

Insurance

Like banking, the insurance sector has also to contend with a lot of routine paperwork—insurance policies, filed claims, survey or investigation reports, payment receipts, etc. It is a perfect opportunity to use IT to reduce costs and processing times.

Typically, insurance companies use computerized databases to keep track of all insurance policies, generating premium due statements, premium received receipts, lodging claims for insurance recovery, etc. Basically, all kinds of transactions are recorded and processed through computerized systems. This not only enables insurance companies to provide quicker and more efficient service to its clients, but it also allows them to minimize their risks and maximize profits by enabling complex financial, economic and demographic analyses of their customers. Using sophisticated computer programmes, an insurance company can determine which customer segments are growing the fastest, which are most profitable and which are more risky than others.

Although a lot of processes have been automated, things like insurance claims etc. are still filed on paper forms first. The volumes involved are quite intimidating prompting some insurance companies in the US and Europe to outsource the entire data entry process to specialized offshore firms—many of them in India.

This is how the typical process works—an insurance agent or the insured party fills up a paper form somewhere in the US. These forms are collected from multiple locations at one location—let's say the insurance company's head office. A team of professionals from the data entry agency (working in the insurance company's head office) scans these forms through high-speed scanners, generates image files for all the forms and then at the end of the day, using the Internet, transmits all these images to their data processing facility, let's say in New Delhi. Due to time difference, by the time this transmission is done at the end of the day in the US, it is morning in India. A team of trained data entry operators, using specialized software, views these forms (as images) on one portion of their screen and then types the same data in a database. Once the data has been properly verified and validated, it is uploaded back to the US within a few hours. This means that the images that were sent from the US the previous night could be available in the US the next morning in the form of a computerized database. Of course, other than the effective use of IT, the time difference between the US and India has helped tremendously to make this 'zero time lag' system a great success. This system of outsourcing one of the business functions is called business process outsourcing or BPO.

Another more sophisticated alternative to this is optical character recognition (OCR) where the images are run through OCR software that automatically converts these into text. OCR is only feasible where the text quality is very (typically typed or computer printed matter) high. Since OCR operations still produce only 90 to 95 per cent accurate text, human intervention is still required to correct the mistakes made by OCR systems. In course of time, however, technological advancements will bring 100 per cent reliability and further change the face of remote processing arrangements.

Financial Accounting

Financial accounting was one of the first business functions for which software applications were developed. The importance of financial accounting and management for any business cannot be overemphasized, but the scale of transactions, the repetitive and structured nature of the data and the sheer volumes involved in the case of large corporates make for an ideal case for computerization. Computerizing accounts also takes the drudgery out of bookkeeping, which means that accountants can now

concentrate more on analysing information rather than devoting countless hours merely in filling out vouchers and updating registers and ledgers.

Typically, this is how a computerized accounting system works. The accounting clerk makes the voucher directly on the computer using a financial accounting software package. The voucher on the screen looks very similar to a regular paper voucher and is in fact much simpler to fill because things like current date and voucher number are generated automatically. The appropriate account names that have to be debited or credited need not be typed but simply selected by the click of a mouse from a list of all ledger accounts. Appropriate checks and validations are also built into the accounting software which reduces the chances of errors. Unless the total of all debit accounts, for example, equals to the total of all credit accounts, software will not allow the voucher to be saved.

Once the basic data has been entered into the computer voucher, the accountant can print out as many copies as required. Unlike a manual accounting system where a voucher once prepared has to be entered into the daybook and then posted in the relevant ledger account, the computer software does this automatically. In fact, the moment the voucher is entered and saved it is not only automatically posted to all the relevant daybooks and ledger but also up-to-date profit and loss account, trial balance and balance sheet can be generated instantly showing the downstream effects on each one of them. Since there is no time lag between voucher preparation and posting, the accounting software always shows an up-to-date statement and final account.

Depending upon the size of the organization and the complexity of its operation, different software packages are readily available in the market. At the bottom end are popular and inexpensive software packages, such as Tally and EX, which are quite sufficient for most small and medium-scale organizations. Tally provides an excellent user-friendly interface through which all accounting transactions can be entered or modified easily and the user can see the effects of each transaction in all financial statements.

At the top end of the market are enterprise resource planning (ERP) software packages such as Oracle Financials, Baan, SAP, etc. which cater to the financial accounting and management needs of huge multi-location, multi-currency, multi-operations organizations such as Nestlé, Pepsi, Coca Cola, Procter & Gamble, etc. Such software is called ERP software, since it provides completely integrated solutions for all functions of a business such as financial accounting, inventory, payroll, production planning and control, etc. Despite the fact that ERP solutions typically cost millions of rupees and are relatively much more complex to implement, they provide an excellent platform for ensuring that the company's system and procedures are uniformly followed across multiple locations (or even countries). Such systems also make it very easy to consolidate huge amounts of information from different profit centres and locations.Thus, effective near real-time management information can be generated to assist the apex-level decision making.

Inventory Control

For any manufacturing firm, managing inventory is crucial. High inventory results in money being locked up unnecessarily, thereby reducing liquidity and indirectly profitability (if you offer immediate payment, most suppliers would be willing to offer you better rates). On the other hand, lower inventory of finished goods may lead to lost sales, or lower inventory of raw material may lead to disruption in production line. Optimum stock levels optimize operational efficiency.

Most large manufacturing units typically need hundreds (if not thousands) of raw material components and produce many products. Managing optimal inventory of such a large number of items is a difficult task. It is here that information technology again plays a very useful role. Inventory management software provides facility for specifying (and determining) the maximum, minimum and reorder levels for each item, so that appropriate levels of inventory can be maintained keeping in mind lead times and just-in-time (JIT) systems (if any) for component suppliers.

Basically, this is how a typical computerized inventory system works. A list of all the inventory items is prepared along with the maximum, minimum, reorder and current levels (quantity in hand as on a fixed date) for each item. This list is fed into the inventory software. Thereafter, all incomings (materials purchased or produced) and outgoings (sales or issues to production floor) are recorded through the inventory package. Since the computer knows all the ins and outs for each item, it can track the exact quantity in hand for each. The package also generates reports for all the fresh stocks that need to be procured (based upon the levels specified). A variety of other useful MIS reports like aging analysis, goods movement analysis, slow and fast moving stock report, valuation report, etc. can also be generated which assist the store keeper and accountants.

Some of the more sophisticated inventory packages (or inventory modules of ERP packages like Oracle financials, Baan, SAP, etc.) automatically generate purchase orders (as soon as the minimum level of any item is reached), provide automatic posting of accounting entries (as soon as any purchase or sale is carried out) and generate analytical reports which show the previous and future trends in inventory consumption.

Some interesting innovations in usage of IT for better inventory management are as follows:

- **Bar coding system:** Bar coding is a technique which allows data to be encoded in the form of a series of parallel and adjacent bars and spaces which represent a string of characters. A bar code printer encodes any data into these spaces and bars and then a bar code reader is used to decode the bar codes by scanning a source of light across the bar code and measuring the light's intensity that is reflected back by the white spaces. Bar coding provides an excellent and fast method for identifying items, their batch numbers, expiry dates, etc. without having to manually type or read the data.

Bar Coding System

- **Hand-held terminals (HHTs):** HHTs are simple devices used to communicate with any type of microprocessor-based device. The standard input device is the keyboard (typically more akin to the calculator, rather than the computer keyboard) and a small LCD display for the output. HHTs are compact, simple and rugged devices designed for outdoor applications like collecting the information about inventory from large warehouses, recording movement of goods in and out, etc.

- **Internet and Intranets:** Many organizations (specially those following 'just-in-time' techniques) now have a system whereby the moment they receive an order or a request for an item (which is not in stock or whose stock is low), the inventory package automatically generates a purchase or supply order electronically and mails it to the preferred supplier—all this without any human intervention!

Hotel Management

The hotel industry is an integral part of the tourism industry, which is a vital source of revenue and foreign exchange for a country's economy. A vibrant hotel industry means greater employment generation. However, since this industry relies on easy and quick availability of information, the role of IT in its development and growth cannot be overstressed. In fact, IT has revolutionized the hotel and tourism industry. This is because of the instant availability of information about the tourists spots, hotel infrastructure, room availability, traiff details, online looking, etc. at the click of a button. IT is playing a critical role in improving performance because of its potential for creating customer relationships and the flow of information between the people and customers.

There are numerous instances of use of IT in hotel industry. Some of these include the following :

- Today's hotel management software means that the moment a guest expresses interest in staying at the hotel till the time he checks out, all transactions with him (room charges, food and laundry bills, business centre and health centre bills, hiring, etc.) are recorded electronically, making information available at the click of a button.
- Many leading hotels offer online booking facility for tourists and guests. This makes it very easy for the tourist as he or she has beforehand knowledge of room availability and charges. There are several Websites wholly devoted to this. Microsoft's MSN has a traveller's section where one can search for hotel accommodation on the basis of criteria like city, location, budget, etc. A tourist, for example, can specify the city and his budget. On the basis of on this information, the search facility throws up a complete list of hotels available. Moreover, the tourist can even specify his or her preferred location. Once the hotel is identified, booking can be made online using an internationally valid credit card.
- Most of the hotels have computerized their records. It is very easy to know the details of room availability at a particular time. The information about the occupant is also available instantly. This computerized system typically integrates all the MIS functions of the hotel into a single system. Cendant Corporation has successfully implemented this practice in its chain of hotels. The Barbizon Hotel and Empire Hotel, New York, has eliminated logbooks and standardized record keeping by the use of customized software. Carlson Hospitality Worldwide has the most efficient reservation system in the US. IMPAC Hotel Group has touch screen lobby kiosk for guest tracking. Inter Continental Hotels & Resorts use a global strategic marketing database. All these are examples of use of IT in hotel industry, which have made significantly transformed operations and profitability.
- Hotel information systems help users in accessing information on the guest database and using the information for creating attractive one-to-one confirmations of reservations, sales messages and e-mail marketing, custom

reports and e-mail comment cards for reinforcing guest relationships. The Balsams Grand Resort Hotel has a comprehensive guest history programme that it has used successfully for productive purposes. Courtyard by Marriott has an intranet system by which it has replaced manuals and printed material.

- Information technology is being increasingly used by international hotel chains to formulate and align their corporate strategies. Marriott International is a successful example of alignment of information technology with corporate strategy.

Education

Teaching has traditionally been associated with classroom instructions on a blackboard with the instructor dependent almost entirely on his or her oratory and presentation skills for holding the attention of the class. From a student's perspective, she had to keep pace with the instructor's pace, which meant that the slower (though not necessarily less intelligent) student was at a natural disadvantage. Similarly, some students were more interested in a more in-depth study than the others. Since access to information was neither easy nor inexpensive, these variables had always posed a major barrier to learning.

Ever since the advent of information technology, the scenario has changed dramatically. Today, the instructor has a repertoire of information technologies. To make the lecture not only more interesting but also more informative, there are advanced electronic teaching tools available. These vary from simple slide presentations to full multimedia presentations which have video clippings, sound effects, animation and graphics to explain even the most abstruse subjects in a simple and easy-to-understand manner. As an example, a medical student does not have to pore over boring textbooks to understand, for example, the human anatomy. Simple computer packages like 'Body Works' are available which explain the same using photographs, images and graphics that make in-depth learning fun rather than a chore. Moreover, learning is not only faster but is also retained longer when test is supported by visuals and sound clips. Multimedia has transformed both classroom as well as online (distance) and packaged (CDs, VCDs, DVDs, etc.) education, in terms of both content as well as interactivity.

Some of the interesting developments in IT for the education sector are as follows:

- **Computer-based training (CBT):** In most of the progressive institutes today, classroom sessions are complemented by CBTs. CBT typically comprises user-friendly software in which the course syllabi is broken up into a series of interactive sessions. These sessions involve imparting a slice of knowledge to the student and then quizzing him to reinforce his understanding. Students have the option of going through these sessions at a time most convenient to them and a pace best suited to them. CBTs also provide an excellent medium for the student to learn by exploration and discovery rather than by rote.
- **Internet:** Thanks to the Internet, any and every type of information is available at the click of a mouse. No longer have students to trudge long distances to visit a library and spend valuable time plodding through library catalogues to find the right information. Using a search engine, one can easily access the desired information. Also, knowledge is no longer restricted within the academic fraternity alone. Thanks to our networked world (Intranet/Internet) information dissemination is faster and widespread.

- **Distance learning:** Information technology has also made distance learning a reality. You need not be physically present in a business school to do a management course from there. By innovative use of information technology, educational institutes have reached out to students who would otherwise never have been able to enroll with them.
- **Computerization of administrative tasks:** Most academic institutes use computerized systems for student enrolment, fee management, examination, administration, etc. Enrolment forms, for instance, are now available on institutional Websites, and examination results are usually available on the Internet. Some schools have also started collecting fees through Internet by using credit cards.

Telephone Exchanges

The first telephone service invented by Alexander Graham Bell was strictly 'point-to-point', i.e. each user had to be physically connected to every other user. There was no 'telephone exchange'. Needless to say, Bell immediately realized the need for an exchange and made one. In this first exchange, each subscriber had to be wired only up to his local exchange. An operator sitting in the exchange connected him to other subscribers upon request (earlier phones did not have dialing facility) by physically connecting the caller's wire to the recipient subscriber's telephone by using a hand-actuated circuit switch. One does not need to stretch one's imagination to appreciate the fact that operator-controlled exchanges were not only extremely labour intensive but also highly error prone.

Now compare this to the digital, computerized telephone exchanges used today. These are electronic systems that do the switching operation based upon a 'stored programme control'. The rules defined in the software assess the destination the caller is trying to connect, plot the most optimal path, intimate the called party, inform the caller about his call status and then if the called party accepts the call, establish the circuit. The call is monitored during its progress and the circuit disconnected once the call is terminated. Computerized exchanges improved and enhanced call-processing capacity, thereby lowering the cost of operations. They also opened up a dazzling array of IT-enabled subsciber services that have made modern telephony an indispensable service.

