A STUDY OF COMPUTER NETWORK TOPOLOGIES IN AND AROUND DHAKA CITY

BY

S. M. ZULKADER

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DECLARATION

This is to certify that the work presented in this thesis is the outcome of the investigation carried out by me under the supervision of Dr. Md. Shamsul Alam in the department of Computer Science and Engineering, Bangladesh University of Engineering and Technology, Dhaka. It is also declared that neither this thesis nor any part of this has been submitted or is being concurrently submitted any where else for the award of any degree or diploma.

S. M. Zulkader

(S. M. Zulkader)

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Submitted by

S.M.ZULKADER
Roll No: 871808p, Registration No: 81218

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Approved as to style and contents by:

1. M. S. Alam 1/11/93
(Dr. Md. Shamsul Alam) (Supervisor) Chairman
Associate Professor
CSE Department, BUET

2. 1/11/93
(Dr. A.B.M. Siddique Hossain) (Ex-officio) Member
Head, CSE Department, BUET

3. (Dr. Md. Kaykobad) Member
Assistant Professor,
CSE Department, BUET

4. (Dr. Md. Lutfar Rahman) Member (External)
Head, Computer Science Department
Dhaka University.

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S. M. Zulkader

(S. M. Zulkader)

ABSTRACT

For solutions of scientific problems, and exchange and sharing of information regarding administrative and financial decisions in national level, establishment of a widearea computer communication network is of vital importance. To provide the users these networking facilities, a hierarchical high speed fiber optic backbone network is proposed. The topology of this network is studied only for users in Dhaka city. This study considers important 16 installations as nodes and their traffics have been estimated on the basis of the number of terminals or PCs used at present and the distances between the nodes. Different communication media have been analyzed and monomode optical fiber with 140 Mbps capacity is chosen for the high speed data communication network. For the minimum cost spanning tree, optimal capacity and delay have been evaluated. A number of other point to point topologies have been generated by adding arcs to the minimum cost spanning tree. Delay, capacity and cost of these topologies have been compared. Hierarchical structures with these nodes have also been considered. Such a study will be very useful in establishing a widearea network in and around Dhaka city. Ultimately a hierarchical computer communication network for Dhaka city is proposed with 30 nodes grouped into 4 clusters.

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ONE

INTRODUCTION

INTRODUCTION

Networks were first introduced in the late 1960s as time-shared systems. In a time-shared system, each of the several terminal users uses the system resources on a time-sliced basis. Later, with a view to providing resources to users of several host computers, different research groups started to investigate various problems in connecting terminal users to more than one host computer. As a result in 1969 ARPANET [Advanced Research Projects Agency NET] [1] with four node was such a output of a Massachusetts based engineering firm. Later in 1975, ARPANET was able to provide network facility to users of about 100 nodes. In early 1980s personal computer networks were announced. Now-a- days due to the reduction of processing and communication cost, both the computing and communication communities are progressing toward a compatible and useful coexistence, leading to the emergence of hundreds of networks with thousands of terminals. In Bangladesh applications of networks are only limited within Local area networks. All the developed countries have established high speed widearea networks. Prospects and topological study of establishing a widearea network in and around Dhaka city are discussed in this thesis.

1.1 Objectives and types of Computer Networks

Objectives of Computer Networks [1-3] : Computer Technology is growing rapidly in Bangladesh. At present there are a number of mainframe computers, about 50 minicomputers and thousands of microcomputers in the country. Most of them are in and around Dhaka City. If a Network is available for communications among the mainframes, minis and important PC based installations, the users will receive a number of facilities. Some of these facilities are as follows:

a) DISTRIBUTION OF DATABASES:

Through computer network it is possible to share databases situated in geographically different locations. Suppose an organization or a company has a number of offices at different locations. They maintain their databases individually. But in case of decision making the higher authority requires information about all the departments. For planning and development, one department requires data from another department. These information retrieval procedures are very easy with the help of networking facility.

b) RESOURCE SHARING:

If network is available then programs, data and other resources within the network are available to any user of the network without regard to the physical location of the resource and the user. One of the best resource sharing networks is ARPANET, a network of Advance Research Project Agency in U.S.A. which interconnects more than fifty universities and research centres (including a few in Europe). Many Universities have unique computer facilities. These will become more valuable if these are shared by a large community of users. Some of the resources that can be accessed via network are: Newspaper services, marketing, Travel booking, Medical assistance etc.

c) LOAD SHARING:

Load sharing is a vital aspect of computer network. In early years of networking, the network was used for two principal purposes: allowing users at one site to log onto a machine at another site and allowing users to transfer files from one site to another. But as technology developed a single large problem is divided into pieces, developed and run on different machines. A large problem can be distributed among different machines or users may avail the computing facility at a different site for speedy processing.

d) **HIGHER RELIABILITY:**

A very important objective of computer network in our country is to provide higher reliability by having alternative sources of computing facility. If one processor within the network breaks down, another processor in the network can continue to provide services. With a network, the temporary loss of a single computer is much less serious, because its users may be accomodated elsewhere until service is restored. For military, banking, industrial process control and many other applications, a complete loss of computing power for even a few minutes may be intolerable.

e) **HARDWARE AND SOFTWARE MAINTENANCE:**

If networking facility is available, then vendors who provide maintenance and repair services can take proper action or instruct the locally responsible person for appropriate action without moving to the customer site. Through networking facility diagnosis of software and hardware problem is also possible from remote location. Thus computer time and maintenance cost can be saved.

