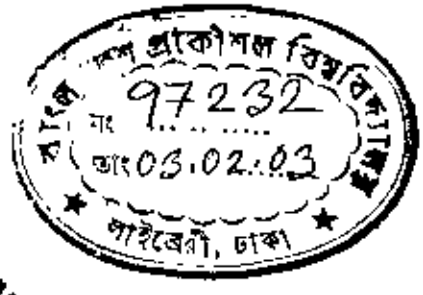
MULTI-CRITERIA EVALUATION OF ALTERNATIVE COMMUNICATION MEDIA

By

MUHAMMAD QUAMRUZZAMAN SHAMEEM

A thesis submitted to the department of Industrial & Production Engineering,
Bangladesh University of Engineering & Technology, Dhaka,
in partial fulfillment of the requirement for the degree of
Master of Engineering in Advanced Engineering Management



October 29, 2002

Department of Industrial & Production Engineering
Bangladesh University of Engineering & Technology
Dhaka-1000, Bangladesh

MULTI-CRITERIA EVALUATION OF ALTERNATIVE COMMUNICATION MEDIA

By

MUHAMMAD QUAMRUZZAMAN SHAMEEM

Approved as to the style and content by:

1. **Dr. M. Ahsan Akhtar Hasin** — Chairman (Supervisor)
   Associate Professor
   Dept. of IPE, BUET

2. **Dr. A. F. M. Anwarul Haque** — Member
   Professor
   Dept of IPE, BUET

3. **Dr. A. N. Mustafizul Karim** — Member
   Professor
   Dept. of IPE, BUET

October 29, 2002

Department of Industrial & Production Engineering
Bangladesh University of Engineering & Technology
Dhaka-1000, Bangladesh

DECLARATION

This is to certify that this work has been done by me and it was not submitted elsewhere for the award of any degree or diploma except for publication.

mshameem

MUHAMMAD QUAMRUZZAMAN SHAMEEM

ACKNOWLEDGEMENT

The author acknowledges his profound indebtedness and sincere gratitude to Dr. M. Ahsan Akhtar Hasin, Associate Professor, department of Industrial & Production Engineering for his constant guidance, supervision and suggestions at all stages in conducting this research work. The author is greatly indebted to him not only for the time and effort he provided but also for his useful comments and sincere advice and encouragement that facilitated completion of the project work.

The author wishes to convey special thanks to his thesis committee members' professor Dr. A. F. M. Anwarul Haque and Professor Dr. A. N. Mustafizul Karim for their encouragement, continued help and useful suggestions.

The author is also grateful to Dr. Mahiuddin Ahmed, Head, department of Industrial & Production Engineering, for his critical observations and valuable suggestions during study.

The author wishes to express his heartiest thanks to his respected teachers of the department of Industrial & Production Engineering and to all those who directly or indirectly helped him in this work.

The author owes thanks to his friends specially Noor-e-Alam who inspired him during this work.

Finally, no words can express the contribution of the author's parents on him. Their constant blessings and encouragement throughout this study was the backbone behind the success of the author in his study. It is to them, the author dedicated this piece of work.

Author

ABSTRACT

Bangladesh Power Development Board (BPDB) has 29 Regional Accounting Offices (RAOs) through out the country. These 29 RAOs are the clients of IMRS Server and 7 other offices are the on-line clients of Database Server at Dhaka Financial Data Processing Center. BPDB has 2 other Database Servers at the Financial Data Processing Center located Comilla and Chittagong. For networking the 29 RAOs and several offices of BPDB situated all over Bangladesh, communication media would play a major role. It must be noted that evaluation of a communication media needs to consider multiple criterion for evaluation For example, some available criteria may be: implementation cost, maintenance cost, speed, security, reliability etc. Some of these are quantitative, where as some are qualitative in nature. This requires multi-criteria evaluation, which can handle both of these types of conflicting criteria This research aims to evaluate possible alternative communication media for use in BPDB using Analytic Hierarchy Process (AHP) technique.

CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
BPDB	Bangladesh Power Development Board
DSL	Digital Subscriber Line
EMI	Electromagnetic Interference
FMUP	Financial Management Upgrade Project
ILD	Injection Lased Diode
IMRS	Integrated Management Recording System
IP	Internet Protocol
IPP	Independent Power Producer
IPSec	Internet Protocol Security
ISP	Internet Service Provider
LAN	Local Area Network
LED	Light Emitting Diode
MAN	Metropolitan Area Network
MCDM	Multi-Criteria Decision Making
MIS	Management Information System
NOS	Network Operating System
OS	Operating System
RAO	Regional Accounting Office
RDBMS	Relational Database Management System
STP	Shielded Twisted Pair
TCP	Transmission Control Protocol
UTP	Unshielded Twisted Pair
VSAT	Very Small Aperture Terminal
WAPDA	Water And Power Development Authority
WAN	Wide Area Network

Chapter 1

Introduction

1.1 Introduction

For many organizations, computer information systems are now at the heart of daily activities and a major consideration in corporate decision making. Businesses consider carefully information systems capabilities when deciding whether or not to enter new markets or when planning a response to competition. Without automated assistance, government organizations would grind to a halt for the sheer volume of activities and would overwhelm workers and managers. Data communications capabilities determine where and when information will flow. Data communication and networks are increasingly becoming common in information systems of all sizes.

The components included in an information system determine how data transmission can occur. If a new system is being developed, selection of the components is the responsibility of the manager. If a system is already in place, the manager must know what communications features to consider when developing a new application that will interact with an existing application

The manager must select or be familiar with the communication media, communication control devices and communication protocol. In addition, the manager must also select network features that will correspond to systems already in place or that can be tailored to the hardware and software characteristics of the computers on which the communications network will operate.

1.2 Background and Statement of the Problem

A decision may be taken through multi-criteria judgment out of several alternatives. Sometimes the decision involves several conflicting criteria. There are several such models to evaluate different alternatives. Among the Analytic Hierarchy Process

(AHP) is very helpful to the decision makers to take the right decision. The main advantage of using AHP method is it's ability to handle a complex problem to prepare a hierarchy of choice and reasons of choices through decomposition and synthesis. It can compare different alternatives and attribute using a scale of relative importance.

A Computer Network is a collection of hardware and software that enables a group of nodes (devices) to communicate and provides users with access to shared resources. A network is composed of two or more nodes that will share information, a communication medium through which they can communicate, and network operating system software. At one time, communication medium choices were determined by the chosen topology; for example, Ethernet used coaxial, and Token Ring used shielded twisted-pair. Nowadays, networks are more accepting of a variety of communication mediums, and thus communication medium choices are a balancing act between budgets and performance needs.

Bangladesh Power Development Board (BPDB) is developing Computerized Billing in Chittagong and Comilla, and Accounting System in Dhaka, Chittagong and Comilla. BPDB is also developing feeder system software (IMRS) for the transitional period BPDB has 29 Regional Accounting Offices (RAOs) through out the country. These 29 RAOs are the clients of IMRS Server and several offices are the on-line clients of Database Server at Dhaka Financial Data Processing Center. BPDB has 2 other Database Servers at the Financial Data Processing Center located Comilla and Chittagong For networking the 29 RAOs and several offices of BPDB situated all over Bangladesh, communication media would play a major role. It must be noted that evaluation of a communication media needs to consider multiple criterion for evaluation. For example, some available criteria may be: implementation cost, maintenance cost, speed, security, reliability etc. Some of these are quantitative, where as some are qualitative in nature. This requires multi-criteria evaluation, which can handle both of these types of conflicting criteria. This research aims to evaluate possible alternative communication media for use in BPDB using Analytic Hierarchy Process (AHP) technique.

1.3 Objectives of the Study

The main objectives of this study are:

- To set the criteria for evaluation
- To study MCDM techniques
- To recommend suitable communication media for selected offices & RAOs of BPDB

1.4 Methodology

The methodology to be adopted for this study is firstly an in-depth examination of the MCDM techniques and the networking & communication media; secondly having an idea about the current scenario & requirements of the organization and collection of data & information for meeting those requirements, and finally, recommendation of suitable communication media for selected offices & RAOs of BPDB on the basis of the calculation of MCDM.

1.5 Sources of Information

The data and information required in this study about communication media are directly obtained from IT firms. Extensive interviews have been taken to grasp an in depth understanding of the communication media. Information collected to furnish this report was collected from the different publications and books.

The organization part of the report is obtained through survey (On the Spot) and inspection conducted in the organization under study. Information was gathered through visits to concerned offices of the organization, interviews with the officials and review & examination of the papers made available

1.6 Scope and Limitations of the Study

The scope of this study covers all 29 (Twenty nine) RAOs, 3 (Three) Financial Data Processing Centers and some other offices of BPDB.

There were situations where the people interviewed could not render the expected assistance, because of lack of information as well as confidentiality.

The data obtained from IT firms are sometimes approximate, but very close to actual data.

The study has taken into account only the major criteria in AHP. Because, introduction of more criteria multiplies complexities in calculations.

Chapter 2

Multi-Criteria Decision Making (MCDM)

2.1 Evaluation of Alternatives

The probable alternatives of any selected item may be evaluated through different multi-criteria models. Because, the alternative items, generally, have multiple characteristics which demand consideration for selection. There are several such models to evaluate different alternatives. The two most favorite techniques are:

- Analytic Hierarchy Process (AHP)
- ELECTRE Method

The above two methods/techniques actually rank different alternatives as a decision support system for the management to decide what alternative system/model they can select from several available alternatives.

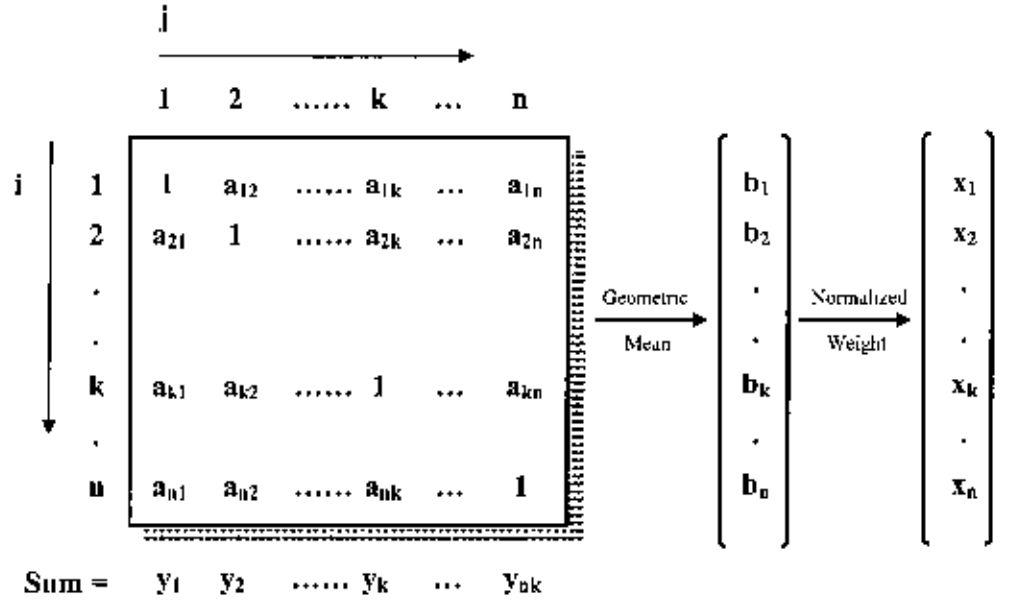
Here, AHP will be used to evaluate different alternative Communication Media.

2.2 The Analytic Hierarchy Process

The Analytic Hierarchy Process, developed by Thomas Saaty, is a multi-attribute decision making technique. The approach made in this methodology is to analyze a complex problem through decomposition and synthesis. This methodology may be applied to numerous fields, such as, transportation planning, portfolio selection, corporate planning, marketing, performance evaluation, etc.

The main advantage of this method is that it can handle a complex problem to prepare a hierarchy of choices explaining the reasons of such choices through decomposition and synthesis. It can compare different alternatives and attributes using a scale of relative importance

The numerical results of attributes are presented to the decision maker to assign relative importance according to a predefined scale. Now a judgment matrix is prepared. It is an (nxn) matrix. From the judgment matrix, normalized weights are calculated as follows.



Where, i and j are the alternatives or attributes to be compared. a_{ij} is a value which represents comparison between alternatives or attributes i and j

The above judgment matrix may be consistent if

$a_{ij}.a_{jk} = a_{ik}$ ..... For all values of **i, j, k**

In the above matrix, sum of the elements in a column

$$y_k = \sum_{i=1}^{i=n} a_{ij} \qquad (2.1)$$

Where, $i = 1, 2, \ldots\ldots n$ and $j = 1, 2, \ldots\ldots n$

Geometric mean is calculated from the elements of row as follows:

$$b_k = [(a_{k1}).(a_{k2}) \ldots\ldots (a_{kn})]^{1/n}$$

Where, $k = 1, 2, \ldots\ldots n$

Normalized weights are calculated as follows:

$$x_k = \frac{b_k}{\sum_{k=1}^{k=n} b_k} \qquad (2.2)$$

Acceptability of alternative or attribute is measured in terms of Consistency Ratio (C.R.)

$$\text{Consistency Ratio} = \frac{\text{Consistency Index}}{\text{Randomly Generated Consistency Index}} \qquad (2.3)$$

Saaty's measure of consistency in done in terms of Consistency Index (C.I.)

$$\text{C. I.} = \frac{\lambda_{max} - n}{n - 1} \qquad (2.4)$$

Where,

$$\lambda_{max} = y_1 x_1 + y_2 x_2 + \ldots + y_k x_k + \ldots + y_n x_n = \sum_{k=1}^{k=n} y_k x_k \qquad (2.5)$$

= largest eigen value of matrix of order n

Now, some Randomly Generated Consistency Index (R.I.) values are as follows:

N	1	2	3	4	5	6	7	8	9	10
R. I.	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

If C.R. ≤ 10 %, then the alternative or attribute is considerable. Otherwise, the alternative or attribute is rejected. The over-all consistency may also be measured to justify the validity of selection.

2.3 Example of the AHP

Three alternative FMS (Flexible Manufacturing Systems) models are considered here. These alternative models need multi-attribute evaluation to be ranked according to a preference order. The AHP is used for that purpose.

A 3-level hierarchy is used which is given below:

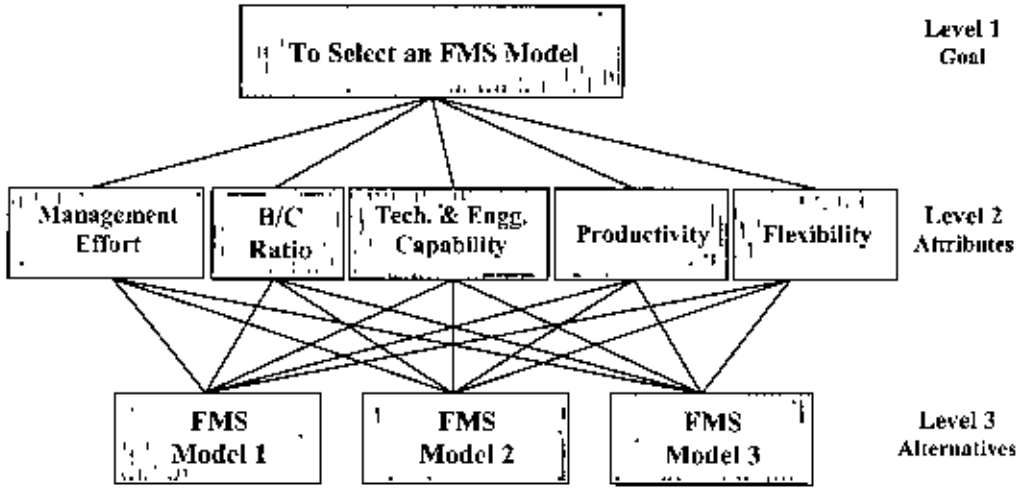


Figure 2.1: Hierarchy used for Multi-attribute Evaluation

The following "Scale of Relative Importance" is used for pair wise comparison.

1 -> Equal Importance
3 -> Moderate Importance
5 -> Essential or Strong Importance
7 -> Dominance of One Demonstrated in Practice
9 -> Extreme Importance

2, 4, 6 & 8 represent Intermediate Importance.

On the basis of expert opinion, the following judgement matrices are prepared at each level of hierarchy.

1) At Level 1:

Alternatives	Management Effort	B/C Ratio	Tech. & Engg. Cap.	Productivity	Flexibility
Management Effort	1	1/3	1	1/3	1/3
B/C Ratio	3	1	2	1	1
Tech. & Engg Cap	1	1/2	1	1/2	1/2
Productivity	3	1	2	1	1
Flexibility	3	1	2	1	1

n = 5

C. I. = 0.003675

C. R. = 0.003280 = 0.328% < 10%

So, acceptable.

2) **At Level 2:**

(i) Management Effort

Alternatives	FMS 1	FMS 2	FMS 3
FMS 1	1	3	3
FMS 2	$^1/_3$	1	1
FMS 3	$^1/_3$	1	1

n = 3
C. I. = 0.001
C. R. = 0.00172 = 0.172% < 10%
So, acceptable.