Bharat Sanchar Nigam Limited (BSNL), one of the main providers of telephony services, extensively uses a product called INFOTEL for managing their telephone exchanges. This product provides the following:

- **Facilities:** Activation, deactivation and modification of subscriber facilities, such as ISD, STD, call waiting, call transfer, computer-generated bills, etc.
- **Fault booking and restoration of service:** To maintain a database of complaint calls either through an interactive voice response system (IVRS) or a customer service cell. The system automatically creates the complaint docket and generates a range of statistical and exception reports.
- **Line data maintenance:** The system provides online data on cable codes, cable pair numbers, cabinet number, pillar numbers, etc. for all subscriber connections to facilitate and expedite line repair and maintenance.
- **Directory enquiry:** The computerized subscriber database also allows extensive online or voice-based directory enquiry based upon subscriber

Mobile Phones

Statistically, major portions of the population of any developing country still do not possess a telephone. Making a simple call to anybody requires locating the nearest telephone booth, waiting for ones' turn in the queue, and then paying for a short chat on (most often) a disturbed line.

In the developing countries, the penetration of landline phones has been low largely due to the hassles of laying cables across long distances. Especially in the case of remote areas, the cost of connecting a few phones to the main land mass becomes disproportionately high. Maintaining these telephone cables across inhospitable terrain also poses a major challenge to network expansion planners and engineers.

However, the advances made in the telecommunications industry in the last two decades, i.e. mobile phones, provide an excellent cost-effective and efficient alternative to the land phones for developing countries like India.

A cellular phone (as mobile phones are also known) is primarily a radio—a very sophisticated variant of a radio telephone. The cellular system divides the city into small cells (hexagons on a big hexagonal grid). There is a base station of each cell consisting of a tower and a small building having the radio equipment. Wireless communication is possible within and across cells allowing a user complete mobility making communication much easier and less time-consuming. Through switching devices in landline telephone exchanges, mobile phone users can also access the global landline network, effectively bringing everyone within speaking distance.

The mobile phone industry owes its growth to information technology, which is in fact central and pivotal in any mobile system. Technologies like PCS, TDMA, CDMA, GSM are often associated with mobile phones.

Personal communications service (PCS) is a wireless phone service that is akin to cellular telephone service but it emphasizes on personal service and greater mobility. It is at times called digital cellular (cellular systems can also be digital). Like cellular service, PCS is for mobile users and needs several antennas for blanketing a coverage area. When a user moves from one place to another, the nearest antenna picks up the user's phone signal and then forwards it to a base station for connecting to the wired network.

Time division multiple access (TDMA) is a technology that is used for communication in digital cellular telephone. In TDMA each cellular channel is broken into three time slots for increasing the amount of data that can be carried.

Code division multiple access (CDMA) uses analogueue-to-digital conversion (ADC) along with spread spectrum technology. Audio input is first digitized into binary elements. The frequency of the signal that is transmitted is then made to fluctuate in accordance to a defined pattern (code), such that the signal is intercepted only by the receiver. The frequency response of the receiver is programmed with the same code; hence, it follows with the same transmitter frequency. Since there can be trillions of possible frequency-sequencing codes, the privacy gets enhanced and cloning becomes difficult.

Global system for mobile communication (GSM), a digital mobile telephone system, is used widely in Europe and other parts of the world. GSM is the most widely used of the three digital wireless telephone technologies (TDMA, GSM and CDMA) and it uses a different kind of TDMA. GSM digitizes and condenses data before sending it down a channel with two other streams of user data, each in its own time slot. GSM is in fact the de facto wireless telephone standard in Europe.

Today, mobile phones are proliferating as handsets are getting cheaper and call rates declining, bringing them within the reach of the common man. They provide an array of functions (some very simple and others very sophisticated). Some of the popular functions which are based upon IT are as follows:

- **Short messaging service (SMS):** Small text messages can be exchanged between people who do not believe in long verbal conversations over communication channels. In fact, today SMS has gained popularity as a medium for sending and forwarding information.
- **Address book:** It is a store of contact information maintained on the mobile handset or the central server. It does away with the usual problem of maintaining a hard copy address book and allows the phone user to dial numbers without having to bother about carrying a bulky file-o-fax or telephone diary along.
- **Schedules or to-do lists:** You can store a list of important tasks that you wish to accomplish. Most mobile phones software also provide for appointments and reminders associated with these tasks.
- **Send or receive e-mail:** Thanks to WAP technology it is now possible to access your e-mails using your mobile phone. Popular portals like Yahoo and Rediff offer a facility whereby users get automatic alerts on their mobile phones as soon as any new mail arrives. You can also use your mobile phone for chatting using your MSN or ICQ account.
- **Get information updates:** All mobile service providers now provide add-on facilities for their subscribers to receive regular updates on news, entertainment, stock market prices. This is done by integrating Web-based databases with the mobile users' database. Service providers also use this capability to advertise for new products, services and schemes.

As you can appreciate, all the above mentioned facilities are based upon the usage of electronic databases and intelligent software available on the mobile phone. Due to the global trend of convergence the dividing line between information technology and telecommunications technology is getting increasingly blurred. Today's computers combine phone, fax, television, VCD/DVD drives, stereo—all in one seamless bundle.

Video Games

Games have been one of the most popular uses of computers. In fact, organizations like Attari, Nintendo and Sony who were developers of video games have been instrumental in the improvements in the multimedia capabilities of desktop computers. Till about a decade ago when personal computers had severe limitations of disk storage, processing speed and memory size, only very simple uni-dimensional video games were possible. But with the development of much faster Pentium series of CPUs with inbuilt multimedia capabilities coupled with improvement in digital storage and acoustics, today's games are limited only by their creators' imagination and not by any technological hindrances. Today's games like Doom, Pokeman, PlayStation, Galaxian, Defender, etc. use very sophisticated graphic and sound techniques to create three-dimensional games.

Some of the interesting developments in this area have been the following:

- Virtual reality
- Improvements in specialized input devices like joysticks
- Special game cards and enhanced graphic capability of CPU
- Web games (Casinos)

Information Kiosks

Traditionally, getting information from any large organization or government department meant standing in a long queue and then having to deal the changing moods of the person sitting at the information desk. Not only did it take a lot of time but also one invariably did not get the complete and authentic information in one go since even if the person responsible for giving information was available and willing, he or she invariably did not provide the complete information.

Proactive organizations decided to use information technology to solve this problem and provide a better level of service to customers and citizens. Information kiosks are computer-based terminals that provide information of any kind. Typically, these kiosks use a touch screen technology where the user does not have to type through the keyboard or click using a mouse but simply touch hot spots on the computer monitor to select the desired option. These kiosks also use sound recorded in vernacular languages to make the content more user-friendly and to reach out to the illiterate and literate alike.

The most popular applications of information kiosks can be seen at the following places:

- **Public access areas:** Shopping malls, holiday resorts, cinema halls, etc. use information kiosks with graphics and audio prompts that assist customers in accessing information about the desired products, services and frequently asked questions (FAQs) about availability, price, attributes, etc.
- **Public utilities:** One of the early users of information kiosks were public utility organizations (in the US and Europe). Most public companies receive enormous amount of requests for information about their services, lodging complaints, application status, etc. Instead of employing an army of front office staff (and taking on the additional hassles of their constant training and ensuring that their motivation is at high levels), most organizations opted for the information kiosks to provide hassle-free, round, the clock service to their customers. Information kiosks reduce personnel cost as well as the need for vast office space and costly support equipment.
- **Web kiosks:** Although the early usage of information kiosks was limited largely to static information (brochures, technical information and collaterals), information kiosks are being increasingly used to provide database driven, online information. For instance, information kiosks at the New York airport are linked to all the major hotels in the city and any traveller can do an online booking after confirming room availability.

Special Effects in Movies

Special effects in movies have come a long way since the early 20th century. During the early years of movie making, special effects were limited to time-lapse cinematography—hand-controlled dummies brought to life by stop motion filming, which meant manually moving the animated model a fraction of an inch and taking a snapshot. The 1933 classic *King Kong*, for example, involved tedious photography of a life-size dummy model moved laboriously inch-by-inch between takes by a team of assistants.

Similarly, the early animation movies (popularly called cartoon films) involved a team of artists and painters who would painstakingly draw and paint each sketch frame by frame. The photography team would then click shots of these sketches at the rate of twenty-four frames a second of film and edit them into a story.

Cut to the 21st century. If another version of *King Kong* were to be made in 2004 (and it has) what you would get is a completely authentic looking Gorilla (made fiercer by even better digitally created and enhanced sound effects) walking in a lush green forest (once again created by a clever mix of amazon rain forest pictures and computer techniques commonly known as digital compositing). Not only would the ape look and behave completely naturally but would also be able to perform stunts (like 360-degree flips or making 100-metre jumps) that would just not have been possible with any physical model.

Some of the interesting techniques used for creating special effects are as follwos:

- **Digital compositing:** Typically done through a process called 'Bluescreen' where the actors perform the scene in a studio in front of a large blue screen. A separate team of computer designers and artists create a virtual background (by mixing multiple photographs and computer generated images). Later the actors' footage is superimposed on the top of the background to create a seamless 'composite picture'.
- **Time slicing:** In this technique, a series of cameras are placed around the object of concern. All these cameras shoot pictures at precisely the same time. When these pictures are played together it appears as if there is one camera moving around the object. Coupled with other special tricks (such as slow motion photography as used in the Matrix series) this creates an ethereal effect.
- **Computer-generated imaging (CGI):** CGI techniques are used to create scenes which are either not possible in real life or would be too expensive or dangerous to film. For instance, to gather a crowd of 150,000 people in the Colosseum to shoot a gladiator fight sequence would cost an enormous amount of money besides creating nightmarish logistical problems. Doing the same though CGI would not only cost a fraction of the money, but also save precious time.

None of the above developments would have been possible without the fantastic developments in information technology.

SUMMARY

- A data communication system is made up of the message, the source, the destination, the medium and the protocol.
- A network is a connection of independent computers to communicate with one another over a shared network medium. The physical layer deals with transmission medium to transport information in the form of bits between different computers on the network.
- A physical layer of a network accepts data from the data link layer in bit streams for subsequent transmission over the physical medium.
- Data communication and networks deal with data or information transmission. Data can be represented in many ways, such as a human voice, a bunch of numbers, images, text and sounds, etc.
- Analog is best explained by the transmission of such signals as human speech or sound, over an electrified copper wire.
- Computers are digital in nature. Computers communicate, store and process information in binary form, i.e., in the combination of 1s and 0s, which has specific meaning in computer language.

Check Your Progress

17. What is the bar coding system?
18. List the important developments that have taken place in the area of video games.

- For transmission across a network, data has to be transformed into electromagnetic signals.
- Signaling System 7 (SS7) is the protocol designed for public switched telephone system for providing services and setting up calls. The various value-added features, such as providing intelligence to PSTN services come under the service of SS7.
- Digital signals are identified through bit interval and bit rate. The bit interval is the time occupied by a single bit and the bit rate is the number of bit intervals per second which is expressed in bits per second or bps.
- In the mainframe and minicomputer environment, each user is connected to the main system through a dumb terminal is unable to perform any of its own processing tasks.
- In packet switched data networks, the source Data Terminal Equipment (DTE) divides all user data that is to be transmitted into one or more message units called packets.
- Circuit switching is a switching method in which a dedicated communication path in physical form between two stations within a network is established, maintained and terminated for each communication session.
- Internet Service Provider (ISP) is a company that access Internet services. This service provider provides a software package in which you get registration with the providing services.
- The basic meaning of hub is 'centre.' We know that the central part of a wheel is called a hub. But this term is used not only in a mechanical system but also in electrical, electronics and computer systems.
- Like repeaters, bridges are used to connect similar LANs together.
- There are three bridge protocols: spanning tree protocol, source routing transparent protocol and source routing protocol.
- A multiplexer or mux is an electronic device which performs multiplexing by selecting one out of many input signals (analog or digital) and forwarding the selected input into a single line.
- A network consisting of routers can have multiple paths unlike bridges. Normally the shortest of all paths in the network is used to transfer packets.
- Brouters are network devices that perform the function of both a bridge as well as a router. It routes packets for known protocols. As a bridge it simply forwards packets.
- A default gateway is a device that allows traffic to pass from devices on a local subnet to those on a other subnets.
- LANs can be defined as privately owned networks offering reliable-high-speed communication channels that are optimized to connect information processing equipment in a small and restricted geographical area, namely, an office, a building, a complex of buildings, a school or a campus.
- A MAN covers large geographic areas such as towns, cities or districts. By linking or interconnecting smaller networks within a large geographic area, information is conveniently distributed throughout the network.
- The difference between MAN and WAN may be understood only from the services that they use. WAN uses both the local and long distance carrier while MAN uses only a local carrier. Hardware and protocols are the same for both.

- TCP/IP stands for Transmission Control Protocol/Internet Protocol. It was developed with the objective to specify a suite of protocols capable of providing transparent communications interoperability services between computers of all sizes, regardless of the hardware or operating system platforms supporting them.
- TCP/IP defines a suite of communications and applications protocols in layer structure, with each layer handling distinct communication services.
- The Internet is becoming a necessary tool rather than a convenient tool in society. It proves its utility in improving the productivity in all walks of life whether it be education, social, political or individual.
- An online ticketing facility has been launched by IRCTC which can be accessed through the Website irctc.co.in.
- The air travel industry is one of the biggest users of information technology. There is hardly any aspect of the airline business in which computer systems have not been deployed for increasing revenues, reducing costs and enhancing customer satisfaction.
- In the 1960s and 1970s, the banking industry was losing the battle of providing good customer services because of impossibly heavy workloads.
- In a typical credit card operation, you purchase an article or a service and give your credit card to the vendor/service provider at the time of clearing the bill.
- Like banking, the insurance sector has also to contend with a lot of routine paperwork—insurance policies, filed claims, survey or investigation reports, payment receipts, etc.

KEY TERMS

- **Analog:** It refers to the transmission of such signals as human speech or sound, over an electrified copper wire.
- **Signalling System 7(SS7) :** It is the protocol designed for public switched telephone system for providing services and setting up calls.
- **Multiplexer:** It is an electronic device which performs multiplexing by selecting one out of many input signals and forwarding the selected input into a single line.
- **Routers:** These are small electronic devices that join multiple computer networks together via either wired or wireless connections.
- **Kiosk:** It is a small, free-standing physical structure that displays information or provides a service.

ANSWERS TO 'CHECK YOUR PROGRESS'

1. The two main types of communication are analog and digital.
2. The functions of SS7 are as follows:
   - It controls the network.
   - The SS7 network sets up and tears down the call.
   - It handles all the routing decisions and supports all telephony services including Local Number Portability (LNP), remote network management, called ID and forwarding.