Types of Computer Networks [1,3] :

Networks can be divided into the two following categories depending on design issue concerned:

a) Point to Point Networks

b) Broad Cast Networks

A point to point network contains numerous cables or leased telephone lines, each one connecting a pair of IMPs (Interface Message Processors) [1]. IMPs that are not directly connected, communicate indirectly via other IMPs. When a message or packet is sent from one IMP to another via one or more intermediate IMPs, the packet is received at each of the intermediate IMPS, stored there until the required output line is free and then forwarded. A network using this principle is called a point to point, store and forward or packet switched network.

Broadcast systems have a single communication channel that is shared by all the machines on the network. Packets sent by any machine are received by all the machines on the network. An address field within the packet specifies for whom it is intended. Upon receiving a packet, a machine checks the address field. If the packet is intended for some other machine, it is just ignored. Most local area networks and a small number of wide area networks are of this type. In a local area network, the IMP is embedded to a single chip embedded inside the host, so there is one host per IMP, whereas in a widearea network there may be many hosts per IMP. Broadcast systems generally also allow the possibility of addressing a packet to all destinations by using a special code in the address field. When a packet with this code is transmitted, it is received and processed by every machine on the network. Some broadcast systems also support transmission to a subset of the machines, which is known as multicasting.

Broadcast subnets can be further divided into static and dynamic, depending on how the channel is allocated. A typical static allocation divides up time into discrete intervals, and follow a round robin schedule, allowing each machine to broadcast only when its time slot comes up. Static allocation wastes channel capacity when a machine has nothing to transmit during its allocated slot, so some systems attempt to allocate the channel dynamically i.e., on the basis of the demand of the machines.

On the basis of the technique applied in transporting messages between nodes networks may be classified as:

1) Circuit-switched network.
2) Message-switched network.
3) Packet-switched network.

Circuit-switched network:

A circuit-switched network transmits a message by establishing a complete path of transmission links from the message origination node to the destination node. The data is transmitted progressively over all the channels in the path with no intermediate store-and-forward delays.

Message-switched network:

A message-switched network transmits a message among the nodes by moving the message through various transmission links and message buffers. A message transmission from a node does not start until a buffer at the next node on the route has been allocated for it. This class of networks is also called store-and-forward networks, since messages are stored in each node and then forwarded to the next node on its route.

Packet-switched network:

A packet--switched network differs from a message-switched network in that long messages are first decomposed into fixed-size segments called packets. These packets independently traverse the network until they reach the desired node, where they are reassembled into corresponding message.

On the basis of the diameter, data transmission rate etc. networks are divided into two categories [1]. These are:

i) Local Area Networks (LAN)

ii) Wide Area Network (WAN)

LANs generally have the following characteristics [1]:

A. A diameter of not more than a few kilometers.

B. A data rate of at least several Mbps (Mega bits/sec).

C. Complete ownership by a single organization.

WANs in contrast, typically span entire countries, have data rates below 1 Mbps, and are owned by multiple organizations. In between the LAN and the WAN is the MAN [1] (Metropolitan Area Network). A MAN is a network that covers an entire city.

1.2 Network Architecture

The set of layers and protocols is called network architecture. To reduce the design complexity most networks are organized as a series of layers and protocols. The purpose of each layer is to provide certain services to the higher layers, shielding those layers from the details of how the offered services are actually implemented. Between each pair of adjacent layers there is an interface. The interface defines which primitive operations and services the lower layer offers to the upper one. Protocols are defined as a set of rules and conventions to permit two or more network components to exchange useful information. Network protocols [3] essentially consist of three elements:

a) **Syntax** - the structure of data and control messages.

b) **Semantics** - the set of control messages to be issued, actions to be performed and responses to be returned.

c) **Timing** - the specification of the order of event executions.

Some of the major functions served by network protocols are:

1. Orderly exchange of data messages.
2. Management of priorities at both the network entry and transmission levels within the network.
3. Process synchronization.
4. Session establishment between network users.
5. Session termination between network users.
6. Establishment of message routes and routing information.
7. Flow control and congestion prevention.
8. Sequenced transmission or delivery of messages.
9. Addressing of network components and users.
10. Efficient network resource utilization.
11. Resource management, monitoring and protection.
12. Layered transparency between network users and nodes.
13. Reliable message transmission, including error control and recovery.
14. Testing of network resources, such as links and routes.
15. Security and privacy.