(ii) B/C Ratio

Alternatives	FMS 1	FMS 2	FMS 3
FMS 1	1	$^1/_{1.5}$	$^1/_{1.3}$
FMS 2	1.5	1	1.2
FMS 3	1.3	$^1/_{1.2}$	1

n = 3
C. I. = 0.0
C. R. = 0% < 10%
So, acceptable.

(iii) Technical & Engineering Capability

Alternatives	FMS 1	FMS 2	FMS 3
FMS 1	1	$^1/_2$	$^1/_3$
FMS 2	2	1	$^1/_2$
FMS 3	3	2	1

n = 3
C. I. = 0.00366
C. R = 0.00631 = 0.63% < 10%
So, acceptable.

(iv) Productivity

Alternatives	FMS 1	FMS 2	FMS 3
FMS 1	1	$^1/_2$	$^1/_{1.5}$
FMS 2	2	1	1.5
FMS 3	1.5	$^1/_{1.5}$	1

n = 3
C. I. = 0.00196
C. R. = 0.00338 = 0.338% < 10%
So, acceptable.

(v) Flexibility

Alternatives	FMS 1	FMS 2	FMS 3
FMS 1	1	5	3
FMS 2	1/5	1	1/3
FMS 3	1/3	3	1

n = 3
C. I. = 0.01933
C. R. = 0.0333 = 3.33% < 10%
So, acceptable.

On the basis of the above matrices, an over-all evaluation is preformed using the calculated weights of the alternatives and five criteria. The composite weights of the three alternatives are calculated. On the basis of these composite weights, we have to rank the alternative FMS models. These are given in the following table.

3) Over-all Evaluation:

Alternatives	*Attributes & their weights*					Composite Weights	Over-all Ranking
	Management Effort 0.0950	B/C Ratio 0.2616	Tech & Engg Capability 0.1202	Productivity 0.2616	Flexibility 0.2616		
FMS 1	0.60	0.263	0.163	0.221	0.637	0.3698	1
FMS 2	0.20	0.400	0.297	0.460	0.105	0.3071	3
FMS 3	0.20	0.337	0.540	0.319	0.258	0.3231	2

2.4 Evaluation Processes: The AHP

Both physical and psychological events are now being measured by many mathematical models developed in the recent past. Approaches made by scientists to model structures of those problems are not uniform but diversified in the sense that some have used mathematical models and some others theoretical ones. Again, many have worked on measurement and on judgment solicitation.

The Analytical Hierarchy Process (AHP) derived by Thomas L. Saaty [17] may be called a mathematical model The AHP provides a comprehensive framework to cope with the intuitive, the rational, and irrational in us all the same time. Saaty represented an example of the application of the AHP to decide about a complex multi attribute problem. The problem is "Choosing the best house to buy".

SWAMIDASS and WALLER [24] also advocated in favor of AHP and Scoring method for evaluation process of advanced manufacturing technologies.

DICKER et al [7] said that multi-attribute evaluation process takes into account both tangible and intangible benefits, whereas discounted cash flow methods consider only tangible benefits. So, he suggested that multi-attribute method could be used for the evaluation of some alternatives.

PARTOVI et al [15] also applied the AHP for the evaluation of some alternatives. He identified some complex problem areas and provided description of the probable hierarchies. They presented the problems of "Fuel System Selection Decision", "Supplier Selection", "Best Location for a Facility", "Finding the Right Forecasting Adjustment Ratio", etc. and also proposed the corresponding hierarchies.

MUSTAFA and AL-BAHAR [14] used the AHP as a tool to analyze and assess project risks. They applied this approach to assess the risk involved in constructing the "Jamuna Multi-Purpose Bridge" in Bangladesh.

SURESH and MEREDITH [23] explained the use of scoring method as an effective evaluation technique of advanced manufacturing technology. It is very simple to apply for management policies especially for strategic level decisions.

ELECTRE I [25] is an interactive multiple criteria decision technique designed to handle qualitative and discrete alternatives, in a situation where the decision maker can only give a priori preference information on a local level. In the ELECTRE II algorithm, [ROY and BERTIER (1971)] complete ordering of alternatives is accomplished. ELECTRE method is found to be used less than the AHP method to evaluate manufacturing alternatives. TABUCANON applied MCDM in diversified fields.

CANADA and SULLIVAN [2] suggested for multi-attribute techniques to evaluate advanced manufacturing technology. He applied AHP and Scoring methods to rank some alternative manufacturing systems.

Chapter 3

Communication System & Networking Technology

3.1 Communication Model

The fundamental purpose of a communications system is the exchange of data between two parties.

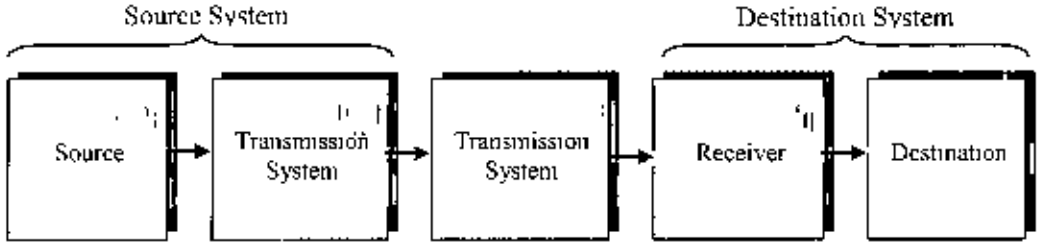


Figure 3.1: General Block Diagram of Simplified Communications Model [22]

The key elements of the model [12] [22] are:

1. ***Source***. This device generates the data to be transmitted.
2. ***Transmitter***. Usually, the data generated by a source system are not transmitted directly in the form in which they are generated. Rather, a transmitter transforms and encodes the information in such a way as to produce electromagnetic signals that can be transmitted across some sort of transmission system.
3. ***Transmission System***. This can be a single transmission line or a complex network connecting source and destination.
4. ***Receiver***. The receiver accepts the signal from the transmission system and converts it into a form that can be handled by the destination device.
5. ***Destination***. Takes the incoming data from the receiver.

3.2 Digital Communications

The use of digital communications may require a considerable amount of electronic circuitry. But now-a-days electronics is relatively cheap, due to the ever-increasing availability of very-large-scale integrated (VLSI) [16] circuits in the form of silicon chips. Indeed, with continuing improvements in the semiconductor industry, the technology favors digital communications over analog communications. Thus, although cost considerations used to be a factor in selecting analog communications over digital communications in the past, that is no longer the case today [9].

3.3 Networking Basics

A ***computer network*** is a collection of hardware and software that enables a group of nodes (devices) to communicate and provides users with access to shared resources. A network is composed of two or more nodes that will share information, a communication medium through which they can communicate, and network operating system software [3][26].

Communication networks are usually defined by their size and complexity. It can be distinguished into three main types:

Local Area Network (LAN) is a collection of computers cabled together to form a network in a small geographic area (usually within one building).

Metropolitan Area Network (MAN) is slightly larger than a LAN and is contained within a single city or metropolitan area.

Wide Area Network (WAN) is relatively large and can span countries and continents. Stated simply, wide area networks are the set of connecting links between local area networks. Most WANs are private and owned by the business that operates with them. Recently, however, the Internet has emerged as both the largest and the least expansive WAN in the world. Many companies are now forming private WANs through encrypted communications over the Internet [3].

Based on the roles of the computers attached, networks are divided into three types:

- Server-Based Networks
- Peer Networks
- Hybrid Networks

Server-based (also called client-server), containing clients and the servers that support them. A server-based network requires a central file server and a networking operating system that can handle the job. They require a separate machine and therefore expensive hardware, expensive NOS, and without the proper training it is difficult to install and maintain. On the other hand, data transfer speeds are higher, security is more robust. LAN expansion is simpler, and there are management tools available [3] [26].

Peer (also called peer-to-peer) which has no servers and use the network to share resources among independent peers. A peer-to-peer network does not rely on the use of a central file server to share file but each workstation relies on another workstation to have its resources made available. It is very difficult to maintain security, must be limited number of peers to keep administration costs low, slow response time, but it is inexpensive, no central point of failure and no special training required [3] [26].

Hybrid network which is a client-server network that also has peers sharing resources. Hybrid computing provides ability to users and network administrators to control security based on the importance of the shared resource. Most networks are actually hybrid networks [3].

3.4 Network Topologies

A ***network topology*** refers to the layout of the transmission medium and devices on a network [3] [26].

There are two categories of topologies [3] [26].

- Physical Topology
- Logical Topology

Physical Topology

- **Mesh**. Provides each device with a point-to-point connection to every other device in the network.

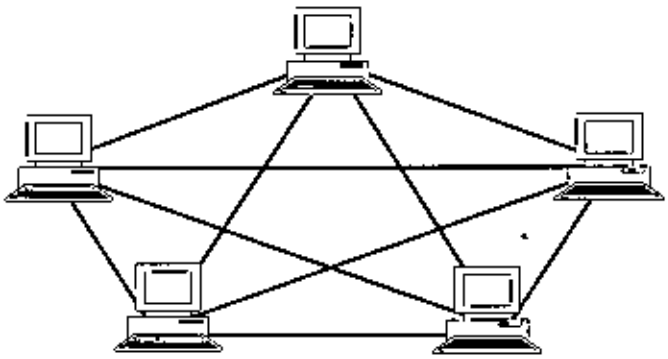


Figure 3.2: Mesh Topology [3]

- **Star** Branches out via drop cables from a central hub (also called a multiport repeater or concentrator) to each workstation. A signal is transmitted from a workstation up the drop cable to the hub. The hub then transmits the signal to other networked workstations.

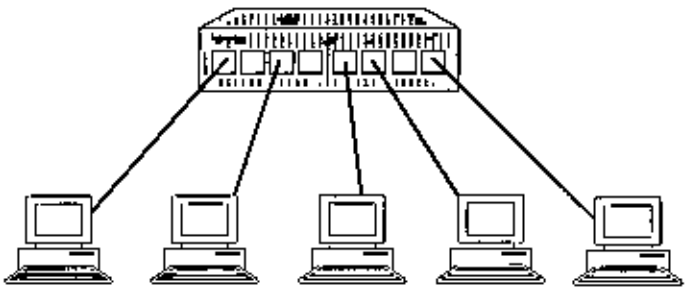


Figure 3.3: Star Topology [3]

- **Ring**. Connects workstations in a continuous loop. Workstations relay signals around the loop in round-robin fashion.

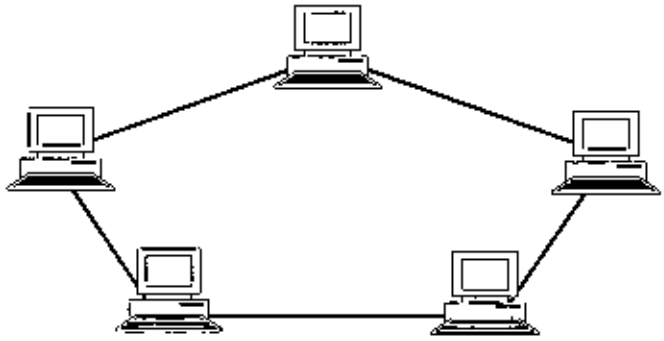


Figure 3.4. Ring Topology [3]

- **Bus**. Uses a single main bus cable, sometimes called a backbone, to transmit data. Workstations and other network devices tap directly into the backbone by using drop cables that are connected to the backbone.

Figure 3.5: Bus Topology [3]

- **Cellular** Refers to a geographic area, divided into cells, combining a wireless structure with point-to-point and multipoint design for device attachment. The devices in each cell directly communication with a central station called a hub.

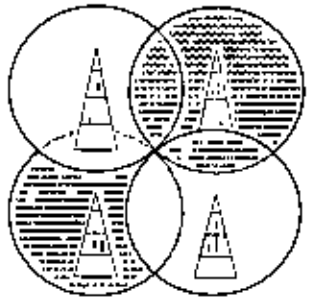


Figure 3.6: Cellular Topology [3]

Logical Topology

- **Ring**. Generates and sends the signal on a one-way path, usually counterclockwise.
- **Bus** Generates and sends the signal to all network devices.

Physical topology defines the cable's actual physical configuration (star, bus, mesh, ring, cellular, and hybrid). Logical topology defines the network path that a signal follows (ring or bus).

3.5 Network Operating Systems

A network consists of resources such as servers, workstations, printers, bridges, routers, gateways, and other peripheral computer equipments. The ***Network Operating System*** (NOS) is a software that communicates with each of these devices to form an integrated system [10].

The major network operating systems are Microsoft Windows NT, Novell NetWare, and UNIX.

Windows NT is Microsoft's advanced operating system that provides full 32-bit operations on high-performance single-processor & multiprocessor systems and can run on Intel (and compatible) and RISC platforms. It is a preemptive multitasking operating system that shares processor time between all running processes. It includes built-in security that meets government ratings and networking support that is optimized to run back-end applications for a large number of clients. The Windows NT operating system was designed specially to serve the needs of network uses and to provide high levels of performance and security [11] [13] [19].

The superuser on an NT system is the user Administrator. This account has complete, unlimited access over the operating system, whether it is used as a workstation or a network server [4].

NetWare is one of the world's most popular network operating systems. With NetWare 5, Novell has incorporated all the advantages of previous versions of NetWare and has added new features that build on the foundation to provide a distributed computing infrastructure [10].

The default protocol for NetWare 4.x and earlier is IPX/SPX. NetWare versions 4.0 and higher use a directory service based network, Novell Directory Services or NDS. NetWare 3.x and previous versions used a bindery-based database to maintain information about users and groups [20].

The superuser on a NetWare system is the user Admin. NetWare 3.x and previous versions used SUPERVISOR rather than Admin, and a separate SUPERVISOR account was required for each server on the network.

UNIX is a family of operating systems developed at Bell Laboratories in the late 1960s. Because UNIX was designed for software development, the needs of the beginning user were ignored in favor of speed and accuracy. However, UNIX has evolved with an ever-increasing focus on the end-user's needs [19].

One of the main reasons for the longevity and popularity of UNIX is its portability. UNIX runs on almost every type of computer from micros to super computers. UNIX provides utilities for everything from email to compilers.

The superuser on a UNIX system is the user root. This account has complete, unlimited access over the operating system, whether it is used as a workstation or a network server [1].

Sun Microsystems' Solaris is perhaps the most popular UNIX system. It is a BSD UNIX with many of the features of the SVR releases (the releases originating from AT&T's original work now called the System V release or SVR). It has been optimized for distributed network environments and performance enhanced for running database and Web applications. The system is also Java-enabled and

includes support for Java VM (Virtual Machine). The HotJava browser is also included. Solaris runs on SPARC and Intel platforms and will be available on PowerPC platforms. Multiprocessor systems are supported and Solaris uses symmetrical multiprocessing techniques to full advantage of these systems. Multithreading is supported, which allows applications to be broken into segments that execute simultaneously on each processor [19].

FreeBSD, another interesting variant, is a version of UNIX that is based on the Berkeley BSD releases and that runs on Intel processors. The FreeBSD operating system is free and can be obtained at the Web site [19]

Linux is another free UNIX-like 32-bit operating system that runs on a variety of platforms, including Intel, SPARC, PowerPC, and DEC Alpha processors as well as multiprocessing systems It is a freely available operating system with open source code. Linux is a "user-developed" product. The original operating system was developed by Linux Torvalds as a college project. It is now well supported and gaining ground as a respectable operating system despite its homegrown roots. The only problem with this approach is that drivers and fixes are only available if some user decides to develop them. Support is another issue since user can't call any particular vendor [19]

3.6 The OSI Model

The ***Open Systems Interconnect*** (OSI) reference model was developed in the early 1970s by the International Standards Organization (ISO). Provides a set of general design guidelines for data-communications systems and also gives a standard way to describe how various portions (layers) of data-communication systems interact. The hierarchical layering of protocols on a computer that forms the OSI model is known as a stack. A given layer in a stack sends commands to layers below it and services commands from layers above it [19].

It consists of seven layers [3] [22] [26]:

- Application
- Presentation
- Session
- Transport
- Network
- Data Link
- Physical

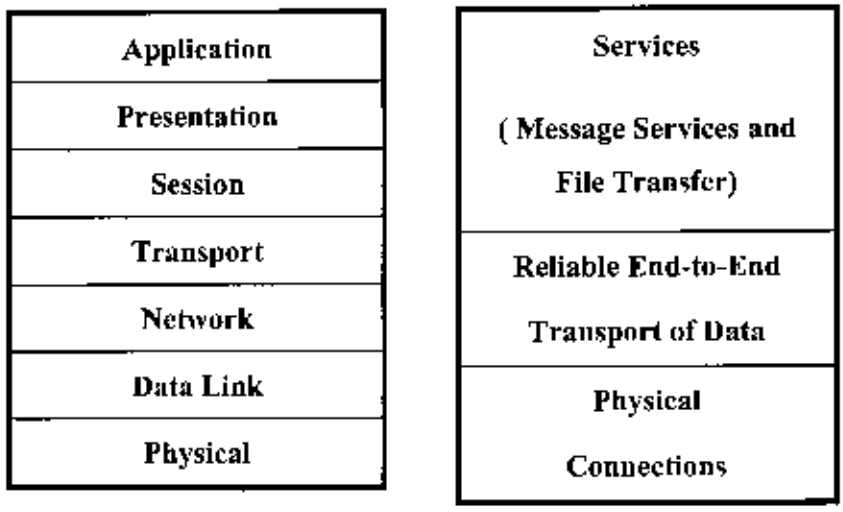


Figure 3.7: Functions and Categories of the OSI Model [3]

3.7 Network Protocols

A ***protocol*** is a set of rules for communication. Protocols are the agree-upon ways that computers exchange information. A computer needs to know exactly how messages will arrive from the network so it can make sure the message gets to the right place. It needs to know how the network expects the message to be formatted so the network can convey the data to its destination [9].