3. Two advantages of telephone networks are as follows:
   - It is circuit switching network, therefore, any receiver can be selected and there is virtually no transmission delay.
   - As it is widely spread, it is available at a low price.
4. Two switching techniques are as follows:
   - Space-Division switching
   - Crossbar Switch
5. The three bridge protocols are spanning tree protocol, source routing transparent protocol and source routing protocol.
6. The basic function of a multiplexer is to combine multiple inputs into one single data stream. At the receiving end, a demultiplexer is used to split the received single data stream into multiple original signals.
7. The characteristics of a router are as follows:
   - Routers are multiport devices with high-speed backbones.
   - Like bridges, routers also support filtering and encapsulation.
   - Like bridges routers are also capable self-learning, as they can communicate their existence to other devices and can learn of the existence of new routers, nodes and LAN segments.
8. Brouters are network devices that perform the function of both a bridge as well as a router. It routes packets for known protocols. As a bridge it simply forwards packets.
9. LANs can be defined as privately owned networks offering reliable-high-speed communication channels that are optimized to connect information processing equipment in a small and restricted geographical area, namely, an office, a building, a complex of buildings, a school or a campus.
10. The three main categories of communication networks are LAN, WAN and MAN.
11. Some of the facilities available through the use of the Internet are as follows:
    - Direct communication
    - Distance learning
    - Wide Area Networks
12. Commercial networks provide access to the backbones to subscribers and networks owned by commercial organizations for internal use and also have connections to the Internet. Mainly, Internet Service Providers come into this category.
13. TCP/IP stands for Transmission Control Protocol/Internet Protocol. It was developed with the objective to specify a suite of protocols capable of providing transparent communications interoperability services between computers of all sizes, regardless of the hardware or operating system platforms supporting them.

14 Routing refers to the process of selecting the shortest and most reliable path intelligently over which to send data to its ultimate destination.

15. Telnet is a virtual terminal emulation facility that allows a user to connect to a remote system as if the user's terminal was hard-wired to that remote system.
16. FTP is a simple featured file moving utility that allows a record-oriented (one record at a time) transfer, a block transfer (which moves chunk of a file) or an image transfer. To transfer a file, the user invokes the host, FTP utility specifies file name, type (if necessary) and remote destination.
17. Bar coding is a technique which allows data to be encoded in the form of a series of parallel and adjacent bars and spaces which represent a string of characters.
18. The important developments that have taken place in the area of video games are as follows:
    - Virtual reality
    - Improvements in specialized input devices like joysticks
    - Special game cards and enhanced graphic capability of CPU
    - Web games (Casinos)

EXERCISES AND QUESTIONS

Short-Answer Questions

1. Write a short note on analog and digital communication.
2. Mention the various types of multiplexers.
3. List the various advantages of using the Internet.
4. Mention the various protocols of the Internet.
5. Write short notes on the following:
   (a) ARPANET
   (b) World Wide Web

Long-Answer Questions

1. 'A data communication system is made up of the message, the source, the destination, the medium and the protocol.' Explain the statement.
2. Discuss the advantages of analog and digital transmission.
3. Explain the working of the LAN technology.
4. Discuss the history of the Internet.
5. Give examples of the application of the Internet.

FURTHER READING

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UNIT-5 DATABASE MANAGEMENT SYSTEM

Structure

INTRODUCTION

Database Management System (DBMS) is a software solution that allows you to create and maintain databases in which data are stored. There are four types of data models: relational, hierarchical, network and object-oriented that you can use to store data. Different individuals, such as a database manager, perform separate roles to manage the database. DBMS supports multiple-layered architecture that provides physical and logical data independence. Data stored in the database can be accessed using different languages such as FML and SQL.

Database design is a process in which you create a logical data model for a database which stores data of a company. You use the normalization technique to create the logical data model for a database and eliminate data redundancy. Normalization also allows you to organize data efficiently in a database and reduce anomalies during data operations. Various normalization forms, such as first, second and third can be applied to create a logical data model for a database. Second and third normal forms are based on partial dependency and transitive dependency. Partial dependency occurs when a row of a table is uniquely identified by one column that is a part of a primary key. A transitive dependency occurs when a non-key column is uniquely identified by values in another non-key column of a table. In this unit, you will learn about the concept of DBMS, its functions, types and benefits. This unit will also deal with the security issues of DBMS.

UNIT OBJECTIVES

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

- Define the concept of DBMS
- Explain the architecture of DBMS
- Describe the different data models
- Explain the process of designing of database
- Identify the issues of DBMS

OVERVIEW OF DBMS

Database Management System (DBMS) is a software solution that allows you to create and maintain databases in which you can store the data. It basically refers to a system which helps store and retrieve the data systematically from a database. The different users such as database manager perform separate roles to manage the database in DBMS which supports multiple-layered architecture that provides physical and logical data independence. You can use DBMS to define a database that involves specifying the data types, structures and constants for the data to be stored in the database. DBMS also allows you to construct and manipulate a database. Constructing a database is a process of storing data on some storage medium such as floppy drive, compact disk (CD) or hard disk drive (HDD). Manipulating a database involves performing functions such as querying the database to retrieve specific data, updating the database to reflect changes made by the user and generating reports from the data. Following is the description of few basic terms of DBMS terminology:

- **Database**: A database is a collection of interrelated data. For example, you may have recorded the names, telephone numbers and addresses of the employees in an indexed addressed book or on a diskette using a personal computer and software such as MS ACCESS or MS EXCEL. This recorded information is a collection of related data with an implicit meaning and hence is a database.
- **Defining a database**: It involves specifying the data types, structures and constants for the data to be stored in the database.
- **Constructing a database**: It is a process of storing the real data on some storage medium with the help of a DBMS.
- **Manipulating a database**: It involves performing functions such as querying the database to retrieve specific data, updating the database to reflect changes made by the user and generating reports from the data.
- **Database system**: The database and DBMS software together is called a database system.

Features of DBMS

To understand the basics of database management systems, you must know the terms and definitions that are used in DBMS technology. These terms and definitions constitute DBMS terminology. DBMS is a software programme which may run on a user machine or a server computer. The DBMS accepts queries from users and responds to these queries. A DBMS has the following features:

- **Structured data**: DBMS enables you to structure the data as tables, records or objects.
- **Query language**: A DBMS provides a query language such as SQL to process the user requests.
- **Multi-user access**: DBMS allows several users to access the data stored in a database. At the same time, it provides security features which restrict some users from viewing or manipulating the data.
- **Data dictionary**: DBMS provides a data dictionary which contains the structure of a database.
- **Data abstraction**: It allows a Database Administrator (DBA) to logically separate the data from the programmes which use the data. There are three

levels of abstraction in a database: external, conceptual and internal. The external level represents the user view of the database, conceptual level allows you to map internal and external levels, and the external level represents the operating system and DBMS level.

Functions Performed in DBMS

In DBMS, several people play important roles in organizing and manipulating the data. These roles are assigned to people according to the work performed by them in creating and maintaining the DBMS. The various roles performed in DBMS are as follows:

- Database administrator
- Database designers
- Database users
- Database manager

Database Administrator

DBA is responsible for making the strategy and policy decisions regarding the organization of data in the database. DBA also provides technical support in implementing the decisions which are taken by the data administrator. DBA performs the following functions:

- Defining the conceptual schema for a database
- Defining the internal schema for a database
- Coordinating with users
- Defining security and integrity constraints for the database
- Defining dump and reload policies for a database
- Monitoring performance and responding to changing requirements

Database Designers

A database designer identifies the data to be stored in a database. The database designer is also responsible for choosing the right database structure to represent and store the data in the database. The tasks of identifying the data and choosing the structure are performed before the implementation of a database. The database designer communicates with the various database users to understand their requirements before selecting the database structure.

Database Users

The database users are the people who need to interact with DBMS. The database users can be categorized according to their requirements of data. The people who interact with DBMS to retrieve data are called the naïve users and the people who interact with DBMS to make some changes in the database are called the developers.

Database Manager

The database manager refers to the software that helps use and management of the data stored in a database. The database manager handles the requests of database users to access the data items from database. The database manager also provides facilities such as support for a query language, to retrieve and update the database. The facilities provided by the database manager depend on the design of the database manager. For example, if the data manager is designed to handle one request at a time,

then multiple users cannot access data simultaneously. Figure 5.1 shows the various kinds of roles performed in the DBMS.

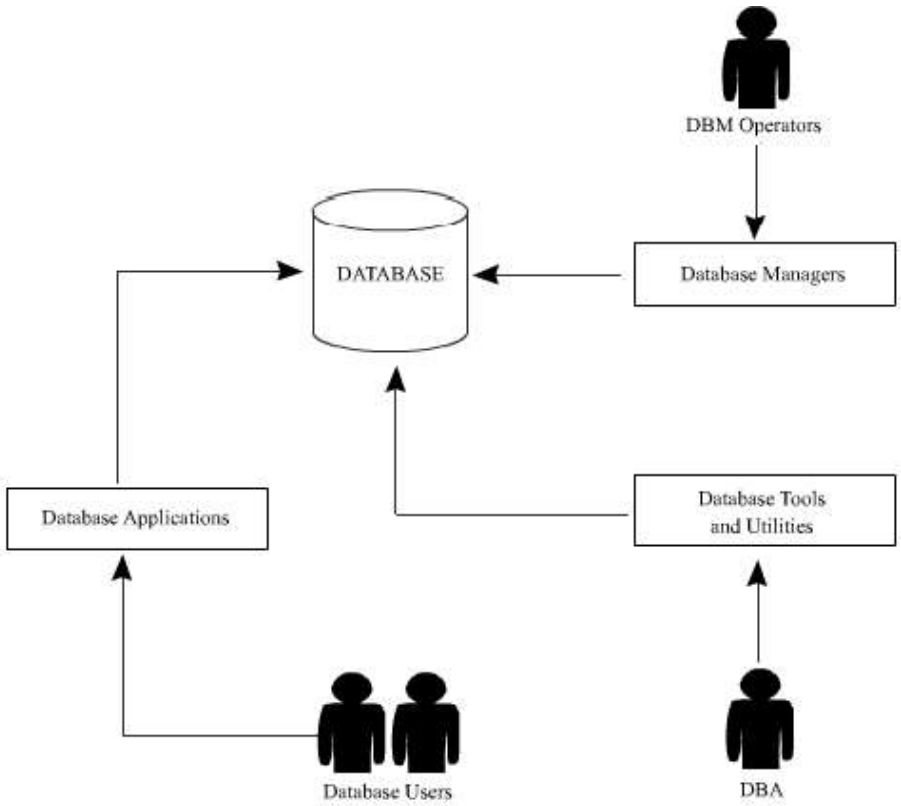


Fig. 5.1 *Different Roles Performed in DBMS*

Levels of Abstraction/Architecture of DBMS

The DBMS architecture is designed so that the storage details of data in a database are hidden from users. The users accessing a database need to work with data only rather than having any concern for how the data is physically stored in the database. The DBMS architecture allows you to perform following functions:

- Different user views of the database to be created for users. It provides a customized view to each user accessing the same data from the database. Each user view is independent and any change to a view does not affect other user views.
- It allows the internal structure of the database to remain unaffected by changes made to the physical storage of data.
- It allows the database administrator to change the structure of a database without affecting the user views of the database.

The architecture of DBMS is also called American National Standards Institute/ Standards Planning and Requirements Committee (ANSI/SPARC) model. The ANSI/ SPARC model or DBMS architecture is divided into three levels which are as follows:

- **Internal**: It specifies the way in which the data are physically stored in a database. The internal or physical level of the database system architecture also provides description of the relationship that exists between different data.
- **External**: It specifies the way in which the data stored in a database are viewed by the users.

- **Conceptual**: It specifies the level of interaction between the internal level and external level of system architecture.

Figure 5.2 shows the representation of the different levels of DBMS architecture.

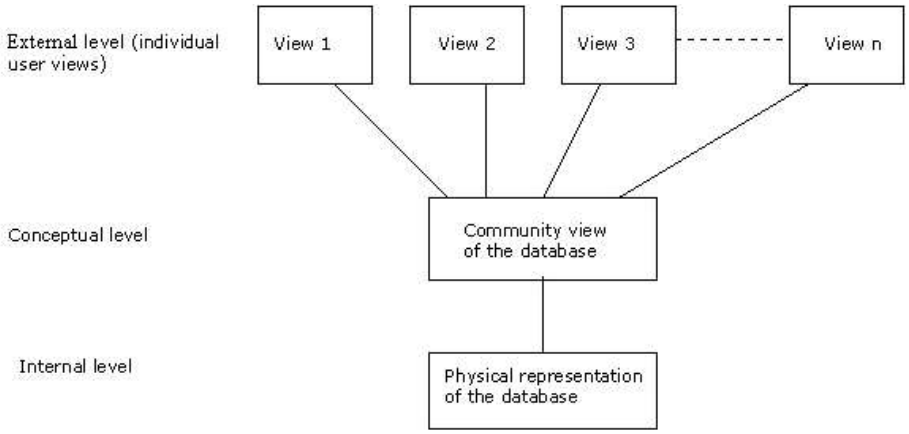


***Fig. 5.2** Different Levels of DBMS Architecture*

To understand the concept of levels in DBMS architecture, consider an employee database that contains details such as employee number and department number of an employee. The internal level of architecture for the employee database can be represented as follows:

```
Stored_emp  BYTES=20
Prefix TYPE=BYTE  (5),  OFFSET=0
Emp    TYPE=BYTE  (6),  OFFSET=5,  INDEX=EMPX
Dept       TYPE=BYTE  (2),  OFFSET=10
Pay    TYPE=FULLWORD,  OFFSET=10
```

In the preceding example for the internal level, employee data is represented by stored record types Stored_emp which is twenty bytes long. The Stored_emp consists of four stored fields which are prefix, emp, dept and pay. The prefix contains control information such as flags or pointers. The other data fields represent three properties number, department number and pay of employees and also the records stored in Stored_emp are indexed by using an index.

At the conceptual level, database contains information about an entity. For example, for an employee database, the conceptual level includes information such as employee_number, dept_number and salary about the employee entity. The conceptual level of architecture for the employee database can be represented as follows:

```
employee
employee_number        CHARACTER  (6)
department_number      CHARACTER  (4)
salary       NUMERIC  (5)
```

At the external level, the view of the database consists of two fields, employee number and salary. The external view shows only the fields that a user needs to view. For example, for an employee database the external level of architecture consists of two fields, emp# and salary and can be represented as follows:

```
DCL 1 empp,
2 emp# CHAR (6),
2 sal FIXED BIN (30);
```

The various data fields can have different names in the various views of a database. For example, the employee number at the internal level is represented by emp and at the conceptual level it is represented by employee_number.