The number of layers, the name and function of each layer differ from network to network. However, The **OSI** (Open System Interconnection) reference model approved by **ISO** (International Standard Organization) contains seven layers. This ISO (OSI) network architecture is shown in Figure 1.1 and short description of its different layers is given below [1] :

1) **Physical Layer**

The physical layer is concerned with transmitting raw bits over a communication channel. The major design issues of this layer include:

* To decide the voltage level for 0 and 1.
* Making sure that when one side sends a 1 bit, it is received by the other side as a 1 bit, not as a 0 bit.
* Establishing initial connection and to disconnect the connection when both sides are interested to do so.
* Mechanical, electrical and procedural interfaces.
* Physical transmission medium.
* Mode of transmission (simplex, half--duplex, duplex etc.).

2) **Data link layer**

The main task of data link layer is to take a raw transmission facility and to provide a well-defined service interface to the network layer. It accomplishes this task by having the sender break the input data up into data frames, transmit the frames sequentially and process the acknowledgement frames sent back by the receiver. Data link layer creates and recognizes frame boundaries. This layer also solves the problems caused by damaged, lost or duplicate frames. Other functions of data link layer include providing a well defined service interface to the

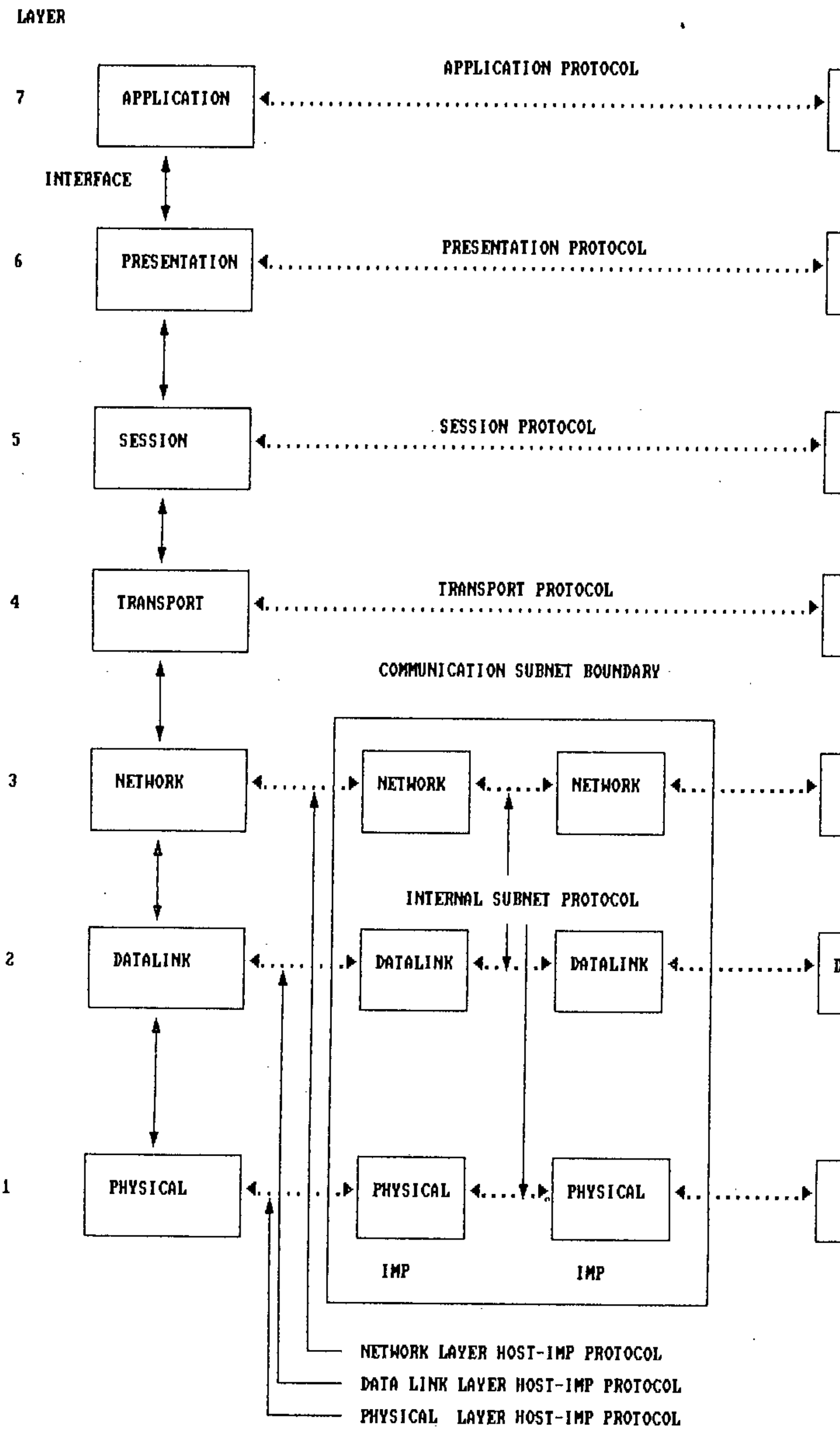


FIG 1.1 : THE NETWORK ARCHITECTURE BASED ON THE ISO OSI MODEL.

network layer, dealing with transmission errors, regulating the flow of frames so that slow receivers are not swamped by fast senders, general link management etc.