There are many levels of protocols in a network. Protocols can be broadly divided into two categories.

- Hardware Protocols
- Software Protocols

A ***protocol suite*** is a set of related protocols that come from a single developer or source. Transmission Control Protocol (TCP) is an example of a protocol. The Internet Protocol suite refers to a protocol suite that includes TCP and several other related data-communication protocols.

A ***protocol stack*** is a set of two or more protocols that work together, with each protocol covering a different aspect of data communications. Typically, TCP and Internet Protocol (IP) are used in combination and might be called a protocol stack

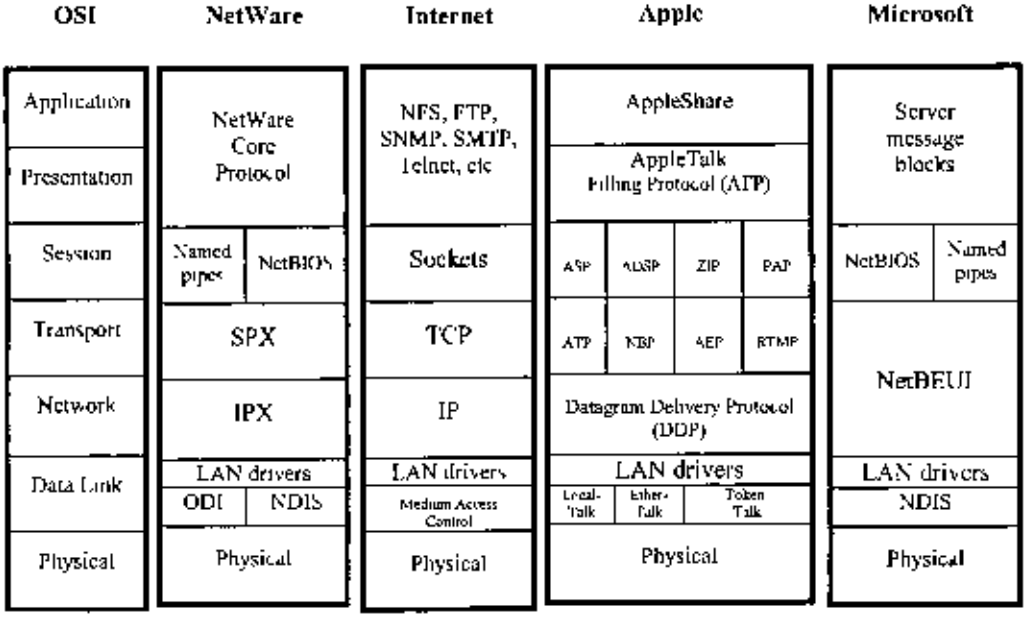


Figure 3.8: Common Protocol Stacks [6]

Long ago, the ISO developed the seven-layer OSI model. This model was supposed to have provided a framework for integrating data processing systems everywhere. The Internet protocols, including TCP/IP, are now commonly used throughout the world. Developed by the Department of Defense, the TCP/IP protocol suite is a standard set of protocols for the communication and interconnection of all types of computer systems. The name is derived from the two most widely implemented protocols in the suite: Transmission Control Protocol (TCP) & Internet Protocol (IP). Only a few years ago, a number of other protocols were vying for this top spot, including the OSI protocols. Other network protocol suites include Novell's IPX/SPX, AppleTalk, and IBM SNA [6].

3.8 Communication Media

A Communication system consists of a communication medium and the devices that connect to it. The medium may be guided or unguided, where guided media is a metal or optical cable and unguided media refers to transmitting signals through air or the vacuum of space. A communication system that connects two devices is said to be a *point-to-point* system. In contrast, a shared system connects a number of devices that can transmit on the same medium, but only one at a time [19].

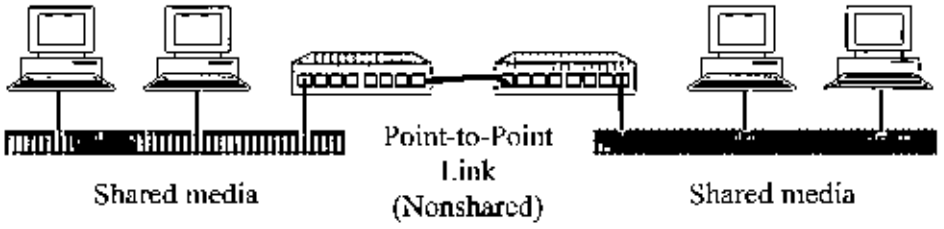


Figure 3.9: Shared and Point-to-Point Communication Systems [19]

3.9 Network Connectivity Devices

Network connectivity devices used to connect devices to networks or to connect networks to other networks. Network connection devices connect the various segments of network media that make up a network or inter-network. A segment is one section of network transmission media that is assigned a specific network address; it provides servers and clients on the network with access to network resources [3].

Some of these devices are given below [3]:

Network Interface Board: A network interface board attaches a device, such as a computer, to a transmission medium. Network interface boards (hardware) and their drivers (software) are aware of their own physical device address, and insert it into the source address field in the Data Link header of every frame they submit.

Repeaters: Repeaters regenerate (repeat) all received frames to all others ports on the repeater. Repeaters work in the Physical layer of the OSI model to provide fast signal regeneration.

Active Hubs: Active hubs, also called multiport repeaters, repeat all received frames to all other ports on the hubs. It can regenerate or amplify a signal.

Passive hubs: Passive hub connects multiple media segments together; it does not regenerate or amplify a signal.

Bridges: Bridges, like a repeater, extends a network's transmission distance; however, a bridge is used to connect segments on different networks. A bridge connects two LANs together that use the same protocol stack.

Switches: A switch is a network device that selects a path or circuit for routing data to its destination. A switch forwards data to one of its ports that will direct the data to the correct destination device. A switch can be through of an intelligent bridge.

Routers: A router is a device or software in a computer that selectively forwards packets to the port attached to the network that will allow the packet to find its destination device. Routers use distance and cost algorithms to determine the best route.

Gateways: A gateway is a device in a network that acts as an entrance to another network. Gateways translate between the protocols of disparate protocol suites. This translation can take place at a single layer or at several layers.

Chapter 4

The Communication & Linking Media

4.1 Introduction

At one time, transmission media choices were determined by the chosen topology; for example, Ethernet used coaxial, and Token Ring used shielded twisted-pair. Nowadays networks are more accepting of a variety of transmission media types, and thus transmission media and link choices are a balancing act between budgets and performance needs [26].

The larger the area LAN covers, the more critical cabling design becomes. Manager must looks at the issue of cabling first to determine whether it will drive network budget and planning cycles, or whether it is only a minor consideration. The type of cabling manager wants to use might be a deciding factor in the design and layout of network, or it might be a minor factor that can be handled quickly [5].

Networks that cover multiple sites frequently use combinations of cable and wireless media to link computers and devices [3].

4.2 The Communication Media

The communication medium is the physical path between transmitter and receiver in a data transmission system [22]. Computers send electric signals to each other using electric currents, radio waves, microwaves, or light-spectrum energy from the electromagnetic spectrum. The physical path through which computers send and receive these signals is called communication / transmission media [3].

There are two types of media for data transmission [6]:

- Guided Media
- Ungnided Media

Guided media have a central conductor that consists of a wire or fiber surrounded by a plastic jacket. They are typically used for small LANs [3]. Guided media transmit signals by sending electricity or light over a cable. Guided media includes metal wire (copper, aluminum, and so on) and fiber-optic cable [6].

The following guided media commonly used for data transmission are [22].

- Unshielded Twisted Pair Cable
- Shielded Twisted Pair Cable
- Coaxial Cable
- Fiber-optic Cable

Unguided media typically employ the higher electromagnetic frequencies, such as radio waves, microwaves, and infrared. Unguided media transmits data without the benefit of a conduit-it might transmit data through open air, water, or even a vacuum. Unguided media are necessary for networks with mobile computers or networks that transmit signals over large distances; they especially prevalent in enterprise and global networks [3]

The unguided media commonly used for data transmission are [6] [22]:

- Narrow band radio, laser, and microwave
- Satellite Microwave
- Terrestrial microwave
- Spread spectrum radio
- Infrared

Wireless LANs, or at least segments of LANs, provide a way out of difficult wiring problems in many installations. Manager can have the wiring for LAN installed by big contractors, by local telephone company, by a local electrical contractor, or by organization's own employees. Major vendors and many smaller vendors developed their own premise distribution system (PDS) plans. These cabling architectures provide for an integrated telephone and data cabling plant using hardware components from a single supplier. The advantage of having one source of supply is

that there is only one place to point the finger of responsibility; the disadvantage is that organization becomes wedded to that vendor [5].

The cost of LAN wiring is divided between the costs of material and labor. Prices vary with the amount of cable is borough. These prices skyrocket for shorter hunks of cable [5]

- Typical fiber-optic cable should cost just under $2 per foot.
- Shielded twisted-pair wiring used for Token-Ring networks runs about 40 cents per foot.
- Thin coaxial cable used for Ethernet costs about 15 cents per foot.
- Four-pair twisted wire casts 10 cents per foot.

A lot of contractors know how to install twisted-pair wiring, and the cable television industry has taken the mystery out of installing coaxial cable. There are few good fiber-optic contractors or people who know how to wire Token-Ring networks, however. Labor costs for cable installations vary widely, driven by locale and the availability of knowledgeable contractors [5].

Companies often elect to have their own computer resource people plan and even install LAN cabling with the help of a licensed electrical contractor. Involving organization's own people in LAN wiring can save money, avoid mistakes, and facilitate expansion [5]

4.2.1 Twisted-Pair Cable

The least-expensive and most widely-used guided transmission medium is twisted pair. A twisted pair consists of two insulated copper wires arranged in a regular spiral pattern. A wire pair acts as a single communication link. Typically, a number of these pairs are bundled together into a cable by wrapping them in a tough protective sheath. Over longer distances, cables may contain hundreds of pairs. The twisting tends to decrease the crosstalk interference between adjacent pairs in a cable. The wires in a pair have thicknesses of from 0.016 to 0.036 inches [22].

Twisted pair is commonly used within a building for local area networks supporting personal computers. Twisted-pair wire is inexpensive, readily available, and adequate for many local network applications. It requires little technical skill to install and connect wire. Installation requires simple and inexpensive hand tools [8].

The two types of twisted-pair cable are:

- Unshielded twisted-pair (UTP)
- Shielded twisted-pair (STP)

4.2.1.1 Unshielded Twisted-Pair Cable

Unshielded twisted-Pair (UTP) cable consists of a number of twisted pairs with simple plastic casing. UTP uses RJ-45, RJ-11, RS-232, and RS-449 connectors, max length is 100 meters. speed is up to 100Mps. Cheap, easy to install, length becomes a problem.

The Electrical Industries Association (EIA) divides UTP into different categories by quality grade. The following categories are defined [3]:

- **Category 1** UTP cable can transmit voice signals but not data. Most telephone cable installed prior to 1983 is Category 1.
- **Category 2** UTP cable made up of four twisted-pair wires. certified for transmitting data up to 4 Mbps (megabits per second).
- **Category 3** UTP cable made up of four twisted-pair wires. each twisted three times per foot. Category 3 is certified to transmit data up to 10 Mbps.
- **Category 4** UTP cable made up of four twisted-pair wires, certified to transmit data up to 16 Mbps.
- **Category 5** UTP cable made up of four twisted-pair wires, certified to transmit data up to 100 Mbps.

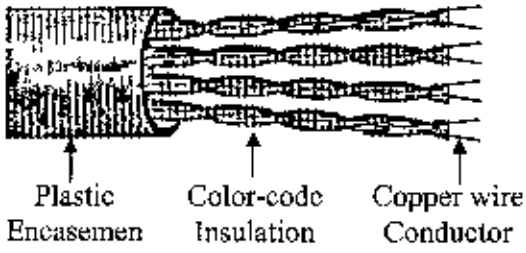


Figure 4.1: Unshielded Four-Pair Cable [3]

Expect for professionally installed Category 5, the cost of UTP is very low when compared with other transmission media. UTP cable is easy to install. Maintenance and network reconfiguration is also relatively simple. UTP tend to attenuate rapidly and is very susceptible to EMI [3].

4.2.1.2 Shielded Twisted-Pair Cable

The only difference between shielded twisted-pair (STP) and UTP is that STP cable has a shield – usually aluminum/polyester – between the outer jacket or casing and the wires. Shielded Twisted Pair uses RJ-45, RJ-11, RS-232, and RS-449 connectors, max length is 100 meters, and speed is up to 500Mps Not as inexpensive as UTP, easy to install, length becomes a problem [3].

The shield makes STP less vulnerable to EMI because the shield is electrically grounded. It is more reliable cable for LAN environments. Although many LANs now use UTP, STP is still used. Transmission media specifications from IBM and Apple Computer use STP cable A completely different type of STP is the standard for Apple's AppleTalk networks.

STP is fairly expensive. STP costs more than UTP and thin coaxial cable but less than thick coaxial or fiber-optic cabling The requirement for special connectors can make STP more difficult to install than UTP. STP does not outperform UTP by much in terms of attenuation The biggest difference between STP and UTP is the reduction of EMI. However, since it is copper wire, STP still suffers from EMI [3].

4.2.2 Coaxial Cable

Coaxial cable consists of two conductors, but is constructed differently to permit it to operate over a wider range of frequencies. It consists of a hollow outer cylindrical conductor that surrounds a single inner wire conductor. The inner conductor is held in place by either regularly spaced insulating rings or a solid dielectric material. The outer conductor is covered with a jacket or shield [22].

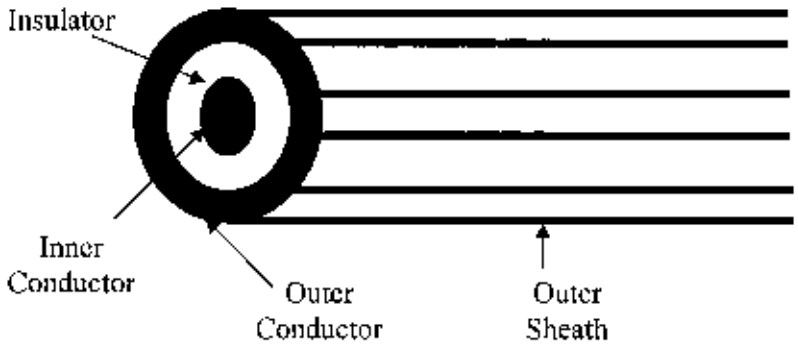


Figure 4.2: Coaxial Cable [22]

A single coaxial cable has a diameter of from 0.4 to about 1 inch. Coaxial cable is much less susceptible to interference and crosstalk than is twisted pair. Coaxial cable can be used over longer distances and supports more stations on a shared line than twisted pair [22].

The following are some coaxial cables commonly used in networking [3]:

- 50-ohm, RG-8, and RG-11, used for Thick Ethernet
- 50-ohm , RG-58, used for Thin Ethernet
- 75-ohm, RG-59, used for cable TV
- 93-ohm, RG-62, used for ARCnet

Coaxial cable is relatively inexpensive. The cost for thin coaxial cable is less than STP or Category 5 UTP. Thick coaxial is more expensive than STP or Category 5 UTP but less than fiber-optic cable. Installation is relatively simple. Because it uses copper wire, coaxial cable suffers from attenuation, but much less so than twisted-pair cables. Coaxial cable runs are limited to a couple of thousand meters. Coaxial

cabling is vulnerable to EMI. However, the shielding provides a much better resistance to EMI's effects [3].

4.2.3 Fiber Optic Cable

Fiber optic cables are fibers of glass, usually about 120 micrometers in diameter, which are used to carry signals in the form of pulses of light over distances up to 50 km without the need for repeaters. These signals may be coded voice communications or computer data [22].

A fiber optic cable has a cylindrical shape and consists of three concentric sections:

- The core
- The cladding
- The jacket

The core is the inner-most section and consists to one more very thin strands, or fibers, made of glass or plastic. Each fiber is surrounded by its own cladding, a glass or plastic coating that has optical properties different from those of the core. The outermost layer, surrounding one or a bundle of cladded fibers, is the jacket. The jacket is composed of plastic and other material layered to protect against moisture, abrasion, crushing, and other environmental dangers [22].