Benefits of DBMS

DBMS provides various advantages that make it useful for storing and maintaining the data. Following are the advantages of DBMS:

- Preventing data redundancy
- Restricting unauthorized access
- Persistent storage
- Multiple user interfaces
- Integrity constraints
- Backup and recovery of data

Preventing Data Redundancy

Unlike the traditional file system that allows data redundancy, as each user group needs to maintain separate files for data processing applications, DBMS prevents data redundancy. For example, consider the database of an organization that stores information about the employees working in the organization. The user groups such as the accounts department and human resource department of the database need to use the employee information from the database. The accounts department needs to store employee information regarding pay roll and query for the leaves taken by the employees. Similarly, the HR department needs to store the employee information for querying about the leaves and application forms, information about any company-specific issue and performance-related updates. In addition, other groups might also need to store the same data in separate files. Therefore, storing the same information causes data redundancy and has following disadvantages:

- You need to perform a logical update such as entering the data for a new employee in each of the files maintained by the various user groups.
- The storage space is wasted when same data are stored repeatedly.
- The files representing the similar data may become inconsistent if each user group updates the files independently.

In the database approach of storing data, the information such as employee name or date of joining is stored at a single place in a database. Therefore, storing data in a database prevents data redundancy and saves the storage space.

Preventing Unauthorized Access

In the database approach of storing data, multiple users can access the data stored in a database, however only some users are authorized to modify the database. For example, for the financial data stored in a database, only a few users are allowed to access and modify the financial information stored in the database. In addition, for security purpose, you can also specify the users allowed to retrieve and update the information stored in the financial database of an organization.

Persistent Storage

The database provides persistent storage for data structures such as class definitions in C++ and programme variables used in programming languages. If the data structure

which is a programme variable used in a programme, is not stored in a permanent file, then the value of the programme variable is discarded when the programme terminates. The data structures can be stored permanently in the DBMS. The data stored in the DBMS are called persistent data because the data can be called by another programme even after the programme in which it was being used is terminated.

Multiple User Interfaces

The DBMS provides multiple user interfaces for users with varying levels of technical knowledge. For example, the query language for users and programming language interface for application programmers.

Integrity Constraints

When you store data in a database, you can specify the integrity constraints for the data. DBMS allows you to define and implement these constraints. For example, you can specify a constraint that each value in the employee_id column must have a unique value. The database designers need to identify the integrity constraints while designing a database.

Backup and Recovery of Data

The data stored in a database can be recovered in case of hardware or software failures with the help of backup and recovery subsystem of DBMS. For example, if hardware failure occurs when the database is being updated, then data stored in the database are restored and the programme is resumed from where it was interrupted.

TYPES OF DATABASE

Nowadays, there also exist three new types of databases: parallel database, distributed database and object-oriented databases. Parallel databases use parallel processors for computing. These databases use high-speed processors, memory and disks. Parallel databases uses relational data model which uses SQL query language to manipulate the data.

Distributed Databases (DDBs) store data over a computer network. In these databases, data may be stored in multiple computers located at the same physical location or spread over a network. It also helps in solving many problems such as data distribution and transaction processing. Another type of database is the object-oriented databases. These databases use the object-oriented programming languages such as C++ or java. Object-oriented databases have salient features that are inheritance, encapsulation and polymorphism.

Parallel Database

Parallel database architecture follows parallel dataflow architecture with new designs used for high speed of database while processing relational database queries. In parallel database systems, the relational data model is used; for parallel dataflow, relational queries and various relational operators, which are composed of parallel dataflow graphs, are used. Parallel database supports the concept of pipelined and partitioned parallelism. When the output of one operator is used as the input of the other operator, then the two operators can work in a series which in turn is called pipelined parallelism. When the input data are partitioned among multiple processors and memories, then this partitioned data and execution is known as partitioned parallelism. Figure 5.3 shows the partitioned and pipelined parallelisms.

Check Your Progress

1. Define the term DBMS.
2. List the features of DBMS.

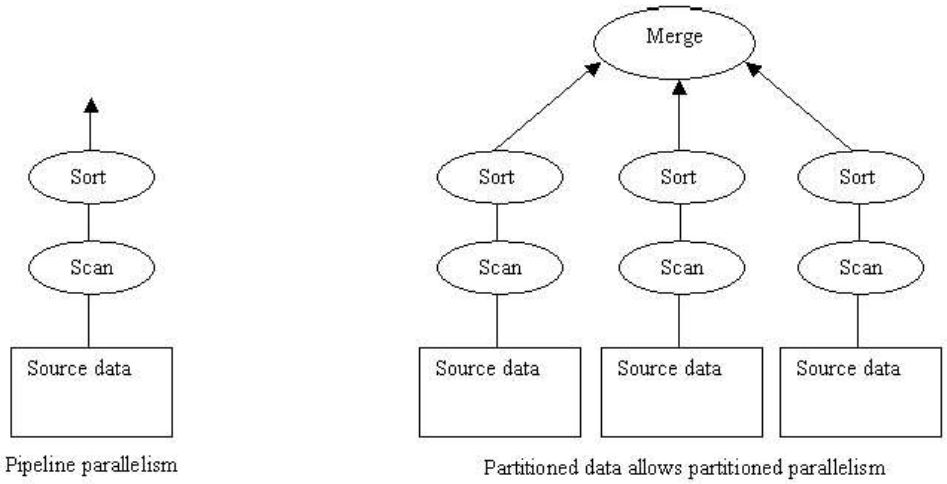


Fig. 5.3 *Pipeline and Partitioned Parallelism*

The dataflow approach of the parallel database systems needs a message-based client-server operating system to interconnect the parallel processes that requires high-speed network to interconnect the parallel processors. Parallel database systems are built from conventional processors, memories and disks and they have highly parallel architecture. Parallel systems have two properties that are linear speedup and linear scaleup. When run on a four times larger system, the linear speedup design performs a one-hour job four times faster, whereas ten times bigger system scaleup design performs ten times bigger job at the same time.

Following are the advantages of parallel database:

- **Higher performance**: Higher speedup and scaleup can be attained with CPU availability. Synchronization activities improve the performance in which lock operation is a processor and message intensive.
- **High availability**: In the parallel database, nodes, which are also called terminals, are apart from each other so the entire system will not get down if the failure occurs. System continues to provide data access to the users when the surviving nodes recover the failed node. The availability of data, even if there is a node failure, shows higher database availability.
- **Greater flexibility**: There is more flexibility in parallel database, as you can allocate or deallocate instances as per your requirements. You can allocate more instances as the database demand increases. Once the instances are no longer required, they can be deallocated.
- **More users**: Parallel database technology makes it possible to enable a single system to serve thousand of users simultaneously.

Distributed Databases (DDB)

DDB is a collection of multiple interrelated databases that are spread over a computer network. Each computer contains its own database which is managed by an individual database management system. A Distributed DBMS (DDBMS) manages DDBs and makes the distribution transparent to the user so that the user is not aware of the distribution and accesses the data as they are stored at one place. The applications that use the data, which are distributed across different sites, operates from a logical point of view, i.e., the application is not aware of the fact that the data are stored at different places and executes as if all data are managed by a single DBMS.

DDB technology has evolved as a combination of two technologies: one is the database technology and other is network and data communication technology. DDBs provide the advantages of distributed computing to the field of database management. These components are interconnected by a computer network and work together to perform the tasks that are assigned to them. Distributed databases simplify the complex task of managing large amount of data by subdividing it into smaller units thus making the entire task manageable in an efficient and coordinated manner.

Thus, a distributed database can be defined as a collection of different sites where each site is a full database system on its own and these nodes work in coordination with one other, so that a user at one site can access the data stored at another site. DDBs are used for several reasons such as organizational decentralization and cost-effective processing. Some of the advantages of DDBs are as follows:

- **Increased reliability and availability**: Reliability is a measure of the possibility that a system is running at a given time point. On the other hand, availability is a measure of the possibility that the system is continuously serving the queries made to it during a time interval. When you use DDBs, which are spread over several sites, one site may fail, but other sites continue to function normally. Only the data and software that resides on the failed site cannot be accessed without affecting the performance of other sites in the distributed database. This improves both reliability and availability.
- **Improved performance**: A distributed DBMS fragments the database and keeps the data closer to the site where it is required most. As a large database is fragmented and distributed over many sites, this leads to smaller databases at each site. The queries and transactions accessing data at smaller databases have a better performance. In addition, when the database is fragmented into smaller databases, each site has less overhead of transaction in the execution of a query.

Object-Oriented Database

Object-oriented databases were designed to meet the needs of the complex application. The object-oriented databases give the designer the capability to create the structure of complex objects and the operations which are applied to these objects. The other reason for the creation of the object-oriented databases is the use of object-oriented programming languages such as C++ or java. The object-oriented database provides support to these languages. Some of the object-oriented databases are ORION systems, IRIS systems and ODE systems. Object-oriented database vendors proposed a standard called as ODMG standard which has the standard model and its language was recognized.

Overview of object-oriented concepts

Object-oriented databases originated for the support of object-oriented programming languages. Object-oriented concepts are applied in databases, software engineering, knowledge bases and artificial intelligence. C++ programming language added the object-oriented features in C programming language.

An object has two components—value and operations—and is similar to the programme variable in programming languages. Objects exist during programme execution and hence they are called transient objects. Other programmes can share objects and these are stored on the secondary storage using the other features of database management systems such as indexing, concurrency control and recovery.

To provide shared object capabilities, the object-oriented databases interface with one or more programming languages. Object-oriented databases provide unique system generated Object IDentifier (OID) for each object so as to maintain the direct correspondence between the real world and the database objects so that objects can be easily identified and operated upon. It can be compared with a relational model where the tables are in the forms of relation and in each relation there is a primary key attribute whose value uniquely identifies the other attributes and tuple. Another feature of object-oriented database is the object structure of arbitrary complexity that contains all the information of the object.

Object-oriented programming language has the specification of instance variables that hold the values which define the internal state of the object. Object-oriented systems allow the definition of the operation or functions that can be applied to objects of particular type. All the operations on the object must be predefined that forces the encapsulation of objects. Encapsulation is the wrapping up of data and function into a single unit. To encourage encapsulation, an operation is defined in two parts. The first part is the signature or the interface of the operation that depicts the operation name and arguments. The second part is the implementation of the operation in the method or body.

Another, most commonly used and important object-oriented features are the inheritance and polymorphism. Inheritance can be defined as reusability of the existing code instead of creating the new code from the scratch. In polymorphism, operation ability is applied to different types of objects. For example, the + operator can be used for addition as well as for concatenation of strings. This feature is also known as operator overloading.

DATA MODELS

A data model in DBMS is defined as a collection of concepts which is used to describe the structure of a database. Data model describes logical structure of a database by considering following concepts:

- **Structure**: It represents how the data are organized in a database. The data can be organized using hierarchical, network, relational or object-oriented data model.
- **Integrity**: It provides a definition of rules to indicate whether or not the defined structure can be used to organize data in a database.
- **Manipulation**: It provides a language in which you can update the data in a database.
- **Querying data**: It provides a language in which the data in the database are queried.

For DBMS implementation you can use various data models which include all database-related concepts for describing the structure of a database. The various data model used in DBMS are as follows:

- Hierarchical
- Network
- Relational
- Object-oriented

Check Your Progress

3. What do you understand by parallel database architecture?
4. Define the term DDB?

Hierarchical Model

Data models can be defined as a collection of various concepts which are used to describe the structure of a database. Implementing a data model includes specifying data types, relationship among data types and the constraint on the data. In the Hierarchical model also called Hierarchical schema, data are organized in the form of a tree structure. Hierarchical model supports the concept of data independence. Data independence is the ability to change the representation of data at one level of a database system without the compulsion of changing the data representation at the next higher level.

Hierarchical model uses two types of data structures, records and parent-child relationship to define the data and relationship among data. Records can be defined as a set of field values which are used to provide information about an entity. An entity is a collection of object in a database which can be described by using a set of attributes. Records of same type can be easily grouped together to form a record type and assigned a name. The structure of a record type can be defined by using a collection of named fields or data items. Each data item or field has a certain data type such as character, float or integer. Parent-Child Relationship (PCR) can be defined as a 1: N relationship between two different record types. The record type on the 1-side is called parent record type and record type on the N-side is called child record type. Occurrence of PCR type, also called instance, consists of one record of the parent record type and a number of records of the child record types. Figure 5.4 shows an example of 1: N relationship between a finance department and the employees of finance department.

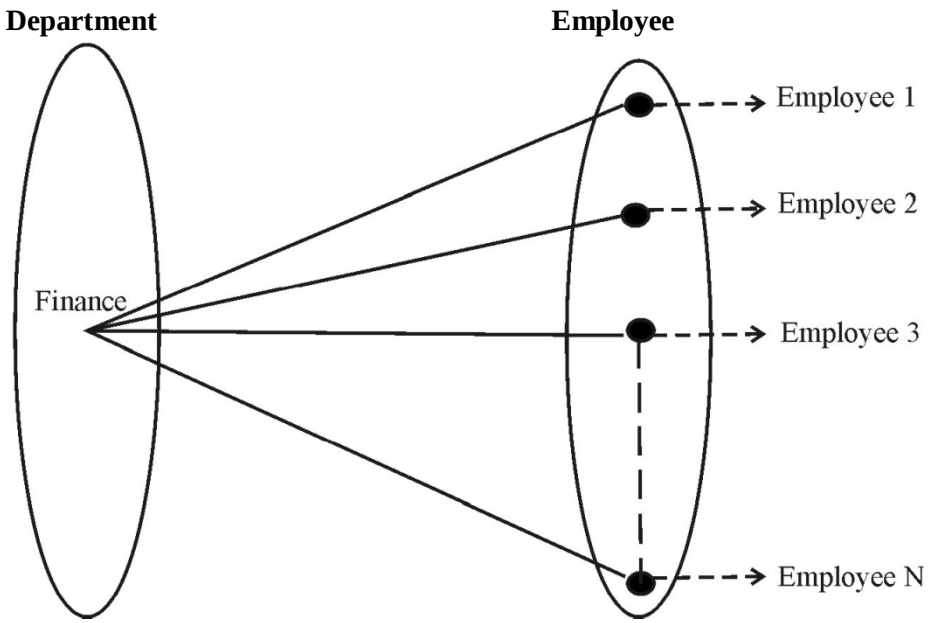


Fig. 5.4 *N Relationship Between Finance Department and Employees*

Hierarchical schema consists of number of record types and PCR types. In hierarchical schema, record types are represented by rectangular boxes and PCR types are represented by the lines which are used to connect parent record type to child record type. Figure 5.5 represents a hierarchical schema which has three record types and two PCR types.