3) **Network layer**

The network layer is concerned with controlling the operation of the subnet. Routing, Congestion control, accounting or billing operations of the network users etc.[1] are the functions of the network layer. It is upto the network layer to overcome all problems to allow heterogenous network to be interconnected.

4) **Transport layer**

The basic function of the transport layer is to accept data from the session layer, split it up into smaller units if needed, pass these to the network layer and ensure that the pieces all arrive correctly at the other end. Under normal conditions the transport layer creates a distinct network connection for each transport connection required by the session layer. However, the transport layer might create multiple network connections, dividing the data among the network connections to improve throughput. The transport layer may multiplex several transport connections on the network connection to reduce the cost. The transport layer also determines what service to be provided to the session layer and ultimately to the users of the network. The most popular type of transport is an error free point to point channel that delivers messages in the order in which they were sent [1].

5) **Session layer**

The session layer allows users on different machines to establish sessions between them. A session allows ordinary data transport, as does the transport layer, but it also provides some enhanced services useful in some applications. A session is used to allow a user to log into a remote time-sharing system or to transfer a file between two machines. One of the services of the session layer is to manage dialogue control. A related session service is token management. Another session service is synchronization.

6) **Presentation layer**

The presentation layer is enclosed with the manipulation of data structures, data encoding, data compression, their abstract types and their external representations on the wire. External representations of data on the wire is known as transfer syntax. Different compression techniques include Huffman coding, arithmetic coding and run length coding. Many of the issues relating to network privacy and security can be implemented in the presentation layer. Encryption can be done using conventional or public key cryptography. Encryption also plays a major role for authentication and providing digital signatures.

7) **Application layer**

One of the major functions of application layer is to handle the problems relating to incompatible terminals among different users in a network. Another important function is file transfer. Different file systems have different file naming conventions, different ways of representing text lines and so on. Transferring a file between two different systems requires handling these and other incompatibilities. Electronic mail, Directory services, remote job entry, job transfer and management, picture storage and transfer, videotext, teletext etc. are other applications of this layer.

1.3 Network Configurations

On the basis of the layout of network nodes and arcs different standard configurations are common to network designers. Some of the common configurations are as follows [1,4,5] :

i) **Ring structure:**

Ring networks have been around for many years and have long been used for both local and wide area networks. Among their many attractive features is the fact that a ring is not really a broadcast medium, but a collection of individual point- to-point links that happen to form a circle. Point-to-point links involve a well-understood and field proven technology and can run on twisted pair, coaxial cable or fiber optics. Several kinds of rings exist. The one standardized IEEE standard 802.5 is called a token ring. IBM has chosen this ring and IEEE has accepted it. A ring network is shown in Figure 1.2.

ii) **Star topology:**

The diagram of a star network is shown in Figure 1.3. In a star network the network controller may communicate with all nodes of the star simultaneously. Star networks are usually operationally faster than rings if both operate at the same transmission rate [5]. Ring topologies are usually lower in cost, however, because of their simplicity. A star layout usually requires more total cable length than the ring or the bus. The star controller may be a simple microcomputer, a minicomputer or a mainframe computer depending on the size and complexity of the network.