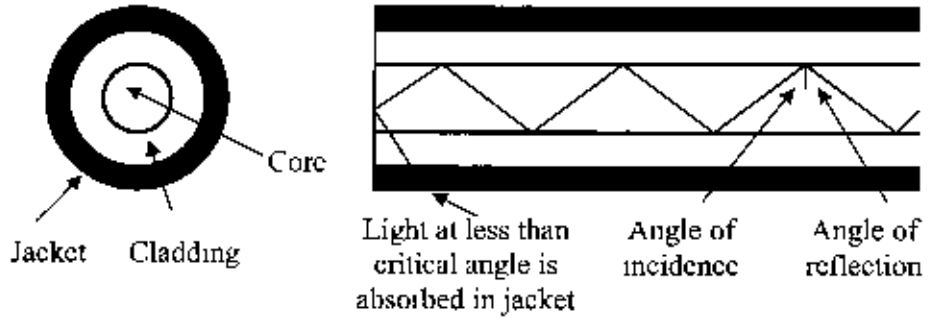


Figure 4.3. Fiber Optic Cable [22]

Two different types of light source are used in fiber optic systems:

- The light-emitting diode (LED)
- The injection lased diode (ILD)

Fiber optic cables are differentiated by core/cladding size and mode. The size and purity of the core determine the amount of light that can be transmitted. The following are the common types of fiber-optic cable [3]:

- 8.3-micron core/125-micron cladding, single-mode
- 62.5-micron core/125-micron cladding, multimode
- 50-micron core/125-micron cladding, multimode
- 100-micron core/140-micron cladding, multimode

Optical fibers carry signals with much less energy loss than copper cable and with a much higher bandwidth. This means that fibers can carry more channels of information over longer distances and with fewer repeaters required. Optical fiber cables are much lighter and thinner than copper cables with the same bandwidth. This means that much less space is required in underground cabling ducts. Also they are easier for installation engineers to handle. Optical fibers are much more difficult to tap information from undetected; a great advantage for banks and security installations. They are immune to Electromagnetic interference from radio signals, car ignition systems, lightning etc. They can be routed safely through explosive or flammable atmospheres, for example, in the petrochemical industries or munitions sites, without any risk of ignition [3] [22]

Optical fiber is slightly more expensive than copper cable, but costs are falling. Associated equipment costs can be much higher than for copper cable, making optical fiber networks much more expensive. Fiber optic cable is more difficult to install than copper cable. Optical fibers cannot be joined (spliced) together as a easily as copper cable and requires additional training of personnel and expensive precision splicing and measurement equipment. Optical fiber cable has much lower attenuation than copper wires. Optical fiber suffers very little from attenuation but has instead a different problem: chromatic dispersion. Fiber optic cable is not subject to electrical interference [8]

4.2.4 Wireless Data Networks

This name is misleading. Wireless data networks typically aren't totally wireless, but instead use either radio or infrared technology to connect a node or group of nodes into the main body of the network. It's difficult to categorize wireless data network systems because they have many different architectures. Wireless may be the hottest word in networking, nobody owns the term, and it means different things to different people Wireless networks are always extensions of cabled networks, not replacements of them. The rules of physics apply to wireless connections just as they do to cable, but they are more confining in the wireless environment. Radio waves traveling through space face a much more hostile environment than do electrons traveling through copper. Organization's network can have long-distance connections, fast connections, or inexpensive connections over wireless, but not all three. Distance and signaling speed always work against one another, and raising either of those parameters while keeping the other steady always raises the cost. This relationship makes it difficult to field a wireless system that is less expensive or faster than one based on copper cables. So, far wireless systems to succeed, they must be deployed in niche situations where guided media cable is at some disadvantage. The two most fruitful applications for wireless are in areas where it is difficult to install guided media cables and where people need or are willing to pay for mobility [5].

4.3 The Linking Media

It is difficult and expensive to send data quickly over long distances. Selecting a method of linking LANs is all about costs. In all the decisions manager makes regarding linked LANs, manager has to balance throughput against distance and cost. Because the cost of the internetwork segment is typically the driving factor in the equation, it's smart to pay more for network hardware that makes the best use of the long-distance media [5].

Many organizations need to move a lot of data over distances greater than a few thousand feet, so managers need to learn the techniques of extending and linking LANs. The techniques use to link LANs segments depend upon the distance and speed is needed, the network communications protocols are used and the organization's business philosophy regarding leasing versus owning facilities Just as some manufacturing companies own their own trucks and boxcars, and others contract for all transportation services, some organizations own their MAN and WAN facilities, and others lease these specialized services from commercial supplhers. Many organizations set up their own microwave, light beam, or fiber optic transmission systems to carry data around a metropolitan area or campus. Organizations can use the transportation tunnels under many cities to install their own fiber optic cable systems between their offices or stores and major customers and suppliers. Metropolitan telephone and cable television companies also supply LAN-to-LAN connections under several types of business arrangements. But when the connections extend beyond the metropolitan area, organizations typically lease circuits from commercial suppliers. The suppliers include long-haul carriers, local telephone companies & competitive local telephone carriers, specialized companies and satellite system providers [5] [6].

The internetwork media available to link LAN segments includes telephone lines, satellite networks, microwave radio, fiber-optic networks, and perhaps cable television coaxial systems [5].

4.3.1 Telephone Llue Systems

Stated a little simplistically, there are two types of telephone lines: those going to the public dial network (dial up lines) and those leased for long-term dedicated use Dial-up lines provide a temporary dedicated connection by dialing a long-distance telephone number and the computers in the telephone switches route call. Lease lines provide a full-time dedicated connection that does not pass through the system of switches [5].

4.3.1.1 Dial-up Line

A dial-up line is a connection or circuit between two sites through a switched telephone network. In the data communication world, a dial-up line forms a link between two distant computers or local area networks [19].

Features that are important in data communication are listed below [19]:

- Dial-up lines provide any-to-any connections. The originating site can call any other site, unlike dedicated lines that connect two sites
- Modems are required on both ends of a dial-up line
- A call setup and disconnected sequence is required for dial-up lines
- Dial-up lines are inexpensive and charges are incurred only during connection time and are based on distance. They are useful for occasional file transfers, email transmissions, and backup links
- In many countries, calling long distance is still expensive, and, in some cases, the circuits can't pass high-speed data effectively [5].
- The transmission rate is typically 28,800 bits/sec with the V.34 standard and the use of compression, but higher rates (up to 56 Kbits/Sec) are available for download speeds

4.3.1.2 Leased Line

Selling leased telephone line has been an important business for the long distance telephone industry [5]. A leased line is a communication circuit that is set up on a permanent basis for an organization by a public service provider such as a LEC (local exchange carrier), a long-distance IXC (inter-exchange carrier), or both. Some alternate carriers, such as MCI, provide LEC bypass facilities in various metropolitan areas. Because an organization pays a fixed rate for the lines under contract, the lines are often called leased lines [19].

A leased line in most cases simulates a physical circuit. In reality, the carrier guarantees an agreed-upon bandwidth through its switching system and trunk lines

For all practical purposes, leased line refers as a private dedicated circuit. However, a leased line may also be established on the physical wire that runs from a customer site to the local switching office. To obtain high data rates on these lines, it is conditioned to ensure quality [19].

An organization uses leased lines to build private networks that interconnect its remote sites or the sites of business partners. The lines are called private because no one else competes for bandwidth on the line as with packet-switching networks such as frame relay. They are also more secure than using open networks like the internet for wide area connections [19].

Leased lines can be either analog circuits or digital circuits [19]:

- **Analog Lines** require modems at each end and typically provide the same data rates as dial-up lines except that customers contract with the carrier to keep the line available for permanent use. The carrier may provide a discount rate or a higher quality of service over dial-up lines
- **Digital Circuits** are conditional lines that can provide higher data transmission rates than analog lines

The cost of leased lines depends on the capacity of the line, the distance, and the provider. The most often used high-speed digital line service is the T1 channel, which provides transmission rates of 1.544 Mbits/sec [19].

Integrated Services Digital Network also provides the equivalent of leased-line services starting in increments of 64 Kbits/sec Various protocols are available for providing bandwidth on demand during various times of the day or when traffic levels increase [19].

4.3.2 Cellular Wireless

Cellular data communications use the cellular telephone network to carry data between a mobile PC or terminal and a host computer [6].

The cellular telephone network uses 800 MHz radio signals to communicate between the cellular service provider and a customer's cellular phone. The cellular phone company operates a network of radio receivers and transmitters called sites. Cell sites are typically located a few miles apart, usually on towers about 150 feet tall. Many cellular systems offer a choice between digital and analog service Digital cellular is typically more reliable and has better audio quality than the older analog service, and is better suited for cellular modem communications. While digital cell phones are typically more expensive than their analog counterparts, the monthly service is often less expensive than analog.

Each cell site can support dozens of users at one time, and the cell sites are carefully placed so that each cell site's coverage overlaps its neighboring sites' coverage area. The area of coverage provided by each site is called a cell.

The overlap of the cells ensures that any phone traveling through the area will be able to communicate with at least one site. Moving from cell to cell, the cellular system automatically switches call- a process called handing off.

Cellular data communications require a cellular telephone and a special cellular modem. Most cellular modems are PC Cards designed to fit into laptop computers. The modem attaches to the cell phone via a cable. Cell modems are similar to regular modems; expect that they are more tolerant of noisy and interrupted connections – a common problem with cellular telephones.

Cellular phone connections do not have much bandwidth as ordinary phone lines, so cellular modems runs at slower speeds – typically 4,800bps. A new breed of digital cellular phones promises to increase transmission speeds and provide more reliable communications, but requires users to buy a new phone and modem [6].

4.3.3 Radio Wave Transmission System

The range of the electromagnetic spectrum between 10 KHz and 1GHz is called radio frequency (RF). Radio waves have frequencies between 10 KHz and 1 GHz.

Radio waves include the following types:

- Short-wave
- Very-high-frequency (VHF) television and FM Radio
- Ultra-high-frequency (UHF) radio and television

Most radio frequencies are regulated. To use a regulated frequency, organization must be received a license from the regulatory body over the area. Getting a license can take a long time, costs more, and makes it more difficult to move equipment. The advantage of unregulated frequencies is that there are few restrictions placed on them. Unregulated frequency equipment must operate at less than 1 watt This makes unregulated radio communication bandwidths of limited use [3].

The power of the radio frequency signal is determined by the antenna and transceiver. Each range has characteristics that affect its use in computer networks For computer network applications, radio waves fall into three categories [3]:

- Low-power, single-frequency
- High-power, single-frequency
- Spread-spectrum

Low-power, single-frequency products can use any radio frequency. Most systems are moderated priced compared with other wireless systems. Most systems are easy to install. Data rates range from 1 to 10 Mbps. Low-power, single-frequency transmissions suffer from attenuation because of their low power. Resistance to EMI is low [3]

High-power, single-frequency can use any radio frequency, but networks favor higher gigahertz ranges for better data rates. Radio transceivers are relatively inexpensive, but other equipment can make high-power, single-frequency radio moderately to very expensive. Installations are complex. Skilled technicians must install and maintain high-power equipment. Bandwidth is typically between 1-to10 Mbps. Attenuation rates are fairly low. Much like low-power, single-frequency transmission, vulnerability to EMI is high [3].

Spread-Spectrum generally operates in the unlicensed frequency ranges. Costs are typically fairly inexpensive when compared with other wireless media. Installation problems can range from simple to fairly complex. The most common systems, the 900 MHz systems, support data rates of 2 –to 6 Mbps, but newer systems operating in gigahertz produce higher data rates. They usually have high attenuation. Immunity to EMI is low [3].

4.3.4 Terrestrial Microwave

Frequencies in the range of about 2 GHz to 40 GHz are referred to as microwave frequencies At these frequencies, highly directional beams are possible, and microwave is quite suitable for point-to-point transmission. The most common type of microwave antenna is the parabolic "dish". The antenna is fixed rigidly and focuses a narrow beam to achieve line-of-sight transmission to the receiving antenna. Microwave antennas are usually located at substantial heights above ground level in order to extend the range between antennas and to be able to transmit over intervening obstacles. To achieve long-distance transmission, a series of microwave relay tower is used; point-to-point microwave links are strung together over the desired distance [22].

As with any transmission system, a main source of loss is attenuation. For microwave, the loss varies as the square of the distance. In contrast, for twisted pair and coaxial cable, loss varies logarithmically with distance. Repeaters or amplifiers may be placed farther apart for microwave systems – 10 to 100 km is typical. Attenuation increases with rainfall, the effects of which become especially noticeable above 10 GHz. Another source of impairment is interference. With the growing population of microwave, transmission areas overlap and interference is always a danger [22].

Short-distance systems can be relatively inexpensive, and they are effectively in the range of hundreds of meters. Long-distance systems can be very expensive. Line-of-sight requirements for microwave systems can make installation difficult. Over short

distances, attenuation is not significant. But rain and fog can negatively affect higher-frequency microwave. These signals are vulnerable to EMI, jamming, and eavesdropping. Microwave systems are also affected by atmospheric conditions [3].

The modern urban environment presents a particular challenge, in that bandwidth allocation, RF interference, link obstruction and atmospheric pollution place maximum constraints on the system simultaneously. However, urban environments also have the highest land acquisition values too Many modern cities have found it cost effective to build a single, very high tower to house an entire city's trunk communication microwave dishes. These towers are now a common feature of the modern urban landscape.

4.3.5 Satellite Communications

A communication satellite is, in effect, a microwave relay station. It is used to link two or more ground-based microwave transmitter/receivers, known as earth stations, or ground stations. The satellite receives transmissions on one frequency band (uplink), amplifies or repeats the signal, and transmits it on another frequency (downlink). A single orbiting satellite will operate on a number of frequency bands, called transponder channels, or simple transponders [22].

There are two common configurations for satellite communication. In the first, the satellite is being used to provide a point-to-point link between two distant ground-based antennas. In the second, the satellite provides communications between one ground-based transmitter and a number of ground-based receivers [22].

To remain stationary, the satellite must have a period of rotation equal to the earth's period of rotation. This match occurs at a height of 35,784 km. The optimum frequency range for satellite transmission is 1 to 10 GHz. Below 1GHz, there is significant noise from natural sources, including galactic, solar, and atmospheric noise, and human-made interference from various electronic devices. Above 10 GHz, the signal is severely attenuated by atmospheric absorption and precipitation. Most

satellite providing point-to-point service today use a frequency band-width in the range 5.925 to 6.425 GHz for transmission from earth to satellite (uplink) and a bandwidth in the range 3.7 to 4.2 GHz transmission from satellite to earth. This combination is referred to as the 4/6 GHz band [22].

Because of the long distances involved, there is a propagation delay of about a quarter second between transmission from one earth station and reception by another earth station. It also introduces problem in the areas of error control and flow control. Satellite microwave is inherently a broadcast facility [22]

Satellite communication has a number of advantages:

- The laying and maintenance of intercontinental cable is difficult and expensive.
- The heavy usage of intercontinental traffic makes the satellite commercially attractive.
- Satellites can cover large areas of the Earth. This is particularly useful for sparsely populated areas.

Satellite communication is limited by four factors:

- Technological limitations preventing the deployment of large, high gain antennas on the satellite platform.
- Over-crowding of available bandwidths due to low antenna gains.
- The high investment cost and insurance cost associated with significant probability of failure.

The cost of building and launching a satellite is extremely expensive – as high as several hundred million dollars or more. Satellite microwave installation for satellites is extremely technical and difficult. The earth-based systems may require difficult, exact adjustments. Attenuation depends on the frequency, power, antenna size, and atmospheric conditions. Microwave systems are vulnerable to EMI [3].

The satellite provider can divide the total capacity into a number of channels and lease these channels to individual business users. A user equipped with the antennas

at a number of sites can use a satellite channel for a private network. Traditionally, such applications have been quite expensive and limited to larger organizations with high-volume requirements. A recent development is the very small aperture terminal (VSAT) system, which provides a low-cost alternative. A number of subscriber stations are equipped with low-cost VSAT antennas. Using some protocol, these stations share a satellite transmission capacity for transmission to a hub station. The hub station can exchange message with each of the subscribers as well as relay messages between subscribers.

VSAT technology is a telecommunication system based on wireless satellite technology. The term 'VSAT' stands for 'Very Small Aperture Terminal'. As the definition itself indicates, VSAT technology is made up of a small satellite earth station and a typical antenna of 1.8 meter diameter.

There are three components in a VSAT network.

- Master Earth Station
- VSAT Remote Earth Station
- Satellite

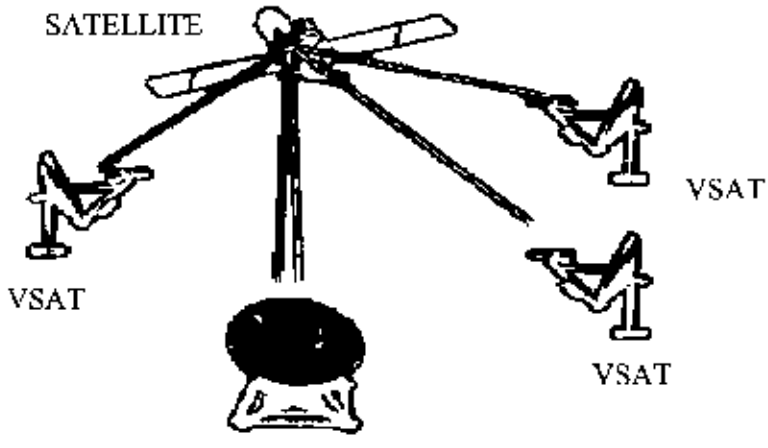


Figure 4.4: Satellite Communications [3] [22]

VSAT service may come with a flat monthly service rate for each installed site, irrespective of where the VSAT unit is installed. The terms and conditions of the VSAT service are specified in a standard service contract agreement A typical agreement has a contract period of at least two years and may be extended for a longer period.

Satellite circuits aren't perfect inter-LAN solution for every organization, but they offer unique features and geographic flexibility that no other service can match [5].