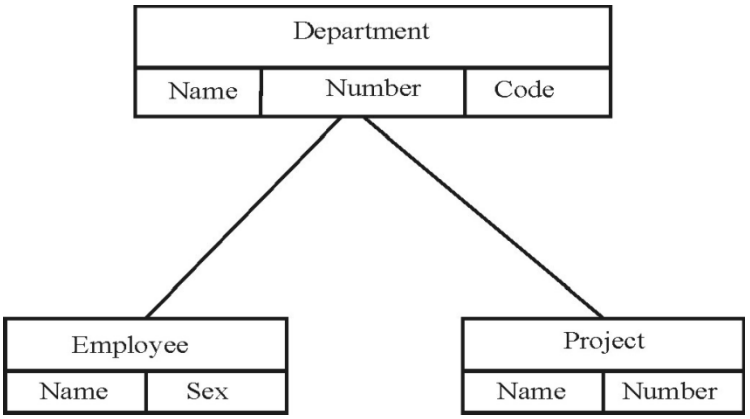


Fig. 5.5 *Hierarchical Schema*

Each record type can have a set of data items or fields. For example, record type department can have department name, number and code as fields or data items. PCR type can be represented by listing pair in parentheses. For example, in Figure 5.6, there are two PCR types which can be represented as (Department, Employee) and (Department, Project). In Figure 5.6, each occurrence of the (Department, Employee) PCR type relates one department record to the records of the many employees who work in that department. The occurrence of (Department, Project) PCR type relates a department record to the records of projects controlled by that department. Figure 5.6 represents the tree like structure of the hierarchical schema.

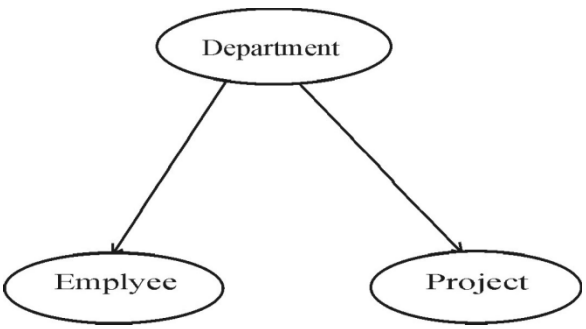


Fig. 5.6 *Tree Representation of Hierarchical Schema*

In tree like structure, a record type is represented by node of the tree and a PCR type is represented by arc of the tree. The following are the properties of the hierarchical schema that contain number of record types and PCR types:

- One record type, called the root of the hierarchical schema, does not participate as a child record type in any PCR type.
- In hierarchical model, each record can have only one parent record but many children records.
- Every record type except the root participates as a child record type in only one PCR type.
- A record type can participate as a parent record type in a number of PCR types.
- A record type, which does not participate as a parent record type in any PCR type, is called leaf node in hierarchical schema.
- If a record type participates as a parent node in more than one PCR type, then its child record types must be in a left to right ordered sequence.

The advantages of the hierarchical data model are as follows:

- It is simple to construct and operate on data in the hierarchical model.
- It involves hierarchically organized domains such as product information in manufacturing and employee information in organization.
- It uses constructs such as GET, GET UNIQUE and GET NEXT.

The disadvantages of the hierarchical data model are as follows:

- It requires navigational and procedural processing of data.
- It provides less scope of query optimization.

Network Model

The network model can be defined as a database model which is used to represent objects and the relationships among these objects. In network model, a record can have a number of parent records and it also can have multiple child records. Like Hierarchical model, network model also supports the concept of data independence which can be defined as the ability to change the representation of data at one level of a database system without the compulsion of changing the data representation at the next higher level. In network model, Data Manipulation Language (DML) is used for searching and retrieving records from the database. DML can also be used for connecting records from the set of instances, deleting and modifying records.

Network model uses two types of data structures: records and set type to define the data and relationship among data. Records can be defined as a set of field values which are used to provide information about an entity. An entity is a collection of object in a database which can be described by using a set of attributes. Records that have a same type can be easily grouped together to form a record type and assigned a name. The structure of a record type can be defined by using a collection of named fields or data items. Each data item or field has a certain data type such as character, float or integer. Figure 5.7 represents a record type employee that has data items name, sex and birth-date.

Employee		
Name	Sex	Birth Date

Fig. 5.7 *Employee Record Type*

Set type is a description of a 1:N relationship between two record types. Each set type definition has following elements:

- Name for set type
- Owner record type
- Number record type

Figure 5.8 represents a set type R-Dept as an arrow. This representation is known as Bachman diagram. In Figure 5.8, Department is the owner record type and Employee is the child record type. This represents a 1:N relationship between the company departments and the employees that are working in that department.

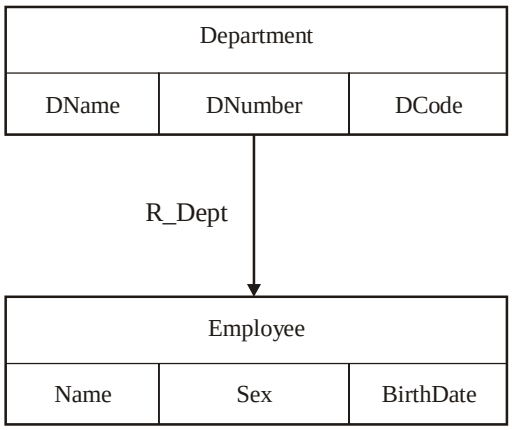


Fig. 5.8 *Set Type R_Dept*

In the database, there are set occurrences, also called set instances, corresponding to a set type. Each instance is used to relate one record from owner record type, i.e., Department to the set of records of member record types, i.e., Employee. Owner serves as parent node and member serves as child node. Each set occurrence consists of following:

- One owner record from owner record type
- A member of related member records from the member record type

A record from the member record type cannot belong to more than one set occurrence of a particular set type. This represents a 1:N relationship. A set occurrence can be easily identified by the owner record or by a number of records. The following are the differences between set instance of database and set in mathematics:

The set instance has one distinguished element called owner record, whereas in mathematics there is no such type of distinction among set elements.

In the network model, all member records of a set instance are ordered. On the other hand, in mathematics, the order of elements of a set is not ordered. The most commonly used implementation of a set type in network model is called system-owned sets. A system-owned set can be defined as a set that does not have any owner record type. In system-owned set, the system can be regarded as an owner record type. System-owned set provides following services to the network model.

- System-owned sets provide entry points into the database through the records of a specified member record type. Processing can be performed through the fields or data items of the member record type.
- System-owned sets can be used to order the records of a given record type by using set ordering specifications. By specifying number of system-owned sets on same record type, you can access your records in different order.

Figure 5.9 shows a network model.

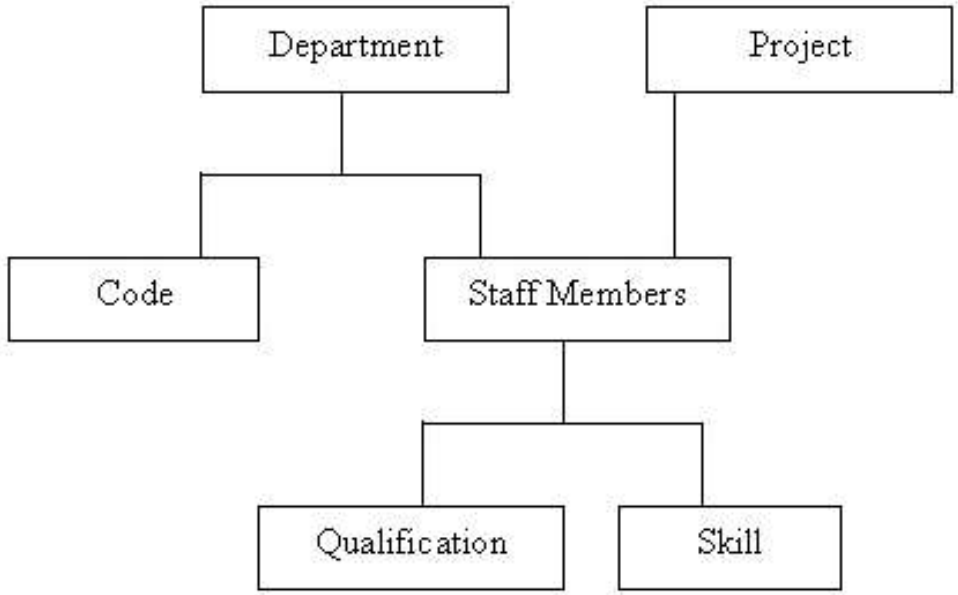


***Fig. 5.9** Network Model*

In Figure 5.9, department, project and staff members are the owner record type and code; qualification and skill are the member record type.

The advantages of the network data model are as follows:

- It enables the representation of complex relationships and effect of operations such as add and delete on the relationships.
- It uses constructs such as FIND, FIND owner and FIND NEXT within a set that allows the users to navigate through the database.
- Network model can inherit the advantages of hierarchical model.
- Many-to-many (M : N) relationships are easier to implement in network model as compare to hierarchical model.
- This model ensures data integrity.

The disadvantages of the network data model are as follows:

- It provides navigational and procedural processing of data.
- It provides complex array of pointers that thread through a set of records.
- It provides less scope of query optimization.

Relational Data Model

In a relational data model, data is stored in tables which are also called relations. The related tables or relations in the relational data model form a database. The properties of relational data model are as follows:

- Each row in a table is unique from every other row in the table.
- Each row contains atomic data which implies that data are not repeated and do not contain structures such as arrays.

In a relational model, tables are used to organize data. A table consists of columns or fields that represent attributes of an entity. Each row or tuple in a table represents occurrence of an entity and must consist of a value that uniquely identifies the row. Such a column that uniquely identifies the rows or tuples in table is called the primary key. The relational model also consists of foreign keys that allow joining data of two tables. To understand relational model consider the following Table 5.1 that represents the customers database.

Table 5.1 *Customer Database*

Cust_name	Cust_id	Cust_city
John	1001	Xyz
Tom	1002	Pqr
Ken	1003	Abc

In the above Table, Cust_name represents the name of the customers, Cust_id is the unique number for each customer and Cust_city represents the city of the customers.

Relational data model makes use of the set theory and is based on the concept of mathematical relation which contains several data elements. The basic characteristics of the relational model are relational algebra and relational calculus. Relational algebra is a set of operations for manipulating relations and specifying queries. Relational calculus provides a declarative way to specify database queries. The relational algebra and the relational calculus are two different means of representing the database queries. Any relational algebraic expression can also be converted into a corresponding expression in the relational calculus and vice versa.

Relations

A relation is a two-dimensional table which is used to represent data in the form of rows and columns. The names of the columns are known as attributes and rows are known as tuples of the relation. There are various parts of a relation which are as follows:

- **Domain**: It is a set of atomic values. The values that cannot be divided into subcomponents are called atomic values. Generally, you specify a domain as a data type from which the values forming the domain are taken. You should also give a name to a domain to help interpret its values.
- **Tuple**: In relational data model, a row is termed as tuple that gives complete information of an entity.
- **Attribute**: It is a column header in a relation that represents the attributes of an entity.

Figure 5.10 shows the employee relation.

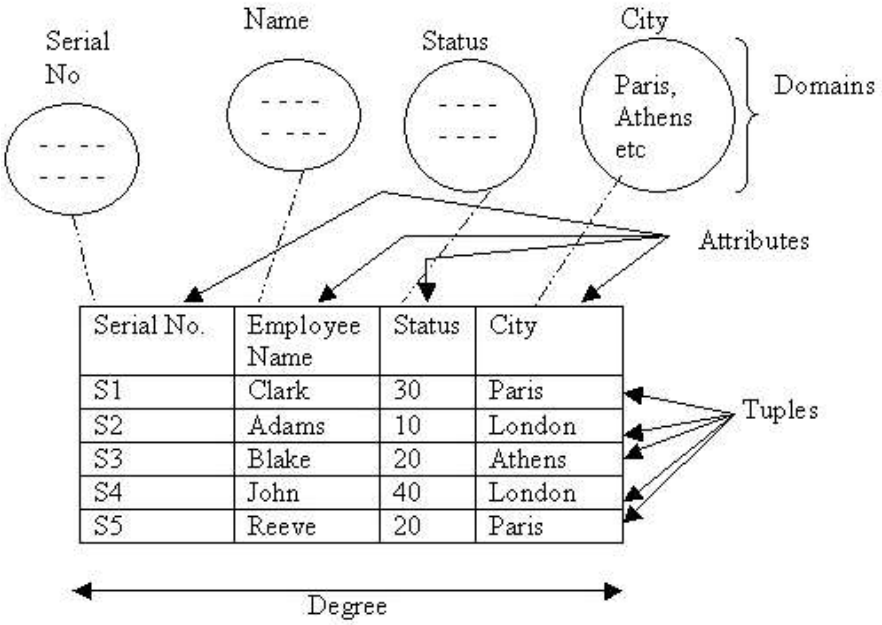


***Fig. 5.10** Employee Relation*

Relational Schema

Relational schema is the description of the database that is specified during database designing. You can graphically represent relational schema which is know as schema diagram. Figure 5.11 shows the schema diagram of the employee relation.

Serial No.	Employee Name	Status	City

***Fig. 5.11** Schema Diagram*

Features of Relations

There are certain features of relations that distinguish relations from a file or a table.

The various features of relations are as follows:

- Ordering of Tuples
- Ordering of Attributes
- Interpretation of a Relation

Ordering of Tuples

In a relation, tuples are not defined in any particular order. Two tables are same if they contain same attributes and tuples but the order of tuple differs. Consider Table 5.2 which contains the employee_1 relation.

Table 5.2 *Employee_1 Relation*

Serial No.	Employee Name	Status	City
S5	Reeve	20	Paris
S4	John	40	London
S3	Blake	20	Athens
S2	Adams	10	London
S1	Clark	30	Paris

Now, consider Table 5.3 which contains the same attributes and tuples with different ordering of tuples. Table 5.3 lists the employee_2 relation.