iii) **Bus topology:**

A bus is a network topology characterized by a single cable that

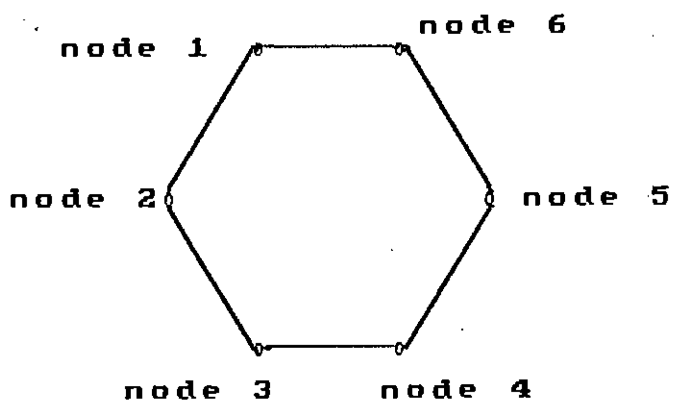


Fig. 1.2: Block Diagram of a Ring Network

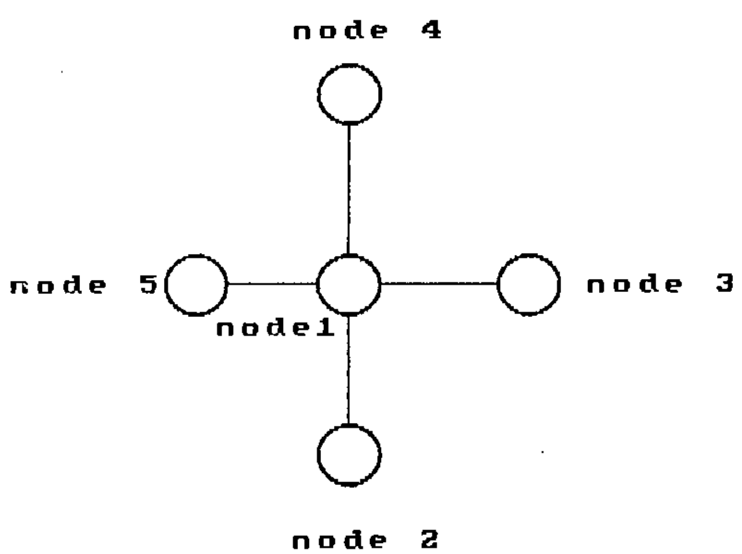


Fig. 1.3: Block Diagram of a Star Network

runs through all the network nodes either directly or through a short cable. The ends of the bus are electrically terminated with resistors. In a bus at any instant one machine is the master and is allowed to transmit, all other machines are required to refrain from transmitting. An arbitration mechanism is needed to resolve conflicts when two or more machines want to transmit simultaneously. The arbitration method may be centralized or decentralized. The diagram of a bus is shown in Figure 1.4. The IEEE standard 802.4 is a token bus which is a linear cable onto which stations are attached.

iv) **Tree:**

A tree type network is shown in Figure 1.5. Network topology with a single master node at the root and with every other node having a single parent and one or more child nodes is known as tree. The number of subtrees of a node is called its degree. Nodes with degree zero have no child. There is no loop in this type of connections.

v) **Composite network:**

Networks often fail to follow any of the standard topologies exactly but are composed of combinations of rings, stars, buses etc. Some of these network elements may be separated from the main network and analyzed separately. A diagram of a composite network is shown in Figure 1.6.

vi) **Hierarchical network:**

Block diagram of a hierarchical network is shown in Figure 1.7. A hierarchical network contains nodes and arcs of different levels. When the number of nodes increases, it is required to have a hierarchical structure for better utilization of line