4.3.6 Internet VPN

An Internet VPN can provide a secure way to move packets across the Internet with the right equipment [6]. There are two methods for doing this:

- **Transport Mode** Describes the techniques of encrypting only the payload portion of an IP packet for transport across the Internet. The header information is left intact and readable so that routers can forward the packet as it traverses the Internet. This is an IP-only technique.
- **Tunnel Mode** With this technique, IP, IPX, SNA, and other packets are encrypted, then encapsulated into new IP packets for transport across the Internet. This technique has the advantage of hiding the source and destination address of the original packet and improves security.

In either case, Internet VPNs trade off the guaranteed capacity and predictability available on frame relay or ATM virtual circuits for the low cost of creating VPNs over Internet. They are much cheaper than leased lines.

While inexpensive, extending a private network across the public Internet has security and privacy implications. However, vendors of Internet VPN products have gone to great lengths to ensure security and privacy. Encryption provides security, but authentication is also required to ensure that people or devices at the other end of the link are authentic and authorized to use the link

There are two types of connections in the Internet VPN scenario.

- **Site-to-site connections** A connection that tunnels large amounts of traffic between two network sites
- **Virtual dial-up services** A tunnel for an individual user into a corporate site

Both schemes take advantage of local connections to ISP and the wide area connections provided by the Internet.

4.3.6.1 Site-to-Site Connection

A site-to-site connection is the most common way to set up an Internet VPN between two network sites. Two encrypting routers are required and an SA (security association) is set up between them. An SA is a symmetrical connection in which the same security techniques (encryption, decryption and authentication) are used by the transmitter and receiver. In the simplest setup, an administrator creates two separate private keys to handle encryption and decryption in each direction. One key is used to encrypt data as it leaves one router and decrypt it as it arrives at the destination. The other key is used to encrypt and decrypt data in the reverse direction. The administrator typically programs the keys into the devices and personally delivers them to the intended sites to avoid compromise [6].

Once the routers are set up and the link is established into the Internet, all data traffic across the link is encrypted to hide it from anyone that might manage to tap the line.

Several initiatives and standards are under development for this type of connection. The IETF is working on IPSec (IP Security), which strives to provide interoperability among different vendors' tunneling products. RSA Data Security helped establish the S/WAN initiative in 1995 to provide an industry forum for interoperability and standardized implementation of IPSec. These protocols are designed to operate in the Network Layer of the protocol stack and encrypt all data that crossed the link [6]

4.3.6.2 Virtual Dial-up Services

Virtual dial-up protocols are designed to support remote user access into the corporate network with might be called personal tunnels. Virtual dial-up protocols help organizations better manage their remote access capabilities and reduce connect charges by taking advantage of the Internet. Instead of dialing in to a corporate remote access server, users dial in to a local ISP or carrier access point. A tunnel is then created between the remote client and the corporate site through the ISP and across the Internet [6].

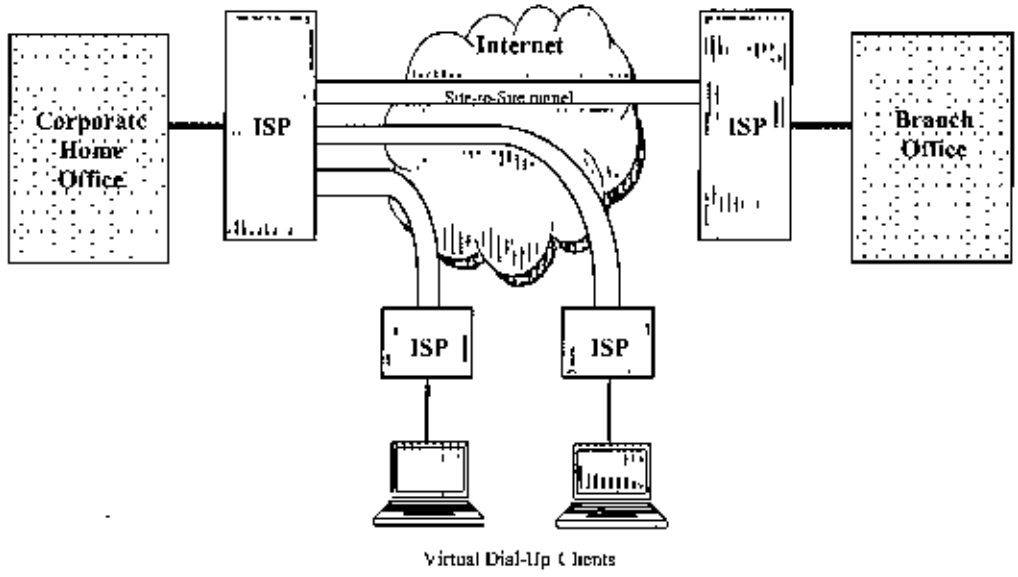


Figure 4.5: Internet VPN [6]

4.3.7 Alternative Connection Schemes

4.3.7.1 DSL

DSL is an all-digital service, and it promises to deliver data at speeds ranging from about 300Kbps to 8Mbps. ADSL (asymmetric digital subscriber line), HDSL (high-bit-rate digital subscriber line), RADSL (rate-adaptive digital subscriber line) etc. are

the variations of DSL. These signaling techniques vary, but the idea is that the link is faster in one direction than in the other. The reverse channel speeds range from 64Kbps to 1Mbps

DSL has promise as a campus-wide system. DSL is deployed as a last mile connection, a term that describes the final line connection between a telco central office (CO) and the subscriber.

DSL is a copper loop transmission technology that achieves broadband speeds over common twisted-pair telephone wire by making full use of the available frequency spectrum, resulting in multiple-megabit service capabilities.

DSL's primary benefit lies in providing a far bigger "pipe" than older analog connections. This is a key advantage in the ongoing battle to avoid Web congestion and provide a quality experience for users. And because DSL runs over standard phone lines, generically called "copper", much of the existing telephony infrastructure can carry digital signals as long as switching equipment at central offices is upgraded to support DSL.

Currently, DSL technology is divided into two main camps:

- Symmetrical DSL (SDSL)
- Asymmetrical DSL (ADSL)

Symmetrical DSL features a bidirectional ranging from 160Kbps to 1.5Mbps, whereas Asymmetrical DSL scales between 384Kbps and 8.1Mbps download speeds and between 128Kbps and 800Kbps upload speeds [5].

4.3.7.2 Cable Modems

Cable television companies and cable modem equipment vendors talk about cable modems and their claimed 27Mbps throughput. Cable modem service is provided by a partnership between national cable Internet access providers and local cable

television providers. The ISP corporations supply technical know-how, a fast Internet backbone connection, and marketing and billing assistance to hundreds of local cable television operators nationwide. They also provide specialized content and their own Web portals to end users. In almost all case, cable modem connection service is also ISP, although this is a point of contention before regulatory and legislative groups.

All the homes in a given neighborhood share a single cable much the way PCs share an Ethernet LAN connection. Several neighborhood cables connect to a cable access unit (CAU), which combines signals from the neighborhood cables into a single signal. In turn, the CAU connects via a high-speed fiber-optic lint to the cable company's main switching center housing the routers and providing the onramp to the Internet.

There are two types of cable modems.

- Two-way hybrid fiber-coaxial modem
- One-way coaxial modem

Two-way hybrid fiber-coaxial (HFC) modems can theoretically achieve download speeds in the 3Mbps to 10Mbps range with upload speeds of around 128Kbps to 10Mbps. One-way coaxial modems average a 2Mbps download speed and require a dial-up modem for the upload of data. A few providers still use the one-way coaxial technology, but most have switched over to HFC

Most cable modems connect to PC via an Ethernet connection, so the cable company's installer must open PC and install an Ethernet card. The installation fee sometimes includes the modem and the Ethernet card, but organization might have to buy or rent a cable modem from the cable company. Cable modem hardware vendors include Cisco, General Instruments, Motorola, Samsung, and 3com.

For now, the local cable company usually sends an installer to organization to set up cable modem service. It can be received cable modem and cable TV service on the same cable, so established cable TV subscribers usually don't need any additional inside wiring to connect a cable modem. Each time when someone turns on PC, the

cable modem automatically establishes a connection to the Internet. This is a high-speed, dedicated connection.

Although cable modem can provide stunning connect speeds. the service has a few caveats· slowdowns, bandwidth congestion, and lack of support for LANs.

Although provider possesses an incredibly fast connection to the Internet, there can be times when the ISP-to-Internet link can reach near capacity, slowing connection to a crawl.

Some users of cable modem service report throughput slower speeds during the peak evening hours. Overall, customers find that getting good technical support can be a real problem for cable modem customers [5].

4.3.7.3 Other Carriers

If organization needs to connect LANs in a metropolitan area, manager might look for communications circuits from unlikely carriers. Many cable television companies have installed two-way coaxial cables and can carry data at high speed. Railroads often have excess microwave radio or fiber-optic channels installed along their routes. Power utility companies can offer circuits on their fiber. These organizations and others might be able to sell a service that can link LANs.

Specialized companies in many metropolitan areas offer circuits for MAN connectivity.

Finally, organization can be its own carrier within a metropolitan area, particularly if organization has at least one office with a top-down view of the skyline. Several companies sell microwave radios operating at 2.3GHz and 23GHz that can be literally set on a desktop and point out window toward the distant LAN. These products can only span line-of-sight distances, for a maximum of 3 to 5 miles, but they can provide throughput of 1.544Mbps, and there are no monthly leased-line charges [5].

Chapter 5

Synopsis of FMU Project, Phase-II, BPDB

5.1 Brief Description of Bangladesh Power Development Board

In the year 1947 when the British colonial rulers left, power generation and distribution of this part of the country were in the hands of some private companies The power supply to then 17 provincial districts was within the township in a limited way. The generation voltage was 400 volts. Power used to be supplied to most of the districts during nighttime only. Only exception was Dhaka City where power used to be supplied by two 1500 kW generators and the generation voltage was 6600 volts and this was the highest supply voltage. There were no long distance transmission lines. Besides power used to be generated by some industries (tea, sugar and textiles) and railway workshops. Dhakeswari Cotton Mills, Pahartali Railway workshop, Saidpur Railway workshop and Sugar Mills were amongst them. In aggregate the generation capacity of the country was 21 MW. The generation capacity of the power utility companies together was only 7 (seven) MW and there was no transmission system [28].

In 1948, Electricity Directorate was created in order to plan and improve power supply situation. In 1959, Water and Power Development Authority (WAPDA) was created and the power sector really started working satisfactorily. In 1960, Electricity Directorate was merged with WAPDA. The basic philosophy was to give more autonomy to an organization for development of this basic infrastructure. At that time relatively higher capacity plants were built at Siddhirganj, Chittagong and Khulna (highest plant size was only 10 MW Steam Turbine at Siddirganj). At the same time Kaptai dam was under construction under Irrigation department. Unit size of Kaptai was 40 MW, which for that time was considered to be a large power plant. Side by side construction of Dhaka-Chittagong 132 KV transmission line was in progress. Construction of Kaptai dam and commissioning of Dhaka-Chittagong 132KV transmission line in the year 1962 may be taken as milestone of power development of this country [28].

In 1972, after the emergence of Bangladesh through a bloody War of Liberation as an independent state, ***Bangladesh Power Development Board (BPDB)*** was created as a public sector organization to boost the power sector. BPDB is under the Ministry of Energy and Mineral Resources.

During mid 1970's government emphasized on the rural electrification for achieving a desirable social upliftment in the country. A different approach and a new model were considered for undertaking a comprehensive scheme. Thus the Government created ***Rural Electrification Board (REB)*** in October 1977. Later in 1991 ***Dhaka Electric Supply Authority (DESA)*** was created basically to operate and develop distribution system in and around Dhaka (including the metropolitan city) and bring about improvement of customer service, collection of revenue and lessen the administrative burden of BPDB [28].

Public investments and state ownership have been the traditional means to exercise control over the electricity sector. Government regulated the natural monopoly of power supply primarily to protect the consumer's interest. The situation is fast changing. Structural changes are taking place and new corporate characters are emerging. The gradual expansion of the infrastructure has also been justified by the need for realizing social goods relating to rural electrification and low cost electricity supply to the public.

The country's total generation was about 14,450 million kilo-watt hour (MKWh) in FY 1998-99. The efforts of BPDB, DESA and REB have made it possible to supply electricity to only about 16 per cent of the country's population. The rest 84 per cent are yet to be connected with the electricity infrastructure.

The involvement of ***Independent Power Producer (IPP)*** was made effective after October 1996. The negotiation with IPPs to finalize different packages requires considerable time. In spite of this, BPDB could finalize and signed contract with IPPs for installation of three Barge mounted power plants to meet the severe power crisis. In about two years, Khulna Power Company Ltd. (KPCL), the first IPP, started its commercial operation from October 1998 and started contributing 110 MW of

power to the national grid. From June 1999 two other IPPs' are supplying 192.3 MW of power.

At present, BPDB has total installed capacity of 3603 MW at 57 units of power plants located at different parts of the country. The main fuel used for power generation is indigenous gas. The maximum demand served during peak hours is 2601 MW in August 7, 1999. The transmission network of BPDB is 3075 km long comprising 230 and 132 KV lines. The total numbers of grid sub-stations are 68 and the total capacity is 7095 MVA operated in 157 numbers of transformers

With the target to provide the public with reliable service of power supply, the basic infrastructure for the country's economic and social development, BPDB power system has been expanded to keep pace with the fast growing demand [28].

5.2 Mission

To help serve electricity through- out the country, to increase access of electricity to more people, and to improve the quality of service [27].

5.3 Key Statistics of BPDB

o Installed Capacity	4230MW
o Present Generation Capability	4055MW
o Peak Demand Served So Far	3084MW
o Transmission Lines (230 & 132 KV)	3206 KM
o Grid Sub-Station Capacity (230 & 132 KV)	7095MVA
o Distribution Lines (33 KV & Below)	40410 KM
o Consumer Number (June 2001)	15,42,650

5.4 Function of BPDB

- Generation
- Transmission
- Distribution

5.5 FMU Project, Phase-II, BPDB

All sorts of Accounting Systems of BPDB are operated manually since its very inceptions. Due to this process of operating accounts, they are slow, cumbersome and difficult to maintain. Sometimes as far as the bank reconciliation is concerned accuracy also comes to question. Besides this, asset values are unreliable. Management Information System (MIS) is delayed and unreliable. To improve and strengthen the Accounting System, Financial Management System and Management Information System, Financial Management Upgrade (FMU) Project had been undertaken with the technical assistance of the Asian Development Bank.

5.6 Main Objectives of FMU Project

- Development of Computerized Billing System and conversion of 200,000 customers to computerized billing & customer accounting in Chittagong & Comilla
- Development of Computerized Accounting System and testing with LIVE data for Dhaka, Chittagong & Comilla
- Procurement of hardware, operating system software , networking application software for Integrated Billing & Customer Accounting & 14 Non-Billing Financial Accounting Modules including Payroll
- Installation of hardware operating & application software system in three financial processing centers located at Dhaka, Chittagong & Comilla

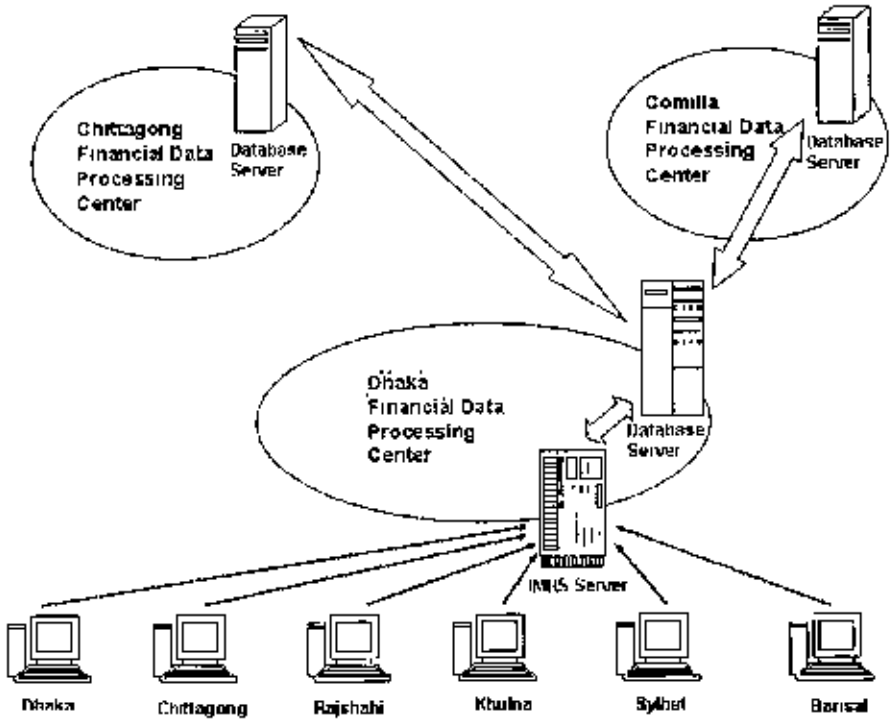


Figure 5.1: Financial Processing Centers under FMU Project, Phase - II

5.7 System to be implemented in FMU Project, Phase II

To fulfill the objective of the Financial Management Upgrade Project (FMUP) to computerization of Customer Billing & Accounting Systems, Billing & the following non-billing modules application software were developed.