Table 5.3 Employee_2 Relation

Serial No.	Employee Name	Status	City
S1	Clark	30	Paris
S2	Adams	10	London
S3	Blake	20	Athens
S4	John	40	London
S5	Reeve	20	Paris

Empolyee_1 Relation is identical to Employee_2 Relation.

Ordering of Attributes

In a relation, attributes are not defined in any particular order. Two tables are same if they contain same attributes and tuples but the order of attributes differ. Consider Table 5.4 which contains the employee_3 relation.

Table 5.4 *Employee_3 Relation*

Serial No.	Status	Employee Name	City
S5	20	Reeve	Paris
S4	40	John	London
S3	20	Blake	Athens
S2	10	Adams	London
S1	30	Clark	Paris

Now, consider Table 5.5 which contains the same attributes and tuples with different ordering of attributes. Table 5.5 lists the employee_4 relation.

Table 5.5: *Employee_4 Relation*

Serial No.	Employee Name	Status	City
S1	Clark	30	Paris
S2	Adams	10	London
S3	Blake	20	Athens
S4	John	40	London
S5	Reeve	20	Paris

Empolyee_4 Relation is identical to Employee_3 Relation.

Interpretation of a Relation

You can interpret a relation in relational data model as a type of assertion and declaration. Consider the relation student listed in Table 5.6. Student relation contains various attributes such as name, SSN and phone number. Each tuple in the relation is an instance of assertion. First tuple asserts the fact that John Bayer is a student whose SSN is 678-54, age is 19, city is Paris, GPA is 4.9 and phone number is 373-654. Thus, interpretation of relation provides some facts.

Table 5.6 Student Relation

Name	SSN	Phone No.	City	Age	GPA
John Bayer	678-54	373-654	Paris	19	4.9
Charles Ashly	564-90	Null	London	20	6.7
Barbara Ashly	999-10	675	Athens	22	3.29
Katherine Banson	111-45	404-999	London	23	7.8
Michel Ponting	456-98	839-060	Paris	18	5.7

Object-Oriented Model

The Object-Oriented (OO) data model consists of a collection of entities. Entity refers to the concept or object described in a database and is represented as a class in the object-oriented data model. The instances of a class are called objects. Attribute provides additional information to describe an entity. The attributes of a class help distinguish an object from another object in a class.

For example, in an Employee database, employee is an entity and employee name, salary and ID are the attributes of an employee entity. Relationship describes the interaction between the various entities in a database.

Consider an employee database that can be represented in OO data model as follows:

- Class
  - o Employee
- Attributes
  - o Employee_name
  - o Employee_code
  - o Employee_ salary
- Behaviour
  - o Works for manager

The OO data model consists of the following:

- **Object**: It represents a real world entity.
- **Attributes and methods**: It represents the set of values for the attributes of the object and set of methods to operate on the attributes of the object.
- **Class**: It is a group of all the objects that share the same set of attributes and methods.
- **Class hierarchy and inheritance**: It represents derivation of a new class from an existing class which is called superclass. The new class is called subclass and it inherits all the attributes and methods of the existing class.In addition, it also consists of additional attributes and methods of the class.

5.4.1 Data Mapping

Data mapping is the process of creating data element mappings between two distinct data models. Data mapping is used as a first step for a wide variety of data integration tasks including: Data transformation or data mediation between a data source and a destination.

It is a process used in data warehousing by which different data models are linked to each other using a defined set of methods to characterize the data in a specific definition. This definition can be any atomic unit, such as a unit of metadata or any other semantic. This data linking follows a set of standards, which depends on the domain value of the data model used. Data mapping serves as the initial step in data integration.

DESIGNING OF DATABASE

Database design is a process in which you create a logical data model for a database which stores data of a company. The goal of designing of database schema is to minimize the storage space which is occupied by the data stored on the hard drive. Database anomalies are the errors in the data contained in the database that reduces the performance of Database Management System (DBMS). The database anomalies also affect the performance of the DBMS by increasing the size of data files. The following type of database anomalies can increase the size of data files:

- **Insertion anomalies**: These occur when it becomes difficult to insert a data in the database. You can not insert the data having null values in a table which has a primary key constraint. So, when you have a record that contains values for all the columns apart from the primary key column, you cannot insert that record into the table. This restricts the ability of inserting the records into the database.
- **Deletion anomalies**: These occur when the deletion of a particular record affects the existence of a particular relation in the database. For example, in a database, a table contains the records of students. The subject column of the table contains the information about the subjects which the students have opted. Now, if you delete all the records for the multimedia subject, then you can lose the information about the students who are studying only multimedia.
- **Modification anomalies**: These occur when a database user changes the value of a data item and the value of that data item does not change in other tables.

Normalization

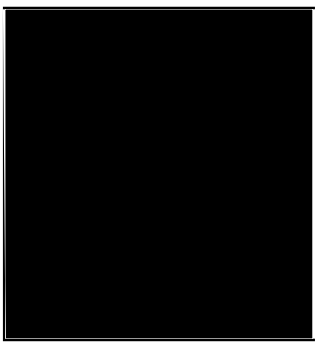
Normalization is integral to the database design and it can be defined as the process of eliminating the redundancy of data in a database. A relational table in a database is said to be in a normal form if it satisfies certain constraints. The normalization process involves various levels of normal forms that allow you to separate the data into multiple related tables. The various normal forms are first normal form (1NF), second normal form (2NF), third normal form (3NF), fourth normal form (4NF) and fifth normal Form (5NF).

The goals of normalization are as follows:

- Removing the redundant data
- Ensuring that only related data is stored in a table

Therefore, normalization helps you to remove data redundancy and update inconsistencies when data are inserted, deleted or modified in a database. The benefits of normalization are as follows:

- Provides better overall database organization and data consistency within a database



- Allows you to create tables that can be easily joined with other tables with related information
- Helps to reduce redundant data across the tables
- Prevents data loss by assigning primary and foreign keys in a table
- Helps to reduce modification anomalies such as deletion, insertion and update anomalies
- Defines relation constraints that are a logical consequence of keys

Normalization terminology

Normalization terminology consists of various concepts frequently used in normalization such as primary key and functional dependency.

Primary Key

The primary key of a relational table uniquely identifies each row in a table. A primary key is either a column in a table that is unique such as identification number and social security number or it is generated by the DBMS such as a Globally Unique Identifier (GUID). Primary key is a set of single column or multiple columns from a table. For example, consider a student records database that contains tables related to student's information. The first table, STUDENTS, contains a record for each student at the university. The table consists of various attributes such as student_id, first_name, last_name and student_stream. Table 5.7 lists the various attributes in the STUDENTS table.

Table 5.7 *Students Table*

Student_id	First_name	Last_name	Student_stream
S01	John	Wilkins	Computers
S01	Chris	Burton	Electronics
S01	Ken	Wilkins	Electronics

A unique Student_id number of a student is a primary key in the STUDENTS table. You cannot make the first or last name of a student a primary key because more than one student can have the same first name and can have same stream.

Functional Dependency

A functional dependency is a constraint between two sets of attributes from the database. Functional dependency is represented by X □ Y between two attributes, X and Y, in a table. The functional dependency X □ Y implies that Y is functionally dependent on X. Table 5.8 lists the various attributes in the EMPLOYEE table.

Table 5.8 *Employee Table*

Employee_id	Employee_name	Employee_dept
K067263	John	Sales
K067264	Chris	Accounts
K067265	Ken	Sales

In Table 5.8, the various attributes of the EMPLOYEE are Employee_id, Employee_name and Employee_dept. You can state that:

```
Employee_id " >Employee_name
```

The above representation that the Employee_name attribute is functionally dependent on the Employee_id implies that the name of an employee can be uniquely identified from id of the employee. However, you cannot uniquely identify the Employee_id from the Employee_name column because more than one employee can have the same name. However, each employee has different value in the Employee_id column.

Functional dependencies are a type of constraints based on keys such as primary key or foreign key. For a relation table R, a column Y is said to be functionally dependent on a column X of the same table if each value of the column X is associated with only one value of the column Y at a given time. All the columns in the relational table R should be functionally dependent on X if the column X is a primary key.

If the columns X and Y are functionally dependent, the functional dependency can be represented as:

R.x R.y

For example, consider the following functional dependency in a table.

Employee_id Salary, the column Employee_id functionally determines the Salary column because the salary of each employee is unique and remains the same for an employee, each time the name of the employee appears in the table.

A functional dependency, represented by X Y, between two sets of attributes, X and Y, that are subsets of R, is called as trivial functional dependency if Y is a subset of X. For example, Employee_id Project is a trivial functional dependency.

A functional dependency, represented by X Y, between two sets of attributes, X and Y, which are subsets of R, is called a non-trivial functional dependency if at least one of the attributes of Y is not among the attributes of X. For example, Employee_id Salary is a non-trivial functional dependency.

Inference Rules

Inference rules for functional dependencies define the new dependencies which can exist between two relations. The inferences rules help deduce these new dependencies from a given set of functional dependencies, F. The set of dependencies, which cannot be specified, is called the closure of F and is denoted by F+. Following are the six inference rules of functional dependencies F:

- **IR1 (reflexive rule): If X Y, then X Y**: This rule states that if X Y and two tuples t1 and t2 exist in a relation instance r of relation R such that t1 [X] = t2 [X]. Now, t1 [X] = t2 [X] because X Y. This implies that X Y holds true in relation instance r of relation R.
- **IR2 (augmentation rule):{ X Y } |= XZ YZ**: This rule states that if X Y holds true in a relation instance r of R but XZ YZ does not exist, then tuple t1 and t2 must exist in relation R.
- **IR3 (transitive rule): { X Y, Y Z } |= X Y**: This rule states that if both, X Y and Y Z hold true in a relation r, then for any two tuples t1 and t2 in r, you must have t1 [Y] = t2 [Y].

- **IR4 (decomposition or projective rule)**: This rule states that if X □ YZ holds true, then X □ Y and X □ Z also hold true.
- **IR5 (union or additive rule)**: This rule states that if X □ Y and X □ Z hold true, then in the relation R, X □ YZ also holds true.
- **IR6 (pseudotransitive rule)**: This rule states that if X □ Y and W Y □ Z hold true, then WX Y also holds true.

Attribute closure

To compute the closure J^+ of a given set J of functional dependencies, you can apply the inference rules until they stop producing new functional dependencies. You can test whether a set of attributes J is a super key or not by finding the set of attributes which are functionally determined by J. You can use the following algorithm to compute the closure J^+:

```
Result: = J
while (changes to result) do
for each functional dependency B ® Y
in F do
 begin
    if B  result;
    then result: = result UY
 end
```

The above code assumes that J is a set of attributes and you can call the set of attributes determined by a set F of functional dependencies. The closure of J under F is denoted by $J^{+.}$

First Normal Form

A table is in 1NF if the data in the table has an identifying key and does not include repeating groups of data. To reduce data redundancy by using first normal form, you need to:

- Remove the duplicate columns from a table.
- Create a separate table for related data and identify the primary key in the table.

According to the first normal form, a table should be atomic which implies that no duplicate data exist within the same row of a table. For example, consider the items table given in Table 5.9.

Table 5.9 *Items Table*

Order_No	Item1	Item1_Qty	Item1_Price	Item2	Item2_Qty	Item2_Price
011	IT90	322	36$	IT91	564	45$

In Table 5.9, the information provided is redundant. The multiple values of the same type are stored in multiple columns such as quantity and price of two items are stored in different columns.

The requirements of first normal form are as follows:

- Eliminate the multivalued fields from the table.
- Each column in the table must be atomic.

- Each column in the table must have a key such as primary or foreign key.
- Remove the repeating information from the table.

NOTES

Eliminate the multivalued columns from the table

The first requirement to apply 1NF to a table is to ensure that the table does not contain multivalued columns. For example, consider a Books table with attributes Book_name, Book_author, Book_ISBNno, Book_price, Book_publisher and Book_category. Table 5.10 lists the various attributes in the Books table.

Table 5.10 *Books Table*

Book_author	Book_ISBNno	Book_price	Book_publisher	Book_category
John Wilkins	8790478	35	ABC	Sales
Chris Burton	8790388	25	PQR	Accounts
Ken Wilkins	8790689	77	ABC	Sales

In the table, since a book can have more than one author and also a book can be included in different categories, therefore, such columns that consist of multivalued elements should be removed from the table. Therefore, the Books table should contain Book_ISBNno, Book_price and Book_publisher columns.

Table 5.11 lists the various attributes of the Books table after the multivalued elements are removed.

Table 5.11 *Books Table After the Multivalued Elements are Removed*

Book_ISBN no	Book_price	Book_publisher
8790478	35	ABC
8790388	25	PQR
8790689	77	ABC

Table 5.12 lists the Books category table.

Table 5.12 *Books Category Table*

Book_ISBNno	Book_category
8790478	Sales
8790388	Accounts
8790689	Sales

Each column in the table is atomic

You need to ensure that each column in a table that is to be normalized is atomic. For example, the author table can be divided into two columns which are first name and last name to make the table atomic.

Table 5.13 lists the various attributes in the author table.

Table 5.13 Author Table

Book_ISBNno	First_name	Last_name
8790478	John Wilkins	Wilkins
8790388	Chris Burton	Burton
8790689	Ken Williams	Wilkins

Each column must have a key

You can determine if each column in a table contains unique value by verifying the keys in table. The various keys that can exist in a table are as follows:

- **Super key**: It refers to one or more than one column that identifies a unique row within a table.
- **Candidate key**: It refers to the super key consisting of minimum number of columns required to identify a unique row in a table.
- **Primary key**: It refers to the candidate key required to uniquely identify a row in a table.
- **Alternate key**: It refers to the candidate key which is not selected as a primary key.
- **Foreign key**: It refers to one or more than one column in a table that matches a candidate key in the same or different table. You can link a row in a table to a row in another table by using a foreign key.

In the Books table, the super keys are Book_author and Book_ISBNno. The super keys for the author table are the combination of first_name and last_name. Similarly, for the categories table, the super key is category.

The primary key for the Books table is Book_ISBNno and the primary keys for the author table are first_name and last_name. The primary key for the categories table is CategoryID. To ensure that each row in the author table is unique, you can add the Author_city and Author_zipcode columns in the primary key field.

Table 5.14 lists the various attributes in the author table.