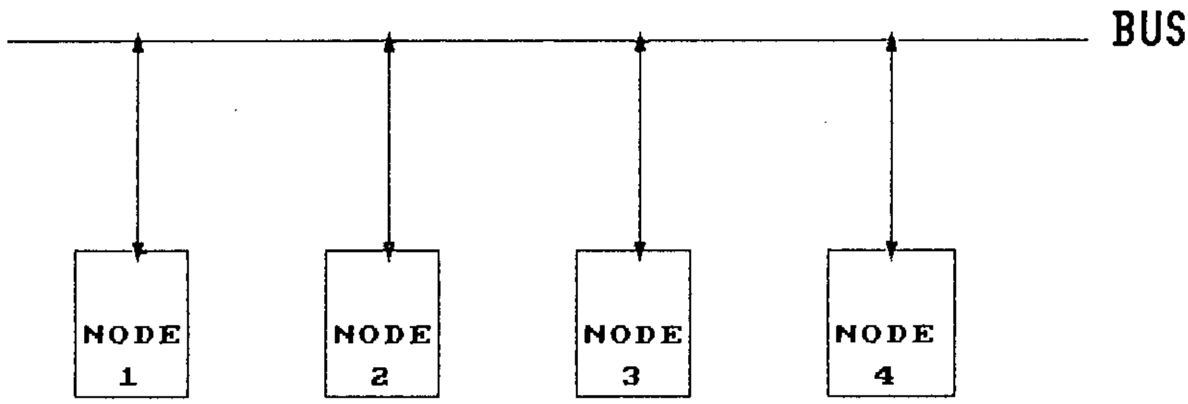


Fig. 1.4: Block Diagram of a Bus Network

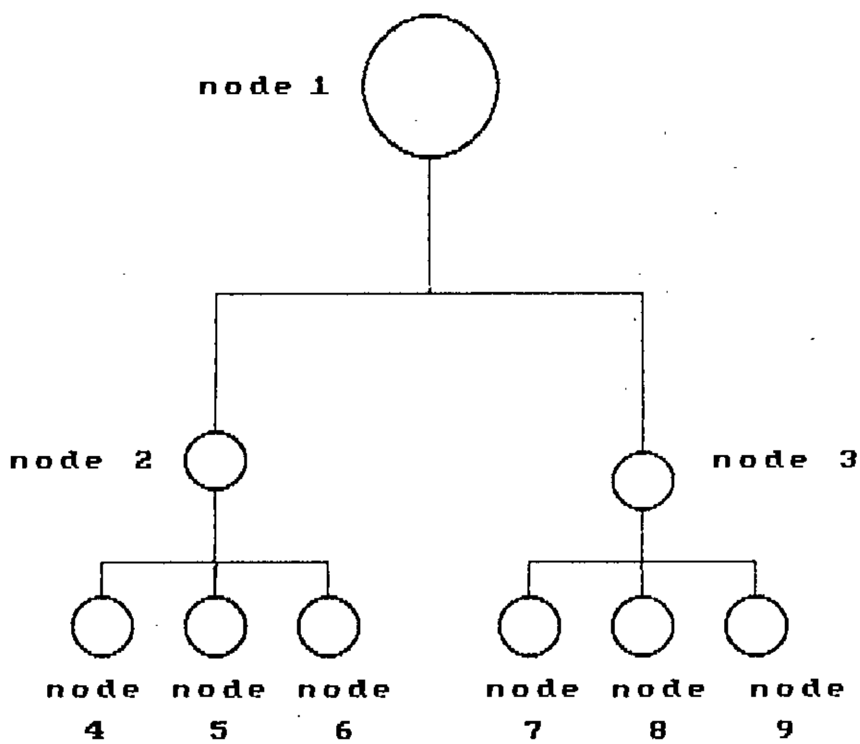


Fig 1.5: Block Diagram of Tree Structure

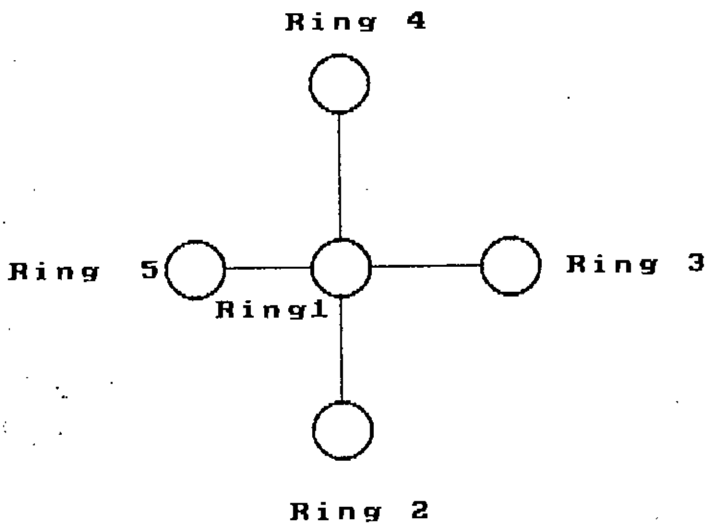


Fig. 1.6: Block Diagram of a Composite Network

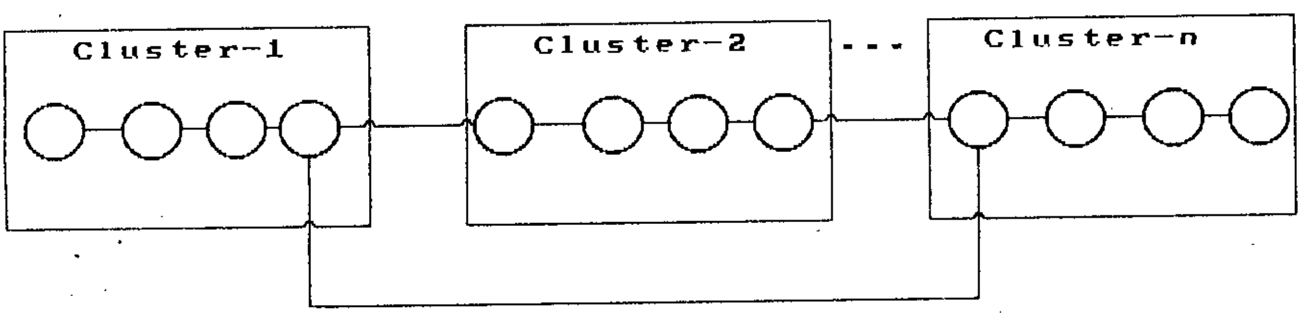


Fig 1.7: Block Diagram of a Hierarchical Network

capacities, network resources etc. Bridges, gateways etc. are used to interconnect different individual networks in a hierachical structure.

1.4 Communication Media

Network nodes are connected through transmission links. Selection of proper transmission media is a major part of network design. The different types of communication media are described below:

a) Twisted Pair:

The oldest and common transmission medium is twisted pair. A twisted pair consists of two insulated copper wires, typically about 1 mm thick [1]. The wires are twisted together in a helical form to reduce electrical interference between the similar two wires. The most common application of the twisted pair is the telephone system. Twisted pairs are used to establish both switched and leased telephone links. When a telephone connection is provided through one or more exchanges this is known as switched connection. On the other hand, if there is a permanent connection between two telephones, this is called a leased or dedicated link. Both types of links may be used for computer communication. The link speed depends on the thickness of the wire and the distance traveled. This speed is available in a wide range; from 55 bps to 6.3 Mbps [3].

b) Coaxial Cable [1,3]:

Coaxial Cable is another common transmission media. A coaxial cable consists of a stiff of copper wire as the core, surrounded by an insulating material. The insulator is encased by a cylindrical conductor. The outer conductor is covered in a protective plastic sheath. Two kinds of coaxial cables are widely used. These are: baseband cable and broadband cables.