1. General Ledger
2. Accounts Payable
3. Accounts Receivable
4. Fixed Assets
5. Purchase Management System
6. Store Accounting System
7. Project Accounting & Job Costing System
8. Rechargeable Deposit Works
9. Loan Capital Accounting System
10. Energy Accounting System

11. Annual Development Program
12. Revenue Budget
13. Cash & Bank Management System
14. Management Information System (MIS)

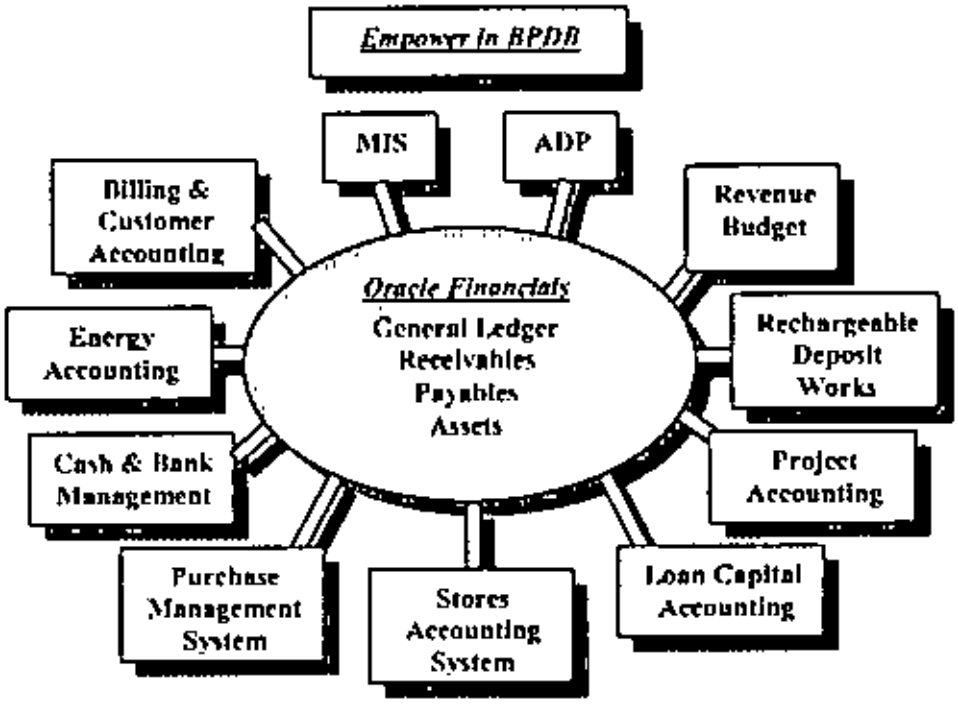


Figure 5.2: Billing and Non-Billing Modules Application Software

5.8 Shortfall of the objectives of FMU Project (Accounting System)

- Objective only for development and testing of the software not for implementation
- Location for Dhaka, Chittagong and Comilla only

5.9 IMRS (Integrated Management Reporting System)

- Consultant recommendation for a feeder system software (IMRS) for transitional period
- IMRS will collect all data electronically and upload into the server

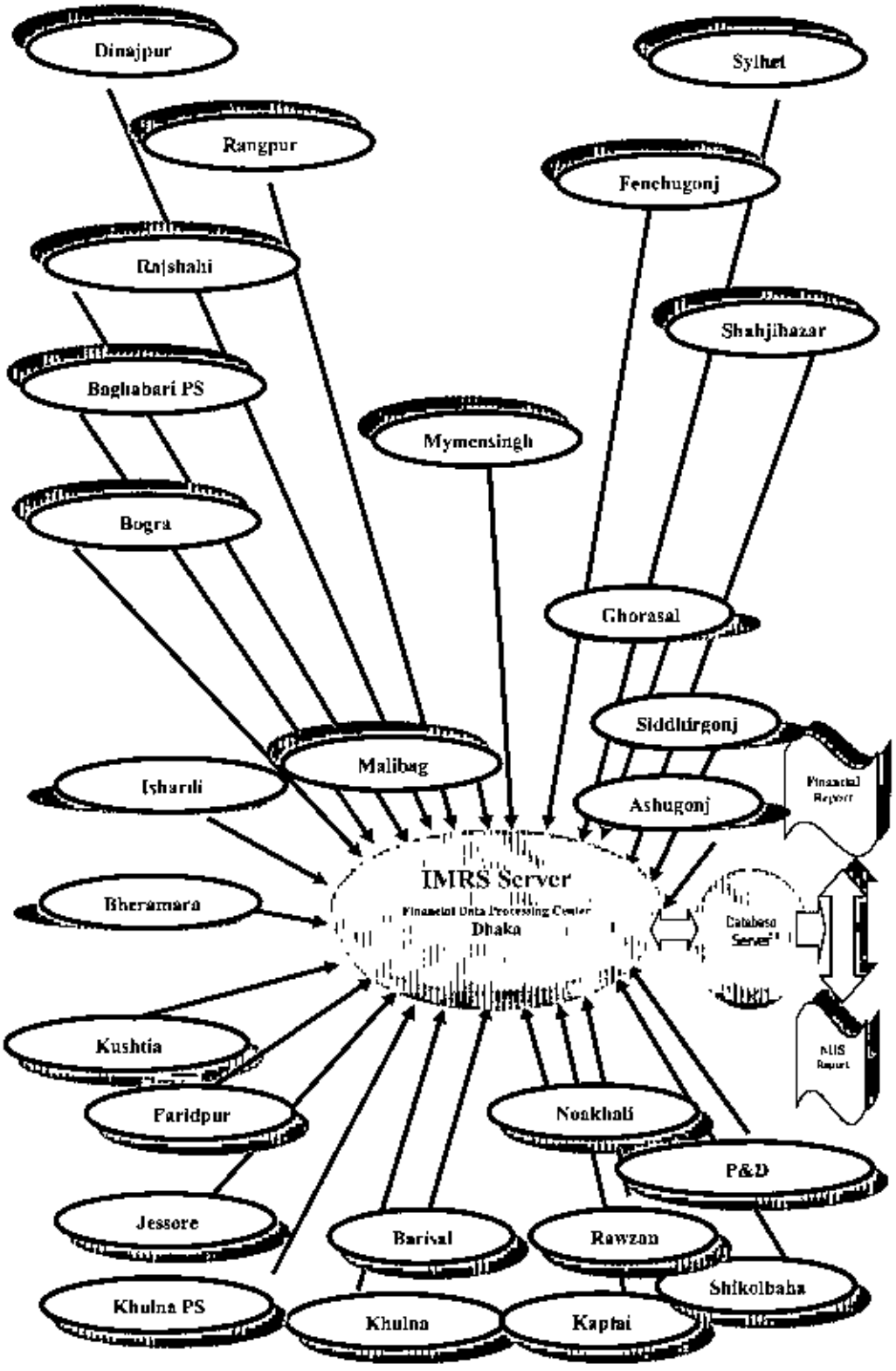


Figure 5.3: IMRS Data Flow Diagram of BPDB

5.10 IMRS in the Regional Accounting Offices

5.10.1 The present RAO system

- Hand written Ledgers for all Unit Offices
- Hand written Trial Balances for all ESUs, summary level with supporting sub-codes
- Hand written consolidated ledgers for the RAO by unit type
- Hand written Bank Reconciliations, in many RAOs updated only once a year
- Manual posting of billing receivables and revenue from hand written MODs from ESUs

5.10.2 Problems with the present RAO system

- Errors in consolidated of RAO trial balances
- Un-reconciled clearing accounts
- No brought forward balance sheet figures
- No project accounting by line item to integrate with monthly project reports to GOB
- Time-consuming writing of manual ledgers for all Unit Offices
- Only consolidated trial balance data to Head Office, no Unit Office reporting centrally

5.10.3 Solutions using the IMRS

- Only manual record required is a list of cheques issued and deposits received
- All Receipts and payments entered into the computer system from payment (or deposit) documents
- Automated control of entries to clearing accounts
- Can be used to capture project line items
- Produces all trial balances, by unit, and consolidated
- Produces general and project ledgers

5.10.4 The Benefits of IMRS

- An enterprise-wide Management Information System
- Simplification of accounting at RAOs and Head Office through computer processing
- No additional demands on operating units
- Provision of present MOD and accounting requirements
- Preparation of Government returns
- Consistent MOD, MIS and accounting data
- Simplification of bank reconciliation procedures
- A central data-base of statistical and accounting data

5.10.5 Additional IMRS features

- Enter MODs for Distribution and Generation, and monthly data from projects
- Send data to Head Office to produce MIS reports
- Interface with Oracle Financials and Empower systems at Head Office
- Consolidate Unit Offices from all RAOs at Head Office

Chapter 6

Analysis of the Case

6.1 Introduction

In case of BPDB, three separate Oracle RDBMS and Oracle Financials license have been procured for three installations. This means that there would be three separate installations of the Empower System at the three Financial Data Processing Centers. The primary issue is to synchronize the databases of the three Financial Data Processing Centers periodically. The above architecture assumes a distributed environment. Each of the locations has their own database server running applications specific to the location. Each location would be required to have a database administrator.

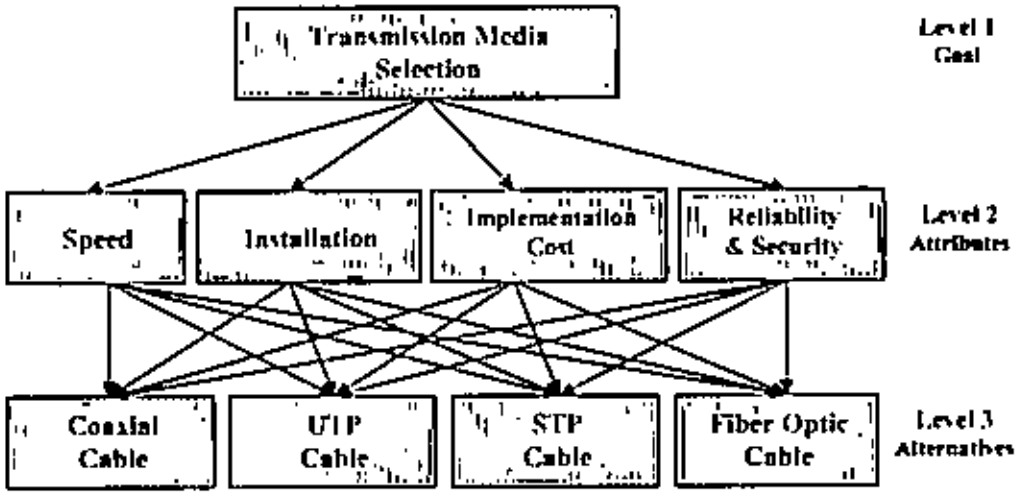
BPDB has 29 Regional Accounting Offices (RAOs) through the country. These 29 RAOs are the clients of IMRS Server and several offices are the on-line clients of Database Server at Dhaka Financial Data Processing Center. BPDB has 2 others Database Servers at Comilla and Chittagong Financial Data Processing Center.

The transactions are mostly accounts related and the rest are Store, Purchase & Project Accounting transactions. The servers will give output of Financial and MIS reports

Based on area of coverage, the network of BPDB can be divided into four types:

- Building / Campus
- City (Dhaka)
- Intercity (Dhaka-Chittagong-Comilla)
- Remote Access from RAOs

6.2 Building/Campus



At Level 1:

Attribute	Speed	Installation	Implementation Cost	Reliability & Security	b_i	x_i
Speed	1	$^1/_2$	$^2/_3$	$^1/_2$	0.580	0.134
Installation	2	1	$^2/_3$	1	1.075	0.250
Implementation Cost	3	$^3/_2$	1	$^3/_2$	1.610	0.374
Reliability & Security	2	1	$^2/_3$	1	1.075	0.250
y_k	8	4	$^8/_3$	4		

$y_1 = 1 + 2 + 3 + 2 = 8$

$b_1 = (1 * {}^1/_2 * {}^1/_3 * {}^1/_2)^{1/4} = 0.580$

$x_1 = 0.580 / (0.580 + 1.075 + 1.610 + 1.075) = 0.134$

$\lambda_{max} = \Sigma\, y_k\, x_i = (8 * 0.134) + (4 * 0.250) + ({}^{8}/_{3} * 0.374) + (4 * 0.250) = 4.072$

Consistency Index (C.I.) = $(\lambda_{max} - n) / (n - 1)$ n = number of column or row

C I = (4.072 - 4) / (4 - 1) = 0.024

Some randomly generated consistency index (R.I.) values are as follows:

N	1	2	3	4	5	6	7	8	9	10
R.I.	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Consistency Ratio (C.R.) = C.I. / R.I.

C R. = 0.024 / 0.9 = 2.68% < 10%; So, Acceptable.

At Level 2:

a. Coaxial Cable
b. UTP Cable
c. STP Cable
d. Fiber Optic Cable

Speed

Alternatives	Coaxial Cable	UTP Cable	STP Cable	Fiber Optic Cable	b_i	x_i
Coaxial Cable	1	$^{1}/_{3}$	$^{1}/_{3}$	$^{1}/_{8}$	0.340	0.067
UTP Cable	3	1	1	$^{3}/_{8}$	1.030	0.200
STP Cable	3	1	1	$^{3}/_{8}$	1.030	0.200
Fiber Optic Cable	8	$^{8}/_{3}$	$^{8}/_{3}$	1	2.750	0.534
y_k	15	5	5	$^{15}/_{8}$		

$\lambda_{max} = \Sigma\ y_k\ x_i = 4.00625$

Consistency Index (C.I) = $(\lambda_{max} - n) / (n - 1)$ n = number of column or row

C I. = $(4.00625 - 4) / (4 - 1) = 2\ 08*10^{-3}$

Consistency Ratio (C.R.) = C.I. / R I

C.R. = $(2.08*10^{-3}) / 0.9 = 2.3\% < 10\%$

So, Acceptable

Installation

Alternatives	Coaxial Cable	UTP Cable	STP Cable	Fiber Optic Cable	b_i	x_i
Coaxial Cable	1	$^5/_3$	$^5/_3$	5	1.930	0.410
UTP Cable	$^3/_5$	1	1	3	1.158	0.250
STP Cable	$^3/_5$	1	1	3	1 158	0.250
Fiber Optic Cable	$^1/_5$	$^1/_3$	$^1/_3$	1	0 386	0.083
y_k	$^{12}/_5$	4	4	12		

$\lambda_{max} = \Sigma\ y_k\ x_i = 4.004$

Consistency Index (C.I) = $(\lambda_{max} - n) / (n - 1)$ n = number of column or row

C.I. = $(4.004 - 4) / (4 - 1) = 1.33*10^{-3}$

Consistency Ratio (C.R.) = C.I. / R.I.

C.R. = $(1.33*10^{-3})$ / 0 9 = 0.148% < 10%

So. Acceptable.

Implemeutatiou Cost

Alternatives	Coaxial Cable	UTP Cable	STP Cable	Fiber Optic Cable	b_i	x_i
Coaxial Cable	1	$^{7}/_{6}$	$^{7}/_{5}$	7	1.840	0.360
UTP Cable	$^{6}/_{7}$	1	$^{6}/_{5}$	6	1.600	0.320
STP Cable	$^{5}/_{7}$	$^{5}/_{6}$	1	5	1.320	0.264
Fiber Optic Cable	$^{1}/_{7}$	$^{1}/_{6}$	$^{1}/_{5}$	1	0.263	0.053
y_k	$^{19}/_{7}$	$^{19}/_{6}$	$^{19}/_{5}$	19		

$\lambda_{max} = \Sigma\ y_k\ x_i = 4.028$

Consistency Index (C.I.) = $(\lambda_{max} - n) / (n - 1)$ n = number of column or row

C.I. = (4.028 - 4) / (4 - 1) = $9.27*10^{-3}$

Consistency Ratio (C.R.) = C.I. / R.I.

C.R. = $(9.27*10^{-3})$ / 0.9 = 1.03% < 10%

So, Acceptable.

Reliability & Security

Alternatives	Coaxial Cable	UTP Cable	STP Cable	Fiber Optic Cable	b_i	x_j
Coaxial Cable	1	$^1/_5$	$^1/_5$	$^1/_7$	0.275	0.050
UTP Cable	5	1	1	$^5/_7$	1.375	0.280
STP Cable	5	1	1	$^5/_7$	1.375	0.280
Fiber Optic Cable	7	$^7/_5$	$^7/_5$	1	1.930	0.390
y_k	18	$^{18}/_5$	$^{18}/_5$	$^{18}/_7$		

$\lambda_{max} = \Sigma\ y_k\ x_i = 4.098$

Consistency Index (C.I.) = $(\lambda_{max} - n) / (n - 1)$ n = number of column or row

C.I = (4.098 - 4) / (4 - 1) = 0.0326

Consistency Ratio (C.R.) = C.I. / R.I.