Table 5.14 *Author Table*

Book_author	Book_ISBNno	Author_address	Author_phoneno
John Wilkins	8790478	Houston	0098392978
Chris Burton	8790388	New York	008273827
Ken Wilkins	8790689	Denver	002632878

Eliminate the repeating values

To make a table compliant with 1NF, you need to eliminate the repeated values from the table. For example, in the Books table the publisher column can contain same values for different books. Therefore, to remove the repeating values you can make a

separate table, publisher, with attributes Publisher_id and Publisher_name. The Publisher_id can be identified as the primary key for the publisher table.

Table 5.15 lists the various attributes in the Publisher table.

Table 5.15 *Publisher Table*

Publisher_id	Publisher_name
P0240	ABC
P0240	PQR
P0240	ABC

Partial Dependency

In a table, a primary key consists of one or more than one column to uniquely identify each row in the table. Partial dependency occurs when a row of a table is uniquely identified by one column that constitutes a primary key without requiring the entire primary key to uniquely identify the row. For example, consider a table 'Stocks' with attributes Cust_id, stock and Stock_price.

Table 5.16 lists the various attributes in the stocks table.

Table 5.16 *Stocks Table*

Cust_id	Stock	Stock_price
C012	Stk1	15
C013	Stk2	10
C014	Stk3	20

In the above table, suppose cust_id and stock are identified as the primary key for the stocks table. However, the column stock_price is partially dependent on the primary key because only the stock column determines the stock_ price. Also, the values in the stock_price column do not need the cust_id column to uniquely identify the price of the stocks. Therefore, you need to make a separate table for the stock_price where the stock column is the primary key. In the new table, partial dependency is eliminated because the stock_price column is dependent on the entire primary key.

Partial dependencies can only occur when more than one field constitutes the primary key. If there is only one field in the primary identifier, then partial dependencies cannot occur.

Second Normal Form

A table is in 2NF if the table satisfies all the conditions of first normal form and does not consist of any column that depends on only one part of the identified primary key. The 2NF is based on the concept of full dependency.

To apply 2NF to a table you need to:

- Ensure that the table conforms to 1NF.
- Create a separate table for sets of values that apply to multiple records.
- Relate these tables with a foreign key.

NOTES

For example, consider the following table employee_project.

Table 5.17 lists the various attributes in the employee_project table.

Table 5.17 *Employee_Project Table*

Emp_id	Proj_no	Proj_hrs	Emp_name	Proj_name	Proj_loc
H76320	W36	08	Abc	Payroll	Houston
H76321	W37	02	Xyz	Billing	Denver

Table 5.17, employee_project conforms to 1NF since it does not contain repeated values and Emp_id and Proj_id are identified as the primary keys for the table. However, the table is not in 2NF because all the columns of the table depend on only a part of the primary key which comprises Emp_id and Proj_no identified for the table. For example, the column Emp_name is dependent on only the Emp_id and does not depend on the Proj_no part of the primary key. Similarly, the Proj_name column is dependent on only the Proj_no column and not on the Emp_id primary key.

Therefore, to apply 2NF to the employee_project table, you need to make a separate table for columns that depend on only a part of the primary key. The new table should contain columns that are dependent on the entire primary key identified for the table. The tables formed after applying 2NF to the employee_project table are emp_proj table and EMP table and proj table. Table 5.18 lists the various attributes in the emp_proj table.

Table 5.18 *Emp_project Table*

Emp_id	Proj_no	Proj_hrs
H76320	W36	08
H76321	W37	02

Table 5.19 lists the various attributes in the EMP table.

Table 5.19 *Emp Table*

Emp_id	Emp_name
H76320	W36
H76321	W37

Table 5.20 lists the various attributes in the proj table.

Table 5.20 *Proj table*

Proj_no	Proj_name	Proj_loc
H76320	Payroll system	Houston
H76321	Billing system	Denver

Similarly, consider an ORDERS table that you need to normalize to 2NF:

Table 5.21 lists the various attributes in the ORDERS table.

Table 5.21 *Orders Table*

Order_no	Item_no	Customer	Item	Qty	Price
H76320	01	ABC Corp	IT90	322	36$
H76320	02	ABC Corp	IT91	564	45$
H76321	01	XYZ Corp	IT92	736	12$

In the above table, Order_no and Item_no are identified as the primary keys for the table. Also, the table conforms to 1NF since it does not contain repeated value. However, to apply 2NF to the ORDERS table, you need to create a separate table for the columns that do not depend on either Order_no or Item_no primary key.

The tables which are created after 2NF is applied to the ORDERS table are Order_cust table and orders table.

Table 5.22 lists the various attributes in the order_cust table.

Table 5.22 *Order_Cust Table*

Order_no	Customer
H76320	ABC Corp
H76321	XYZ Co

In the above order_cust table, the customer column is dependent on the primary key Order_no. Similarly, another table is created in which all the columns such as Order_no, Item_no, Item, Qty and Price are dependent on the primary keys, Order_no and Item_no. Table 5.23 lists the various attributes in the orders table.

Table 5.23 *Orders Table*

Order_no	Item_no	Item	Qty	Price
H76320	01	IT90	322	36$
H76320	02	IT91	564	45$
H76321	01	IT92	736	12$

Transitive Dependency

A transitive dependency occurs when a non-key column is uniquely identified by values in another non-key column of a table. A non-key column of a table refers to the column that is not identified as a key such as candidate or primary key. For example, consider a SUPPLIER table with attributes supplier_id, supplier_status and Supplier_address. The functional dependencies that exist in the SUPPLIER table help to understand the concept of a transitive dependency.

Table 5.24 lists the various attributes in the SUPPLIER table.

***Table 5.24** SupplierR Table*

Supplier_id	Supplier_status	Supplier_address
S01	10	Houston
S02	20	Denver
S03	30	Texas

In Table 5.24, the following functional dependencies hold:

```
Supplier_id → Supplier_status
Supplier_id → Supplier_address
Supplier_address → Supplier_status
```

In the SUPPLIER table, both the primary key Supplier_id and non-key column Supplier_address identifies the non-key column Supplier_status. Therefore, transitive dependency exists in the above table. To eliminate transitive dependency, you need to apply 3NF to the table.

Third Normal Form

A table is in 3NF if the table satisfies the requirements of 2NF and the non-key columns are functionally dependent on only the primary key. The third normal form is based on the concept of transitive dependency. A functional dependency, A → B, in a relation, R is a transitive dependency if the following conditions are satisfied:

- A column or set of columns, C, exists in the table that is neither the candidate key of R nor the subset of any key of R.
- The functional dependencies A → C and C → B hold in the table.

For example, consider a Subject table with attributes such as Subject_no and Chapter_name. Table 5.25 lists the various attributes in the Subject table.

***Table 5.25** Subject Table*

Subject_no	Chapter_name	Instructor	Department
H76320	Data structure	ABC	Computer
H76320	Communication	XYZ	Electronics

In the above table, Subject_no is the only candidate key. Therefore, the following functional dependency exists for the subject table.

```
Subject_no    → Chapter_name
Subject_no    → Instructor
Instructor    → Department
```

From the above functional dependencies, you can say that Subject_no → Department and therefore the above table is in 2NF. However, the table is not in 3NF since Department is not directly dependent on Subject_no. In the Subject table, the Department column is determined by another non-key column, Instructor. Therefore, to apply 3NF to the Subject table, you need to decompose the table in two tables, Subject_inst table and instructor table.

Table 5.26 lists the various attributes in the Subject_inst table.

Table 5.26 *Subject_inst Table*

Subject_no	Subject_name	Instructor
H76320	Data structure	ABC
H76320	Advanced OS	XYZ

Table 5.27 lists the various attributes in the instructor table.

Table 5.27 *Instructor Table*

Instructor	Department
ABC	Computer
XYZ	Electronics

Boyce-Codd Normal Form

Boyce-Codd Normal Form (BCNF) is stricter than third normal form. The relation present in BCNF is also found in 3NF; however, the relation in 3NF form is not necessarily present in BCNF. In 3NF, anomalies can occur, when a relation has more than one candidate key. In the situation of overlapping candidate keys, 3NF is unable to stop occurrence of the anomalies. This provides a base for BCNF which is based on the concept of determinant. A determinant is an attribute on which some other attribute is fully functionally dependent. The following code shows the relation and determinants:

```
R (a, b, c, d)
    a, c □ b, d
    a, d □ b
```

In the above code, the first determinant states that you can change the primary key of relation R from a, b to a,c. After applying this change, you can still determine the non-key attributes present in relation R. The second determinant indicates that a, d determines b, but as a, d do not determine all the non-key attributes of R, it cannot be considered as the primary key of R. This implies that the first determinant is a candidate key, but the second determinant is not a candidate key; hence, this relation is not in BCNF but is in 3NF.

To be in BCNF, every determinant of the relation has to be a candidate key. The definition of BCNF specifies that a relation schema R is in BCNF if a non-trivial functional dependency X □ A holds in R, then X is a super key of R.

Decomposition

The relational database design algorithm start with a single universal relation schema, $R = \{A_1, A_2, A_3, ..., A_n\}$, which includes all the attributes of a database. The database designers specify the set, F of functional dependencies, which holds true for all the attributes of R. This set, F of functional dependencies, is also provided to the design algorithms. With the help of functional dependencies, these algorithms decompose the universal relation schema, R into a set of relation schemas, $D = \{R_1 R_2, \ldots, R_m\}$,

which becomes the relational database schema. In this case, D is referred as a decomposition of R. The properties of decomposition are as follows:

- **Attribute preservation**: It involves preserving all the attributes of the relation which is being decomposed by the design algorithms. While decomposing a relation, you need to make sure that each attribute in R exists in at least one relation schema, R_i, while decomposing the relation.
- **Lossless-join decomposition**: It ensures that the join remains in the same relation, as it was before the decomposition of the relation. The decomposition of the relation R into several relations, R_1, R_2, …, R_n is called a lossless-join decomposition, if the relation R is the natural join of the relations R-$_1$, R_2, …, R_n. To test whether a given decomposition is a lossless-join for a given set F of functional dependencies, you need to decompose the relation, R into R_1 and R_2. If the decomposition of the relation R is lossless-join, then one of the following conditions has to be true:
- (R_1 intersection R) □ (R $_1$ R)$_2$ and
- (R_1 intersection R) □ (R $_2$ R)$_1$
- **Dependency preservation**: It states that if each functional dependency X □ Y, specified in F, either directly appears in one of the relation schemas R_i in the decomposition D or is inferred from the dependencies that appear in the relation, R_i. The need of dependency preservation arises because each dependency in F represents a constraint on the database. When a decomposition do not preserve the dependency, then some dependency can be lost in decomposition. You can check for a lost dependency by creating a join of two or more relations in a decomposition to get a relation, which includes all the left and right-hand side attributes of the lost dependency. Then, check whether or not the dependency is preserved on the result of join.

Fifth Normal Form

The fifth normal form (5NF) is based on join dependency. Join dependency implies that after a table is decomposed into three or more tables, the tables can be joined to form the original table. A table is in 5NF if the table cannot have lossless decomposition into smaller tables. A lossless decomposition implies that after a relational table is decomposed into smaller tables, the joining of the tables results in exactly the same relation table which was decomposed. If an instance is added to a table, which is not in 5NF, it results in spurious results when the tables are decomposed and then rejoined.

Table 5.28 lists the various attributes of Instructor-MID-Location Table.

Table 5.28 *Instructor-MID-Location Table*

Instructor	MID	Location
Smith	1	New York
Smith	2	Chicago
Jones	1	Chicago

If you were to add the MID-2 to New York, you would be faced with adding a line to the table for each instructor located in New York. If Jones were certified for MID-2 and could travel to New York, you would have to add two lines to reflect this.

Table 5.29 shows the instructor-MID-Location table. It is decomposition into fifth normal form.

Table 5.29 *Fifth Normal Form of Instructor-MID-Location Table*

Instructor-Seminar Table		Seminar-Location Table		Instructor-Location Table	
Instructor	**MID**	**MID**	**Location**	**Instructor**	**Location**
Smith	1	1	New York	Smith	New York
Smith	2	1	Chicago	Smith	Chicago
Jones	1	2	Chicago	Jones	Chicago

SECURITY ISSUES OF DBMS

When many users access a database simultaneously, it becomes essential to make sure that there is no effect on the values of the data items and the association among them to disturb the database's integrity.

Hence, the data manipulation operations should be performed in such a way that it does not disturb the integrity of the database. Integrity of a database refers to the correctness of the data items. Integrity ensures the non-occurrence of accidental deletion or alteration.

The data stored in the database has to be protected from unauthorized access, malicious destruction or alteration and accidental introduction of inconsistency. The integrity of a database can be ensured by designing it in such a way that it helps check the integrity constraints. In spite of crashes, failures and potential damage from parallel processing, database integrity can be preserved. Integrity checks can be performed at the level of data entry by checking whether the data values adhere to preset/specific rules. The age of an employee, for example, will be within a certain range of say 20–60 years.

Data Security Risks

The threats to the database security involve the following:

- Unauthorized access can damage a database.
- The authorized users can give privileges/benefits, deliberately or accidentally, to those users who lack the time to access databases.
- As a result of concurrency, the database items can be read or written simultaneously, by two items of different transactions. This causes inconsistency in the database.
- Insertion of virus and destruction of data in the database or any kind of unauthorized access by unwanted users or application programs could also be considered fatal to the database.

Check Your Progress

8. What is database design?
9. List the goals of normalization.

- A database user can cause serious damage to the database by bypassing the security mechanisms intentionally or by making unauthorized copies of secret data for malicious purposes.
- Secret information can be transmitted forcefully or under pressure by authorized persons; may be even for some personal benefit or gain.
- Errors in the DBMS (Database Management System) package may be caused due to memory protection failure in warding off attacks by viruses.
- It may so happen that a user may gain access to that part of a database which he is otherwise unauthorized to access. This could happen due to system malfunctioning of some kind.

Database Security

Database security comprises policies taken to protect data from being accessed by unauthorized users. This also includes the policies needed to ensure that data items are not modified or deleted from the database by unauthorized users, applications or viruses. Simply, the following issues are handled by data security:

(a) Maintenance of database integrity

(b) Maintenance of privacy of certain data elements

(c) Security level for the system

(d) Preservation of organizational policies

- **Privacy of Certain Data Elements**

Privacy is concerned with the ethical and legal rights regarding access to personal data items. The medical details of a person, for instance, may be considered critical information. Unauthorized persons should be denied access or prevented from modifying such information/records.