i) **Baseband Cable:** 50 ohm cable which is used for digital transmission is baseband cable. The bandwidth in baseband cable depends on the cable length. For 1 km cables, a data rate of 10 Mbps is feasible. Higher datarates are possible if length of the transmission line is shorter. Baseband cables are widely used for local area networks and for long distance transmission within the telephone line.

ii) **Broad band cable:** 75 ohm cable which is used for analog transmission is broadband cable. Since broadband networks use standard cable television technology, the cables can be used upto 300 Mhz and can run for nearly 100 km. Broadband systems are normally divided into multiple channels, the 6 MHz channel is frequently used for television broadcasting. Each channel can be used for transmitting any one of analog television, high quality audio or a digital signal independent of the other channels.

Cables for the coaxial cable systems are of two types.

1) 1.2/4.4 mm (small diameter)

2) 2.6/9.5 mm (Large diameter)

On the basis of the method of sheath finishing above two types of cables are further divided into three types.

1) Cable duct use

2) Underground use

3) Aerial use

Typical 12 MHZ Coaxial Cable System of larger diameter provides a communication circuit with the maximum capacity of 1200 telephone channels and 1 TV video channel. The band of 1 TV video channel is equal to the frequency band of 1200 voice channels. So, if TV video signal is not transmitted then the capacity of the cable will become 2400 voice channels. Each voice channel occupies 4 KHZ. With the 12 MHZ coaxial cable system, a 60 MHZ system can easily be implemented by reducing the repeater spacing to 1/3 than that of the 12 MHZ system. Line equipment for coaxial cable system include terminal repeater equipment, dependent repeater equipment, remote supervisory equipment etc.. Maximum allowable distance between two repeaters is 4.5 km.

c) **Satellite Communication:**

Communication Satellites have some interesting properties that make them attractive for certain applications. A communication satellite can be thought of as a big microwave repeater in the sky. It contains one or more transponders, each of which listens to some portion of the spectrums, amplifies the incoming signal and then rebroadcasts it at another frequency to avoid interference with incoming signal. The downward beams can be broad, covering an area of hundreds of kilometers in diameter. To prevent total chaos in the sky, there have been international agreements about who may use which frequencies. The 3.7 to 4.2 GHz and 5.925 to 6.425 GHz bands have been designated as telecommunication satellite frequencies for downward and upward beams respectively. A typical satellite splits its 500 MHz band-width over a dozen transponders, each with a 36 MHz bandwidth. Each transponder can be used to encode a single 50 Mbps data stream, eight hundred 64 kbps digital voice channels, or various other combinations [1].

d) **Terrestrial Microwave Transmission:**

For long distance communication microwave radio transmission is widely used as an alternative to coaxial cable. Antennas can be mounted on towers to send a beam to another antenna tens of kilometers away. The higher the tower the greater the range. With a hundred meter high tower distances of hundred kilometers are feasible. The advantage of microwave is that building two towers is frequently much cheaper than digging 100 km trench, laying cable or fiber in it, and closing it up again. Laying the cable is not the only problem, repeaters along the way need to be installed, maintained periodically and cables can be broken due to various reasons.

e) **Optical Fiber:**

An optical fiber consists of a very fine cylinder of glass, called the core, surrounded by a concentric layer of glass, called the cladding. The glass in the cladding has a lower refractive index than the glass in the core. When a light ray passes from a medium with a higher refractive index to a medium with a lower refractive index, the ray is bent back toward the original medium. Hence, if a ray of light is launched into a fiber core at an angle greater than the critical angle, it is reflected back into the core by the cladding. The process is repeated as the ray travels down the core. In other words, the difference in refractive index between the core material and the cladding material guides the light ray from one end of the fiber to the other. The major components in an optical system include a transmitter which converts the electrical signal into optical signal, fiber which transmits the optical signal from the source to the destination and the receiver which converts the optical signal to electrical signal.

Because optical fiber possesses an extremely low loss per unit length and because it can carry very high data rates over long distances, Computer Network installations utilize them to carry signals over long distances without the need to store and retransmit information. This results in less delay and less cost for interface equipment. In a system using helium-neon laser (free space wavelength 0.63 micrometer, 4.7×10^{14} Hz) a bandwidth of 1% of the laser frequency would be 4700 GHz which is enough to carry nearly a million simultaneous television channels [6]. But nowadays the gas lasers are not used in communication system because they are physically large and power outputs range from milliwatts to megawatts [5]. Solid-state lasers are forefront of fiber optic technology at present. The solid state lasers are used both in short wavelength operatioon (800-900 nm) and long wavelength operation (1300-1550 nm) [5]. Optical communication has the following advantages over electrical communication.

a. Optical fibers have lower transmission losses and wider bandwidth as compared with copper wires. So, with Optical fiber systems more data can be sent over long distances, thereby decreasing the number of wires and reducing the number of repeaters (in co-axial cable) needed over these distances. The need for underground repeaters with associated problems for power supply and maintenance is largely elimininated.