C.R. = 0.0326 / 0.9 = 3.63% < 10%

So, Acceptable

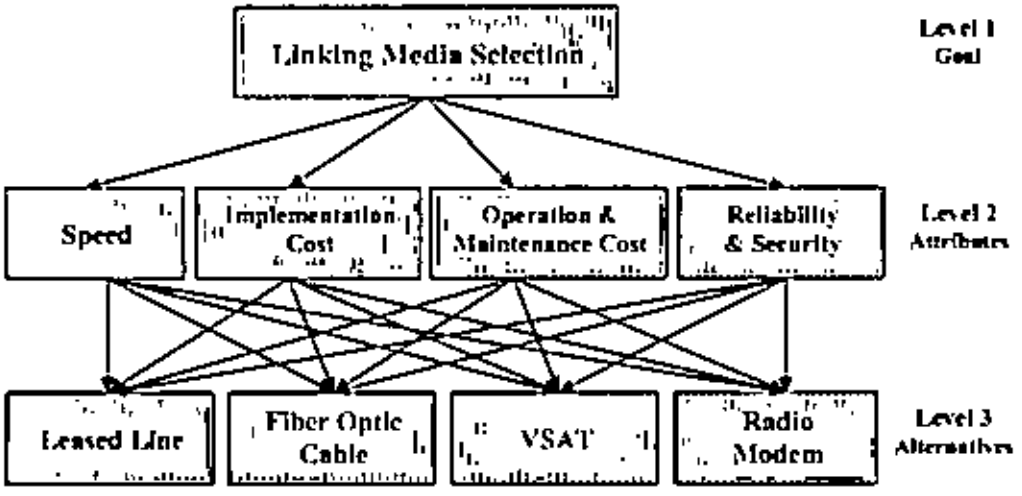
At Level 3:

On the basis of the above matrix, an overall evaluation is performed using the calculated weights of the alternatives and 4(four) measuring criteria as followers:

Alternatives	*Attributes & their weights*				Composite Weight	Overall Ranking
	Speed 0.134	Installation 0.250	Implementa -tion Cost 0.374	Reliability & Security 0.250		
Coaxial Cable	0.067	0.410	0.360	0.050	0.2586	2
UTP Cable	0.200	0.250	0.320	0.280	0.2789	1
STP Cable	0.200	0.250	0.264	0.280	0.2580	3
Fiber Optic Cable	0.534	0.083	0.053	0.390	0.2096	4

From the above result, it is better to select the UTP Cable.

6.3 City (Dhaka)



At Level 1:

Attribute	Speed	Implementation Cost	Operation & Maintenance Cost	Reliability & Security	b_i	x_j
Speed	1	1/2	1/2	1	0.707	0.167
Implementation Cost	2	1	1	2	1.414	0.333
Operation & Maintenance Cost	2	1	1	2	1.414	0.333
Reliability & Security	1	1/2	1/2	1	0.707	0.167
y_k	6	3	3	6		

$y_1 = 1 + 2 + 2 + 1 = 6$

$b_1 = (1 * 1/2 * 1/2 * 1)^{1/4} = 0.707$

$x_1 = 0.707 / (0.707 + 1.414 + 1.414 + 0.707) = 0.167$

$\lambda_{max} = \Sigma\, y_k\, x_1 = (6 * 0.707) + (3 * 1.414) + (3 * 1.414) + (6 * 0.707) = 4.002$

Consistency Index (C.I.) = $(\lambda_{max} - n) / (n - 1)$ n = number of column or row

C.I. = $(4.002 - 4) / (4 - 1) = 6.667 * 10^{-4}$

Some randomly generated consistency index (R.I.) values are as follows:

N	1	2	3	4	5	6	7	8	9	10
R.I.	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Consistency Ratio (C.R.) = C.I. / R.I.

C.R. = $(6.667 * 10^{-4}) / 0.9 = 0.074\% < 10\%$

So, Acceptable.

At Level 2:

a) Leased Line
b) Fiber Optic Cable
c) VSAT
d) Radio Modem

Speed

Alternatives	Leased Line	Fiber Optic Cable	VSAT	Radio Modem	b_i	x_i
Leased Line	1	$^1/_7$	$^1/_4$	$^1/_5$	0.290	0.059
Fiber Optic Cable	7	1	$^7/_4$	$^7/_5$	2.035	0.412
VSAT	4	$^4/_7$	1	$^4/_5$	1.163	0.235
Radio Modem	5	$^5/_7$	$^5/_4$	1	1.454	0.294
y_k	17	$^{17}/_7$	$^{17}/_4$	$^{17}/_5$		

$\lambda_{max} = \Sigma\ y_k\ x_i = 4.0039$

Consistency Index (C.I.) = $(\lambda_{max} - n) / (n - 1)$ n = number of column or row

C.I. = (4.0039 - 4) / (4 - 1) = 0.0013

Consistency Ratio (C.R.) = C.I. / R.I.

C.R. = 0.0013 / 0.9 = 0.144% < 10%

So, Acceptable.

Implementation Cost

Alternatives	Leased Line	Fiber Optic Cable	VSAT	Radio Modem	b_i	x_i
Leased Line	1	7	$^7/_2$	$^7/_5$	2.420	0 470
Fiber Optic Cable	$^1/_7$	1	$^1/_2$	$^1/_5$	0.350	0.070
VSAT	$^2/_7$	2	1	$^2/_5$	0.690	0.133
Radio Modem	$^5/_7$	5	$^5/_2$	1	1.730	0 333
y_k	$^{15}/_7$	15	$^{15}/_2$	3		

$\lambda_{max} = \Sigma\ y_k\ x_i = 4.050$

Consistency Index (C.I.) = $(\lambda_{max} - n) / (n - 1)$ n = number of column or row

C I = (4.050 - 4) / (4 - 1) = 0.0178

Consistency Ratio (C.R.) = C I / R.I.

C.R. = 0.0178 / 0.9 = 1 980% < 10%

So, Acceptable.

Operation and Maintenance Cost

Alternatives	Leased Line	Fiber Optic Cable	VSAT	Radio Modem	b_i	x_i
Leased Line	1	$^1/_6$	$^1/_3$	$^1/_8$	0.290	0.056
Fiber Optic Cable	6	1	2	$^3/_4$	1.732	0.330
VSAT	3	$^1/_2$	1	$^3/_8$	0.870	0.170
Radio Modem	8	$^4/_3$	$^8/_3$	1	2.310	0.440
y_k	18	3	6	$^9/_4$		

$\lambda_{max} = \Sigma\, y_k\ x_i = 4.008$

Consistency Index (C.I.) = $(\lambda_{max} - n) / (n - 1)$ n = number of column or row

C.I. = $(4.008 - 4) / (4 - 1) = 2.67*10^{-3}$

Consistency Ratio (C.R.) = C.I. / R.I.

C.R. = $(2.67*10^{-3}) / 0.9 = 0.3\% < 10\%$

So, Acceptable.

Reliability & Security

Alternatives	Leased Line	Fiber Optic Cable	VSAT	Radio Modem	b_i	x_i
Leased Line	1	$^1/_7$	$^1/_3$	$^1/_5$	0.310	0.062
Fiber Optic Cable	7	1	$^7/_3$	$^7/_5$	2.190	0.440
VSAT	3	$^3/_7$	1	$^3/_5$	0.940	0.190
Radio Modem	5	$^5/_7$	$^5/_3$	1	1.560	0.312
y_k	16	$^{16}/_7$	$^{16}/_3$	$^{16}/_5$		

$\lambda_{max} = \Sigma\ y_k\ x_i = 4.008$

Consistency Index (C.I.) = $(\lambda_{max} - n) / (n - 1)$ **n** = number of column or row

C.I. = $(4.008 - 4) / (4 - 1) = 2.67 * 10^{-3}$

Consistency Ratio (C.R.) = C.I. / R.I.

C.R. = $(2.67 * 10^{-3}) / 0.9 = 0.3\% < 10\%$

So, Acceptable.

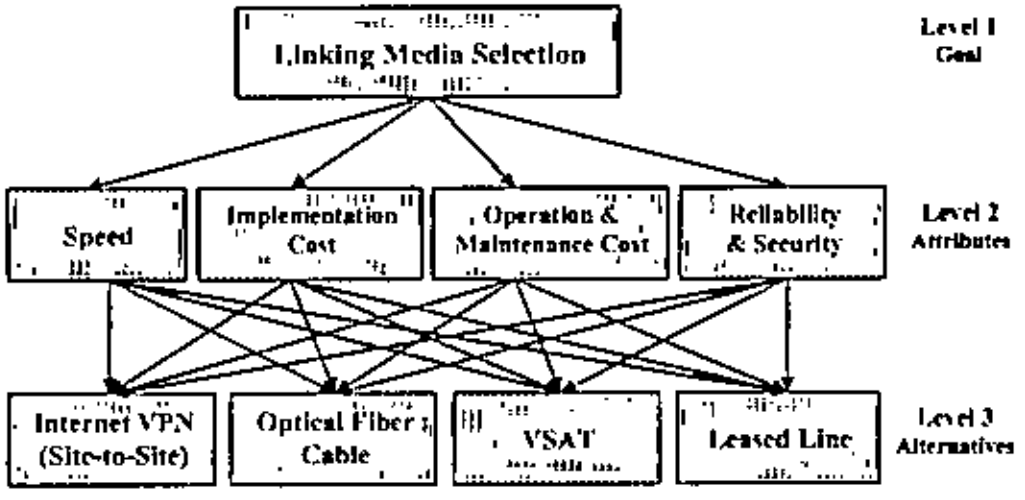
At Level 3:

On the basis of the above matrix, an overall evaluation is performed using the calculated weights of the alternatives and 4(four) measuring criteria as followers:

Alternatives	*Attributes & their weights*				Composite Weight	Overall Ranking
	Speed 0.167	Implementation Cost 0.333	Operation & Maintenance Cost 0.333	Reliability & Security 0.167		
Leased Line	0.059	0.470	0.056	0.062	0.1952	3
Fiber Optic Cable	0.412	0.070	0.330	0.440	0.2753	2
VSAT	0.235	0.133	0.170	0.190	0.1718	4
Radio Modem	0.294	0.333	0.440	0.312	0.3584	1

From the above result, it is better to select the Radio Modem.

6.4 Intercity (Dhaka-Chittagong-Comilla)



At Level 1:

Attribute	Speed	Implementation Cost	Operation & Maintenance Cost	Reliability & Security	b_i	x_i
Speed	1	$^1/_4$	$^1/_3$	1	0.540	0.111
Implementation Cost	4	1	$^4/_3$	4	2.150	0.443
Operation & Maintenance Cost	3	$^3/_4$	1	3	1.620	0 334
Reliability & Security	1	$^1/_4$	$^1/_3$	1	0.540	0.111
y_k	9	$^9/_4$	3	9		

$y_1 = 1 + 4 + 3 + 1 = 9$

$b_1 = (1 * {}^1/_4 * {}^1/_3 * 1)^{1/4} = 0.540$

$x_1 = 0.540 / (0.540 + 2.150 + 1.620 + 0.540) = 0.1113$

$\lambda_{max} = \Sigma\, y_k\, x_i = (9 * 0\ 111) + ({}^9/_4 * 0.443) \div (3 * 0.334) + (9 * 0.111) = 4.002825$

Consistency Index (C.I.) = $(\lambda_{max} - n) / (n - 1)$ n = number of column or row

C.I. = $(4.002825 - 4) / (4 - 1) - 9.41 * 10^{-4}$

Some randomly generated consistency index (R.I.) values are as follows:

N	1	2	3	4	5	6	7	8	9	10
R.I	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Consistency Ratio (C.R.) = C.I / R.I.

C.R. = $(9.41 * 10^{-4}) / 0.9 = 0.104\% < 10\%$

So, Acceptable.

At Level 2:

a) Internet VPN (Site-to-Site)
b) Fiber Optic Cable
c) VSAT
d) Leased Line

Speed

Alternatives	Internet VPN (Site-to-Site)	Fiber Optic Cable	VSAT	Leased Line	b_i	x_i
Internet VPN (Site-to-Site)	1	$^1/_8$	$^1/_5$	$^1/_3$	0.300	0.058
Fiber Optic Cable	8	1	$^8/_5$	$^8/_3$	2.420	0.470
VSAT	5	$^5/_8$	1	$^5/_3$	1.510	0.294
Leased Line	3	$^3/_8$	$^3/_5$	1	0.910	0.180
y_k	17	$^{17}/_8$	$^{17}/_5$	$^{17}/_3$		

$\lambda_{max} = \Sigma\, y_k\, x_i = 4.00435$

Consistency Index (C.I.) = $(\lambda_{max} - n) / (n - 1)$ n = number of column or row

C.I. = $(4.00435 - 4) / (4 - 1) = 1.45*10^{-3}$

Consistency Ratio (C.R.) = C.I / R.I.

C.R. = $(1.45*10^{-3}) / 0.9 = 2.3\% < 10\%$

So, Acceptable.

Implementation Cost

Alternatives	Internet VPN (Site-to-Site)	Fiber Optic Cable	VSAT	Leased Line	b_i	x_i
Internet VPN (Site-to-Site)	1	7	$^{7}/_{3}$	$^{7}/_{5}$	2.200	0.440
Fiber Optic Cable	$^{1}/_{7}$	1	$^{1}/_{3}$	$^{1}/_{5}$	0.310	0.062
VSAT	$^{3}/_{7}$	3	1	$^{3}/_{5}$	0.940	0.186
Leased Line	$^{5}/_{7}$	5	$^{5}/_{3}$	1	1 600	0.320
y_k	$^{16}/_{7}$	16	$^{16}/_{3}$	$^{16}/_{5}$		

$\lambda_{max} = \Sigma\, y_k\ x_i = 4.013$

Consistency Index (C.I.) = $(\lambda_{max} - n) / (n - 1)$ n = number of column or row

C I = (4 013 - 4) / (4 - 1) = $4.33*10^{-3}$

Consistency Ratio (C.R.) = C.I. / R.I.

C.R. = $(4.33*10^{-3})$ / 0 9 = 0.48% < 10%

So, Acceptable.

Operation and Maintenance Cost

Alternatives	Internet VPN (Site-to-Site)	Fiber Optic Cable	VSAT	Leased Line	b_i	x_i
Internet VPN (Site-to-Site)	1	1	2	6	1.860	0.375
Fiber Optic Cable	1	1	2	6	1.860	0 375
VSAT	$^1/_2$	$^1/_2$	1	3	0.930	0.187
Leased Line	$^1/_6$	$^1/_6$	$^1/_3$	1	0.310	0.063
y_k	$^8/_3$	$^8/_3$	$^{16}/_3$	16		

$\lambda_{max} = \Sigma\ y_k\ x_i = 4.008$

Consistency Index (C.I.) = $(\lambda_{max} - n) / (n - 1)$ n = number of column or row

C.I. = $(4.008 - 4) / (4 - 1) = 2.67*10^{-3}$

Consistency Ratio (C.R.) = C.I. / R.I.

C.R. = $(2.67*10^{-3}) / 0.9 = 0.3\% < 10\%$

So, Acceptable.

Reliability & Security

Alternatives	Internet VPN (Site-to-Site)	Fiber Optic Cable	VSAT	Leased Line	b_j	x_i
Internet VPN (Site-to-Site)	1	$^1/_5$	$^1/_4$	$^1/_2$	0.400	0.084
Fiber Optic Cable	5	1	$^5/_4$	$^5/_2$	1.990	0.420
VSAT	4	$^4/_5$	1	2	1.600	0.330
Leased Line	2	$^2/_5$	$^1/_2$	1	0 800	0.167
y_k	12	$^{12}/_5$	3	6		

$\lambda_{max} = \Sigma\ y_k\ x_i = 4.008$

Consistency Index (C.I.) = $(\lambda_{max} - n) / (n - 1)$ n = number of column or row

C I = (4 008 - 4) / (4 - 1) = 2 67 * 10^{-3}

Consistency Ratio (C.R.) = C.I. / R.I.

C.R. = (2.67 * 10^{-3}) / 0.9 = 0.3% < 10%

So, Acceptable.

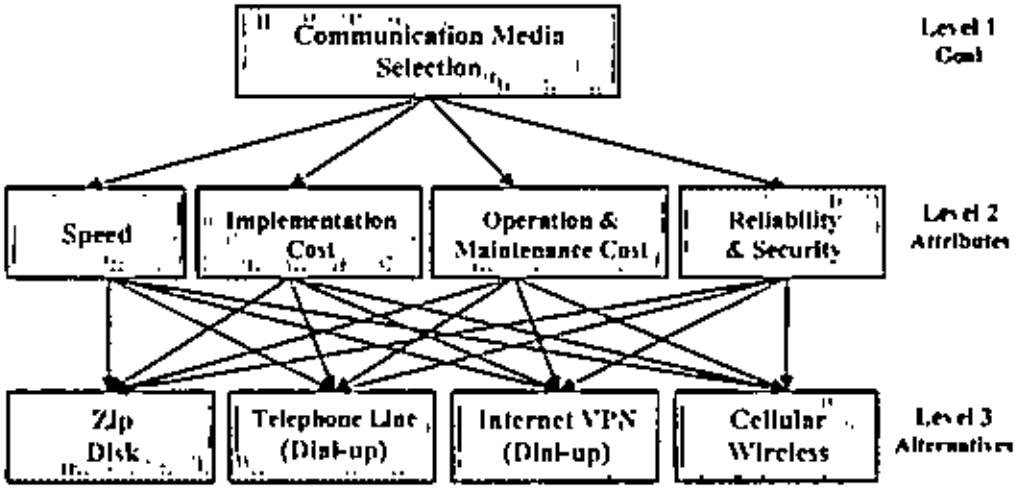
At Level 3:

On the basis of the above matrix, an overall evaluation is performed using the calculated weights of the alternatives and 4(four) measuring criteria as followers:

Alternatives	*Attributes & their weights*				Composite Weight	Overall Ranking
	Speed 0.111	Implementation Cost 0.443	Operation & Maintenance Cost 0.334	Reliability & Security 0.111		
Internet VPN (Site-to-Site)	0.058	0.440	0.375	0.084	0.3359	1
Fiber Optic Cable	0.470	0.062	0.375	0.420	0.2515	2
VSAT	0.294	0.186	0.187	0.330	0.2141	3
Leased Line	0.180	0.320	0.063	0.167	0.2013	4

From the above result, it is better to select the Internet VPN (Site-to-Site).