- **Preserving Organizational Policies**

Organizations, government and corporate-level, as well as various institutions have certain policies regarding the type of information that needs to be publicized. An individual's credit rating or medical history, for instance, should be kept private.

- **System-Related Security Level**

It is important to know the level at which security should be enforced on the system. It could be enforced at the level of the operating system, or at the level of the hardware or even at the DBMS level.

- **Maintaining Database Integrity**

Items of data stored in the database should be consistent as well as valid. Database integrity constraints play a significant role in ensuring database integrity. Controlling access to the database items also ensures integrity of the database.

Traditionally, following types of security mechanisms are in use.

(i) Discretionary Security Mechanisms: Here, each user (or a group of users) is granted privileges and authorities to access certain records, pages or files and denied access to others. The discretion normally lies with the Database Administrator (DBA).

(ii) Mandatory Security Mechanisms: These are standard security mechanisms that are used to enforce multi-level security by classifying the data into different levels and allowing the users (or a group of users) access, to certain levels only based on the security policies of the organization. Here, the rules apply uniformly across the board and the discretionary powers are limited.

Database Security Requirements

Database security requires the following:

- The primary requirement of database security is to forbid an individual from obtaining something by unfair means and entering into an organization's computing facility. Security laws should be so implemented that if any attempt is made to by the unauthorized users to access systems resources it should be illegal.
- Use of computers and terminals should be limited to authorized users only. Securing physical storage devices (such as, magnetic tapes, disk drives) both inside the organization and while sending them outside is a must.
- The database administrator determines whether a user should be given the privilege to access a particular resource or not, and according to that the user should be provided with the username and password, and it should be kept confidential from the others.
- Along with database the operating system should also be made secure by providing some built-in safety mechanisms, such as user authentication and identification. Direct access to the data in primary files should also be avoided.

Dimensions of Security

Different levels of security are provided by database management systems. These are discussed as follows:

(a) Network Level Security: Distributed database systems require security at the network software level. Network software ensures security by means of some in-built methods that actually provide login security control permitting only the authorized users to log onto the system and gain access over the resources. Network software also provides security by giving rights. The directories, subdirectories and files, accessed by a user or a group of users, are controlled by rights security. Attribute security is also offered by network software. Attribute security allows or disallows a user or a group of users to view, share, rename, modify or delete a particular file (or directory). Therefore, only if the attribute of a file allows a privileged user or a group of users to delete a particular file, can it do so.

(b) Operating System or OS Level Security: Only a strong DBMS software can provide enough security. A weak operating system often allows unauthorized access to database files. So, it is equally important to secure the OS.

(c) Database System Level Security: Certain users of database are allowed to access some specific portions of the database. In other words, they can generate only certain operations on the database. Suppose a user, Mr. Mukherjee is permitted to view information. That is, he can issue `SELECT` queries only. He cannot issue `INSERT`, `UPDATE` or `DELETE` queries as he does not have the permission to make any modification.

(d) Program Level Security: Program level security ensures that no unauthorized user can get access to particular programs accessing the database. For example, a bank clerk who retrieves only the customer account details has access to the program responsible for that particular job. He does not have access to the program that modifies the accounts.

(e) Record Level Security: It denies unauthorized access to certain kinds of records, for example the records of managers in the EMPLOYEE table.

(f) Field Level Security: It prohibits unauthorized access in certain fields of a table, such as the Salary field.

Implementing Security Features

It is the responsibility of DBA (Database Administrator) to ensure integrity of database by taking appropriate steps and preventing the database from being accessed by unauthorized users. The DBA permits the use of the database and also stores the profile of each database user. This profile describes the permissions which are given and which portions of the database the users can operate on. Through the user profile, DBA monitors the access rights given to a particular user and also the time frame within which the permission is valid.

Complex User Management Requirements

Despite its importance, user management is often neglected in maximum database management systems. It is necessary to have an effective system for addition of users, for management of turnover, for support of connectivity, for issuance of passwords and for directory authentication to be able to implement a good user management system.

These systems should be implemented not only for the existing users and applications but also for the new ones. This is especially true for organizations dealing with business partners, customers, suppliers and other third party users who have queries, place orders, buy products and communicate online.

To meet these requirements using current IT tools is almost next to impossible as it takes too long to add and remove users. Addition and removal of privileges, and users should be done in real time. The method followed by the current IT tools to approve and register e-mails and manuals is very slow.

The major issues with the existing methods of user authentication are as follows:

- It takes too long to check the validation of user identity. The procedure is costly too.
- Accounts of the users who leave without any notification are often left non-deleted which increases security risks.
- In some cases, corruption of authentication directory or disturbances due to system failure prevents users from accessing applications.

Solutions to user management problems are as follows:

- One way to solve the problem related to cost can be solved by following a centralized administration system. The user's account and administration system are combined at one place and hence, reduces the infrastructure cost. The responsibility of adding, deleting and approving users are handed over to the local administrators.

- The user management methodology being followed, should provide provision for enrollment, administration and support for external user communities (such as, vendors, customers, etc.)
- The methodology should provide provision for generation of reports on user performance on daily, weekly and monthly basis. Accepted or rejected authentication attempts should also be listed in the report.
- Apart from making sure that the users can authenticate and access applications round the clock, the user management methodology being employed should offer scalability, performance and availability backed up by a service level agreement.
- Often, invalid or old accounts are mistakenly left active. This causes risks. These risks can be mitigated by revoking user's access privileges in the least possible intervals.

Protecting Data within the Database

The primary requirement of protecting data stored in the database is that it should be kept confidential to the unauthorized users and application programs. We adopt numerous security measures to prevent the database from unauthorized accesses. These are discussed in the following sections.

Database Audit

Database system lists the required information regarding all the users and the operations performed by them during a login session. As soon as a user logs in, the system records the account number and the terminal from which it has logged in. Until the user logs off all the operations performed by the user is recorded and associated with the user's account number.

Any suspicion of tampering the database leads to a database audit. The operations or accesses performed on a certain period of time by a particular user account is then reviewed. If an illegal operation is found the DBA immediately determines the account number performing the operation.

A database log that is used mainly for security purposes is called an audit trail.

Authenticating Users to the Database

Identification and authentication of a user can be done through any of the following methods:

(a) **What You Know?:** The easiest way to identify that an authorized user is making use of its username and password for authentication purpose. Some database systems ask some questions for authenticate valid user. Only the authorized users can come up with correct answers.

(b) **What You Have?:** Identification of valid user can be carried out by giving each of them a badge, card or key. Providing with a password or holding a question–answer session is also possible for identification.

(c) **What You Are?:** Sometimes, it is also done by some software or hardware. These make use of some physical or psychological characteristics of the user.

Statistical Databases

Statistical databases store confidential details about organizations or users, for example a database containing the income and medical records of various individuals.

Statistical database aims at maximizing information-sharing and preserving the privacy of individuals. It lets users have full access to the data in a database with an aim of increasing information sharing. Privacy of individual information is preserved by processing only those queries that produce large records. For example, a statistical database is not going to give any response to the query that wants to retrieve the salary of a particular employee from the database.

A little knowledge about the state of the database can help a malicious user know the salary of a particular employee. For example, suppose Mr Banerjee and Mr Thakur are the only employees in a particular department of a company. Mr Banerjee wants to know the salary of Mr Thakur. However, the statistical database denies retrieving the information. Now, if Mr Banerjee knows that Mr Thakur is the only employee except him in the department then he can easily find out the salary of Mr Thakur by posing the following query as he knows his own salary:

```
SELECT SUM (EMP_SALARY) FROM EMP WHERE DEPT_CODE = 10;
```

Suppose, the answer to the above query comes to be 50,000. Then, Mr Banerjee's salary being ₹20,000, Mr Thakur's salary can be computed as 50,000 – 20,000 = ₹30,000.

To protect private information stored in the database from being accessed by such smart users, the following methods can be used:

- If a query involves a small number of records, it must be rejected.
- If a user makes a query that involves a result whose intersection with the records retrieved in the previous queries is very high, the former query should be rejected. This is to prevent such users as Mr Banerjee. This can be implemented by maintaining a history of records that were used in queries asked by a particular user.
- A third method is random falsification. In this approach, a small amount of data is randomly made wrong. The result of statistical computation of such data remains correct so that normal users do not suffer.
- Another solution is to choose a random data sample representing the database in total. This sample data is then used to give response to any query. This method relieves the normal user from any sufferings and also protects the database from any danger.
- The users can be also discouraged from involving in any malicious activities by performing audit trials at regular intervals and recording the identity of the user and their interaction with the database.

Discretionary Access Control Based on Grant and Revoking Privilege

Access control mechanisms are implemented to restrict database access only to authorized users. Each user is given a username and a password. The database administrator grants access permissions and user accounts to various users of the database.

The responsibilities of DBAs are summarized in Table 5.30.

Table 5.30 *Responsibilities of DBA*

(a) Account Creation	DBA creates user accounts and each user or group of users is given a password.
(b) Privilege Granting	A user or a group of users is granted privilege to access certain parts of a database.
(c) Privilege Revocation	DBA can also revoke permission (that was previously given) to access certain parts of a database from a user or group of users.
(d) Security Level Assignment	Assigning user accounts to the appropriate security level.

Any user or group of users interested in accessing the database needs to apply for a user account first. It is up to the DBA to grant or not to grant permission. If granted, the user or group of users can log in to the system using the username and password. Then, the validity of the username and password is checked. A valid username and password pair permits the user to access certain portions of the database.

Note: Application programmes are also considered as users by the DBMS and are required to supply user account and password.

SUMMARY

- Database Management System (DBMS) is a software solution that allows you to create and maintain databases in which you can store the data.
- DBMS also allows you to construct and manipulate a database. Constructing a database is a process of storing data on some storage medium such as floppy drive, compact disk (CD) or hard disk drive (HDD).
- DBMS enables you to structure the data as tables, records or objects.
- DBMS provides a data dictionary which contains the structure of a database.
- Nowadays, there also exist three new types of databases: parallel database, distributed database and object-oriented databases.
- Parallel databases use parallel processors for computing. These databases use high-speed processors, memory and disks. Parallel databases uses relational data model which uses SQL query language to manipulate the data.
- Distributed Databases (DDBs) store data over a computer network. In these databases, data may be stored in multiple computers located at the same physical location or spread over a network.
- A data model in DBMS is defined as a collection of concepts which is used to describe the structure of a database.
- Data models can be defined as a collection of various concepts which are used to describe the structure of a database.
- In the Hierarchical model also called Hierarchical schema, data are organized in the form of a tree structure. Hierarchical model supports the concept of data independence.
- The network model can be defined as a database model which is used to represent objects and the relationships among these objects. In network model, a record can have a number of parent records and it also can have multiple child records.

- In a relational data model, data is stored in tables which are also called relations. The related tables or relations in the relational data model form a database.
- A relation is a two-dimensional table which is used to represent data in the form of rows and columns.
- Database design is a process in which you create a logical data model for a database which stores data of a company.
- The goal of designing of database schema is to minimize the storage space which is occupied by the data stored on the hard drive.
- Normalization terminology consists of various concepts frequently used in normalization such as primary key and functional dependency.
- Database security comprises policies taken to protect data from being accessed by unauthorized users. This also includes the policies needed to ensure that data items are not modified or deleted from the database by unauthorized users, applications or viruses.

KEY TERMS

- **Database:** A database is a collection of interrelated data.
- **Network model:** The network model can be defined as a database model which is used to represent objects and the relationships among these objects. In network model, a record can have a number of parent records and it also can have multiple child records.
- **Tuple:** In relational data model, a row is termed as tuple that gives complete information of an entity.
- **Attribute:** It is a column header in a relation that represents the attributes of an entity.
- **Normalization:** Normalization is integral to the database design and it can be defined as the process of eliminating the redundancy of data in a database.
- **Audit trail:** A database log that is used mainly for security purposes is called an audit trail.

ANSWERS TO 'CHECK YOUR PROGRESS'

1. Database Management System (DBMS) is a software solution that allows you to create and maintain databases in which you can store the data. It basically refers to a system which helps store and retrieve the data systematically from a database.
2. A DBMS has the following features:
   - **Structured data**: DBMS enables you to structure the data as tables, records or objects.
   - **Query language**: A DBMS provides a query language such as SQL to process the user requests.
   - **Multi-user access**: DBMS allows several users to access the data stored in a database. At the same time, it provides security features which restrict some users from viewing or manipulating the data.
   - **Data dictionary**: DBMS provides a data dictionary which contains the structure of a database.

3. Parallel database architecture follows parallel dataflow architecture with new designs used for high speed of database while processing relational database queries. In parallel database systems, the relational data model is used; for parallel dataflow, relational queries and various relational operators, which are composed of parallel dataflow graphs, are used.
4. DDB is a collection of multiple interrelated databases that are spread over a computer network. Each computer contains its own database which is managed by an individual database management system.
5. A data model in DBMS is defined as a collection of concepts which is used to describe the structure of a database.
6. The various data model used in DBMS are as follows:
   - Hierarchical
   - Network
   - Relational
   - Object-oriented
7. The advantages of the network data model are as follows:
   - It enables the representation of complex relationships and effect of operations such as add and delete on the relationships.
   - It uses constructs such as FIND, FIND owner and FIND NEXT within a set that allows the users to navigate through the database.
   - Network model can inherit the advantages of hierarchical model.
8. Database design is a process in which you create a logical data model for a database which stores data of a company.
9. The goals of normalization are as follows:
   - Removing the redundant data
   - Ensuring that only related data is stored in a table
10. The following issues are handled by data security:
    - Maintenance of database integrity
    - Maintenance of privacy of certain data elements
    - Security level for the system
    - Preservation of organizational policies
11. The primary requirement of database security is to forbid an individual from obtaining something by unfair means and entering into an organization's computing facility.

EXERCISES AND QUESTIONS

Short-Answer Questions

1. What are the different components of database?
2. What do you mean by end-users?
3. Differentiate between SQL and FDL.
4. Mention the advantages and disadvantages of Hierarchical data model.

5. Define the following terms:
   - Domain
   - Tuple
   - Attribute

Long-Answer Questions

1. Analyse the need for database.
2. Discuss the advantages and disadvantages of DBMS.
3. What do you mean by architecture of DBMS? Explain in detail.
4. Describe DBMS interfaces.
5. Discuss the Network model of DBMS.

FURTHER READING

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