6.5 Remote Access from RAOs



At Level 1:

Attribute	Speed	Implementation Cost	Operation & Maintenance Cost	Reliability & Security	b_i	x_i
Speed	1	$^1/_3$	$^1/_2$	$^1/_2$	0 537	0.130
Implementation Cost	3	1	$^3/_2$	$^3/_2$	1.611	0.375
Operation & Maintenance Cost	2	$^2/_3$	1	1	1.074	0.250
Reliability & Security	2	$^2/_3$	1	1	1.074	0.250
y_k	8	$^8/_3$	4	4		

$y_1 = 1 + 3 + 2 + 2 = 8$

$b_1 = (1 * {}^1/_3 * {}^1/_2 * {}^1/_2)^{1/4} = 0.537$

$x_1 = 0.537 / (0\ 537 + 1.611 + 1.074 + 1.074) = 0.130$

$\lambda_{max} = \Sigma\ y_k\ x_i = (8 * 0.130) + ({}^8/_3 * 0.375) + (4 * 0\ 250) + (4 * 0.250) = 4.040$

Consistency Index (C.I.) = $(\lambda_{max} - n) / (n - 1)$ **n** = number of column or row

C.I. = (4.040 - 4) / (4 - 1) = 0.0133

Some randomly generated consistency index (R.I.) values are as follows:

N	1	2	3	4	5	6	7	8	9	10
R.I.	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Consistency Ratio (C.R.) = C.I. / R.I.

C.R. = 0.0133 / 0.9 = 1.48% < 10%

So, Acceptable.

At Level 2:

a) Zip Disk
b) Telephone Line (Dial-up)
c) Internet VPN (Dial-up)
d) Cellular Wireless

Speed

Alternatives	Zip Disk	Telephone Line (Dial-up)	Internet VPN (Dial- up)	Cellular Wireless	b_i	x_i
Zip Disk	1	$^1/_7$	$^1/_4$	$^1/_3$	0.330	0 067
Telephone Line (Dial up)	7	1	$^7/_4$	$^7/_3$	2.312	0.500
Internet VPN (Dial up)	4	$^4/_7$	1	$^4/_3$	1.320	0 270
Cellular Wireless	3	$^3/_7$	$^3/_4$	1	1.000	0.200
y_k	15	$^{15}/_7$	$^{15}/_4$	5		

$\lambda_{max} = \Sigma\ y_k\ x_i = 4.088$

Consistency Index (C.I.) = $(\lambda_{max} - n) / (n - 1)$ n = number of column or row

C.I. = (4.088 - 4) / (4 - 1) = 0.03

Consistency Ratio (C.R.) = C.I / R.I.

C.R. = 0.03 / 0.9 = 3.26% < 10%

So, Acceptable

Implementation Cost

Alternatives	Zip Disk	Telephone Line (Dial-up)	Internet VPN (Dial- up)	Cellular Wireless	b_i	x_i
Zip Disk	1	5	6	3	3.080	0.590
Telephone Line (Dial-up)	$^1/_5$	1	$^6/_5$	$^3/_5$	0.616	0.120
Internet VPN (Dial- up)	$^1/_6$	$^5/_6$	1	$^1/_2$	0.513	0.100
Cellular Wireless	$^1/_3$	$^5/_3$	2	1	1.026	0.200
y_k	$^{17}/_{10}$	$^{17}/_2$	$^{51}/_5$	$^{51}/_{10}$		

$\lambda_{max} = \Sigma\ y_k\ x_i = 4.063$

Consistency Index (C.I.) = $(\lambda_{max} - n) / (n - 1)$ n = number of column or row

C.I. = (4.063 - 4) / (4 - 1) = 0.021

Consistency Ratio (C.R.) = C I / R.I.

C.R. = 0.021 / 0.9 = 2.33% < 10%

So, Acceptable.

Operation and Maintenance Cost

Alternatives	Zip Disk	Telephone Line (Dial-up)	Internet VPN (Dial- up)	Cellular Wireless	b_i	x_i
Zip Disk	1	$^1/_3$	$^1/_5$	$^1/_2$	0.430	0.090
Telephone Line (Dial-up)	3	1	$^3/_5$	$^3/_2$	1.300	0.300
Internet VPN (Dial- up)	5	$^5/_3$	1	$^5/_2$	2.140	0 453
Cellular Wireless	2	$^2/_3$	$^2/_5$	1	0.850	0.180
y_k	11	$^{11}/_3$	$^{11}/_5$	$^{11}/_2$		

$\lambda_{max} = \Sigma\ y_k\ x_i = 4.0766$

Consistency Index (C I) = $(\lambda_{max} - n) / (n - 1)$ n = number of column or row

C.I. = (4.0766 - 4) / (4 - 1) = 0.025

Consistency Ratio (C.R.) = C.I. / R I

C R. = 0 025 / 0.9 = 2 83% < 10%

So. Acceptable.

Reliability & Security

Alternatives	Zip Disk	Telephone Line (Dial-up)	Internet VPN (Dial- up)	Cellular Wireless	b_i	x_i
Zip Disk	1	$^1/_5$	$^1/_3$	$^1/_4$	0 359	0.080
Telephone Line (Dial-up)	5	1	$^5/_3$	$^5/_4$	1.796	0.384
Internet VPN (Dial- up)	3	$^3/_5$	1	$^3/_4$	1.077	0.230
Cellular Wireless	4	$^4/_5$	$^4/_3$	1	1.437	0.307
y_k	13	$^{13}/_5$	$^{13}/_3$	$^{13}/_4$		

$\lambda_{max} = \Sigma\ y_k\ x_i = 4.078$

Consistency Index (C.I.) = $(\lambda_{max} - n) / (n - 1)$ n = number of column or row

C.I. = (4.078 - 4) / (4 - 1) = 0 026

Consistency Ratio (C.R.) = C.I. / R.I.

C R. = 0.026 / 0 9 = 2.9% < 10%

So, Acceptable.

At Level 3:

On the basis of the above matrix, an overall evaluation is performed using the calculated weights of the alternatives and 4(four) measuring criteria as followers:

Alternatives	*Attributes & their weights*				Composite Weight	Overall Ranking
	Speed 0 130	Implementation Cost 0 375	Operation & Maintenance Cost 0 250	Reliability & Security 0 250		
Zip Disk	0.067	0.590	0.090	0.080	0 2725	2
Telephone Line (Dial-up)	0.500	0.120	0.300	0.384	0 2810	1
Internet VPN (Dial-up)	0.270	0.100	0 453	0.230	0.2433	3
Cellular Wireless	0.200	0.200	0.180	0.307	0 2227	4

From the above result, it is better to select the Telephone Line (Dial-up).

6.6 Discussion of Results

Based on area of coverage, the communication network of BPDB has been divided into four types, such as Building/Campus, City (Dhaka), Intercity (Dhaka-Chittagong-Comilla) and Remote Access from RAOs. The communication media deemed most appropriate and discussed earlier have been evaluated on the basis of the attributes. such as, speed, installation, implementation cost, operation & maintenance cost, reliability & security etc. and ranked according to weight calculated.

Accordingly, the UTP Cable is found to be the most suitable option for networking Building/Campus area, out of available alternatives of Coaxial Cable, UTP Cable, STP Cable and Fiber Optic Cable considered in this study.

The City (Dhaka) area is obviously not the same as Building/Campus situation and as such, the UTP Cable is not suitable for this situation. So, in this situation the Radio Modem has been found to be the most suitable option among the alternatives of Leased Line, Fiber Optic Cable, VSAT and Radio Modem.

Similarly, in Intercity (Dhaka-Chittagong-Comilla) situation, none of the above communication media (UTP Cable & Radio Modem) can be suitably applied. So, in this situation, Internet VPN (Site-to-Site) has been found to be the most suitable option for networking among the alternatives of Internet VPN (Site-to-Site), Fiber Optic Cable, VSAT and Leased Line

The Telephone Line (Dial-up) has been found to be the most suitable option for networking the Remote Access from RAOs situation, among the alternatives of Zip Disk, Telephone Line (Dial-up), Internet VPN (Dial-up) and Cellular Wireless considered in this study.

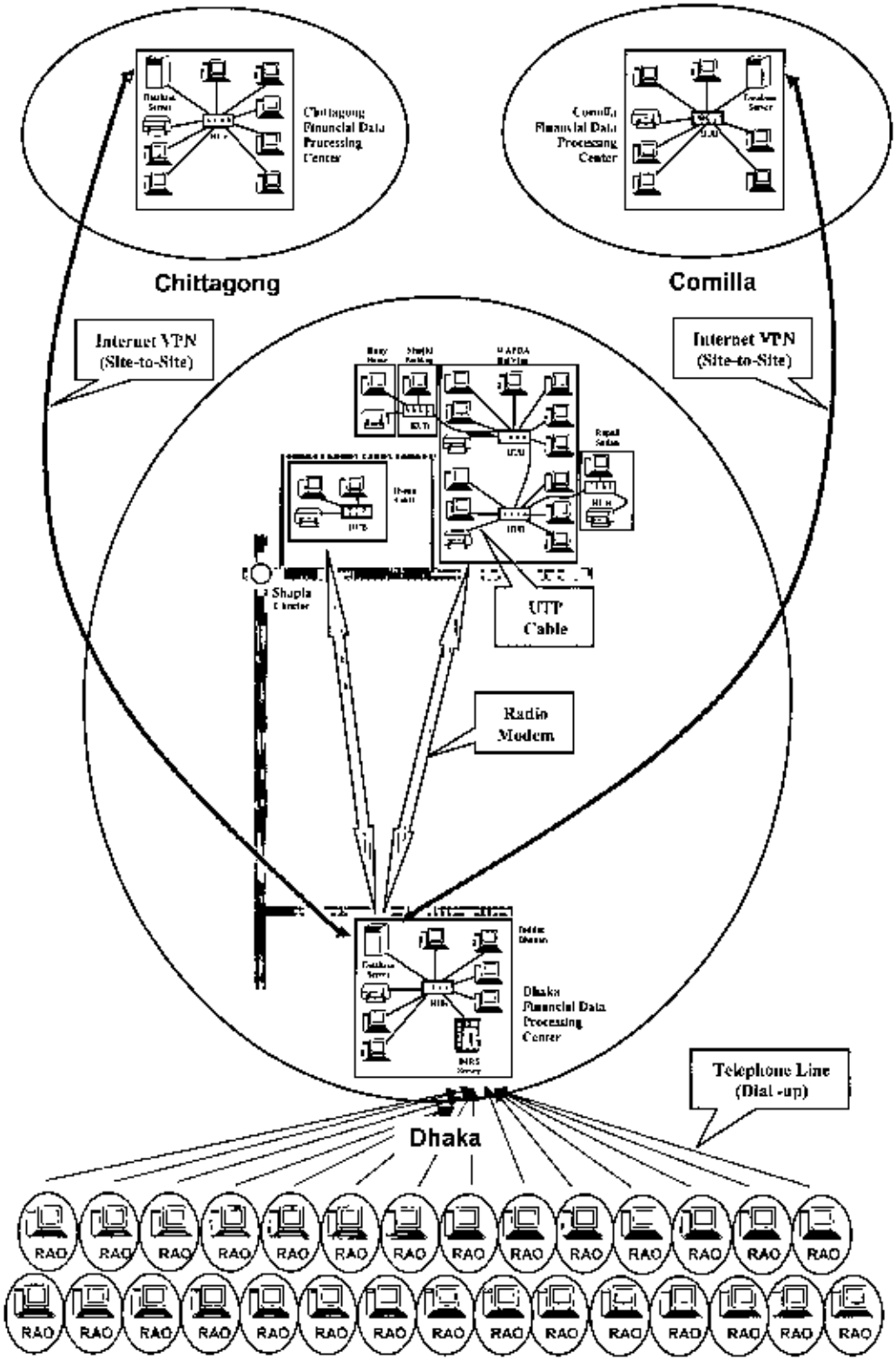


Figure 6.1: Proposed Communication Media of the network of BPDB

Chapter 7

Conclusions

7.1 Conclusions

To summarize the results of this study, the communication network of BPDB has been divided into four types, such as Building/Campus, City (Dhaka), Intercity (Dhaka-Chittagong-Comilla) & Remote Access from RAOs and based on the attributes, such as, *Speed, Installation, Implementation Cost, Operation & Maintenance Cost, Reliability & Security* etc., **UTP Cable, Radio Modem, Internet VPN (Site-to-Site)** and **Telephone Line (Dial-up)** have, however, been found to be the most suitable options respectively for Building/Campus, City (Dhaka), Intercity (Dhaka-Chittagong-Comilla) and Remote Access from RAOs situations.

It may finally be stated that MCDM technique has been used for ranking the various alternatives. The main advantage for using this technique is that it gives not only the quantitative results but also qualitative results which make it easier for ranking in a mixed type of situation.

Although this technique has been used in this study for evaluating the communication media, this can very conveniently be used for evaluating any kind of IT related issues and solving problems thereof.

REFERENCES

1. Burk, R., "Unix", Techmedia, 3rd Edition, 1990

2. Canada, J. R. and Sullivan, W. G., "Economic and Multi-Attribute Evaluation of Advanced Manufacturing Systems", Prentice-Hall International Inc., 1989

3. Chellis, J., Perkins, C., Strebe, M., "MCSE: Networking Essentials, Study Guide", BPB Publications, 2nd Edition, 1998

4. Cowart, R. and Gregg, K., "Windows NT Server 4.0 Administrator's Bible", IDG Books Worldwide Inc., 4th Edition, 1998

5. Derfler, J. F., Jr., "Practical Networking", Prentice-Hall International Inc., 2000

6. Derfler, J. F., Jr., and Freed L., "How Networks Work", Techmedia, 4th Edition, 1999

7. Dicker, P. F. and Dicker, M. P., "The Impact of Flexible Manufacturing Systems on Productivity and Quality", IEEE Transactions on Engineering Management, Vol. 38, No 1, February, 1991, pp. 33-45

8. Green, J. H., "Local Area Networks, A User's Guide for Business Professionals", Scott Foresman and Company, 1985

9 Haykin, S., "Communication Systems", John Wiley & Sons, 3rd Edition, 1996

10. Hughes, J. F., Thomas, B. W., "Novell's NetWare 5 Handbook", Novell Press, 1999

11. Hunt, C. and Thompson, R. B., "Windows NT TCP/IP Network Administration", O'REILLY, 1st Edition, 1999

12. Kennedy, G., "Electronic Communication Systems", Tata McGraw-Hill, 3rd Edition, 1991

13. Minasi, M., "Mastering Windows NT Workstation 4", BPB Publications, 1996

14. Mustafa, M. A. and Al-Bahar, J. F., "Project Risk Assessment Using the Analytic Hierarchy Process", IEEE Transactions on Engineering Management, Vol.38, No.1. February, 1991, pp. 46-52

15. Partovi, F. Y., Burton, J. and Banerjee, A., "Application of Analytical Hierarchy Process in Operations Management", International Journal of Operations and Production Management, Vol.10, No.3, 1990, pp. 5-19

16. Pucknell. D. A., Eshraghian, K., "Basic VLSI Design", Prentice-Hall International Inc., 3rd Edition, 1995

17. Saaty, T. L., "Priority Setting in Complex Problems", IEEE Transactions on Engineering Management, Vol.EM-30, No 3, August, 1983, pp. 141-155

18. Senn. J. A., "Analysis and Design of Information Systems", McGraw-Hill Publishing Company, 2nd Edition, 1989

19. Sheldon, T., "Encyclopedia of Networking, Electronic Edition", Tata McGraw-Hill, 1998

20. Sheldon, T., "NetWare 4.1: The Complete Reference", Tata McGraw Hill, 2nd Edition, 1997

21 Silberschatz, A., Korth, H. F. and Sudarshan, S , "Database System Concepts", McGraw Hill Companies, Inc., 3rd Edition, 1997

22. Stallings, W., "Data and Computer Communications", Prentice-Hall International Inc., 5th Edition, 1997

23. Suresh, N. and Meredith. J., "Justifying Multi-machine Systems: An Integrated Strategic Approach", Journal of Manufacturing Systems, Vol.4, No.2, 1985, pp. 117-134

24. Swamidass, P. M and Waller, M A., "A Classification of Approaches to Planning and Justifying New Manufacturing Technologies", Journal of Manufacturing Systems, Vol.9, No 3, pp 181-193

25. Tabucanon, M. T., "Multi-Criteria Decision Making in Industry", Elsevier Science Publisher B. V.

26. Thomas, R. M., "Introduction to Local Area Networks", BPB Publications, 2nd Edition, 1998

27. Annual Report 1998-99 of Bangladesh Power Development Board

28. Information From the Internet.
Bangladesh Power Development Board http://www.bd-pdb.com