b. The low weight and the small hair sized dimensions of fibers offer a distinct advantage over heavy, bulky wire cables in crowded underground city ducts. This is also of importance in aircraft where small light-weight cables are advantageous and in tactical military applications where large amounts of cables must be unreeled and retrieved rapidly.

c. Bulk material costs low. Because the main bulk material, silica, is more abundant and cheaper than the copper needed for guided electrical systems.

d. Optical fiber systems are not affcted by external electromagnetic fields. Thus the system is not vulnerable to crosstalk, interference or impulse noise.

e. Optical fiber is inherently difficult to tap [7]. This is why higher Security is available in case of optical communication.

f. No Communication licence is required. But in case of radio or microwave, one requires communication license.

1.5 Selection of Communication media

Using modem and utilizing the normal telephone line of Bangladesh Telegraph and Telephone Board data can be transmitted at kilobit/sec range. But with consideration of the increased Computer utilization of the users within the next five years it is required to transmit data at megabit/sec range, i.e. at least at the rate of 10 Megabit/sec or above if possible. Different Communication media has been discussed above. Because of the high data transmission capacity, high repeater less distance and the above advantages of optical fiber in comparison with electrical communication, optical fiber is chosen as the transmission media in this thesis.. Optical fiber is a recent technology in Bangladesh. A brief background and operational aspects of optical communication is described in chapter 4.

1.6 Statement of the problem

To provide the computer users network facilities and for the development of information technology and Computing Services in Bangladesh a study on setting up a computer communication network in and around Dhaka city is the major task of the thesis. Using modem and utilizing the telephone line of Bangladesh Telegraph and Telephone Board data can be transmitted at kilobit/sec range. But with consideration of the increased Computer utilization of the users within the next five years, it will be required to transmit data at megabit/sec range, i.e. at least at the rate of 10 Megabit/sec or above if possible. So, it would be required to consider co-axial cable or optical fiber in the design. The objective of this research is to produce a minimum cost design that meets all the requirements of the users and the whole problem is divided in the following steps.

a) All possible network configurations and communication media in network environment would be studied to choose the best configuration and transmission media for data communication in the final topology.

b) Collection of information regarding all possible resources in all mainframe installations, miniframe installations and important PC based installations in and around Dhaka city. Communication facilities available in T&T Board would also be investigated.

Based on the distances between different installations and market prices of fibers/cables and related interfacing equipment a cost matrix is to be developed.

c) On the basis of the above cost matrix a minimum cost spanning tree will be determined.

d) Based on the number of terminals and PCs in different installations, and the distances among the installations a traffic matrix will be obtained.

e) On the basis of the above network configuration and traffic matrix different important network parameters like delay, capacity etc. would be analyzed.

f) Inclusion of extra paths to gain higher reliability according to some standard heuristics (saturated cut heuristics).

g) Calculation of shortest path from any node to any other node of the above networks according to some standard algorithms (Dijkstra algorithm) and calculate different network parameters.

h) Determination of cost and delay for different network configurations. From this analysis it would be possible to choose the appropriate topology on the basis of maximum delay constraint and allowable budget.

i) If any suitable point to point topology is selected in the step 'g', the network would be inefficient with the increase of network nodes and number of users in each node. In that case a hierarchical structure would be a better solution for better utilization of line capacities and network resources. Techniques for selection of gateways and formation of clusters for hierarchical design would also be studied.

CHAPTER

TWO

PRESENT STATUS OF COMPUTERS AND NETWORKS IN BANGLADESH

PRESENT STATUS OF COMPUTERS AND NETWORKS IN BANGLADESH

Information is a vital resource like the other conventional factors like land, labour, capital etc.. Computer technology and telecommunication technology have merged to a single technology which is known as Information technology (IT). Information is a very powerful and revolutionary management tool, and exact and timely adoption of IT can vastly improve management and administrative efficiency by increasing speed and accuracy of decision making in all productive environment. Present status of Computers and networks in Bangladesh play an important role towards the generation of traffic in Dhaka city. Hence present status of computers and computer networks is to be considered before establishment of a computer communication network in and around Dhaka city. This chapter describes present status of computers and computer networks and recent developments of computer resources and applications in the country. Telecommunication facilities and utilization of telecommunication in computer data transfer is described in next chapter.

Though Bangladesh is lagging behind in computer technology from other developed countries like Japan, U.S.A., different organizations and people of Bangladesh are showing much interest in computer technology. Bangladesh entered the computer era in 1964 with the installation of an IBM 1620 Computer in Atomic Energy Centre, Dhaka [8]. Thereafter, until the late seventies there had not been much development towards Computerization in the country mainly due to nonavailability of financial resources. From the late seventies different public and private agencies, and educational and research institutions have started using computers. Further boost came with the advent of the microcomputer in the early eighties. Since then, a much greater number of public and private agencies have gone for computerization.

2.1 National policies and regulatory bodies

In order to coordinate and regulate the development of an efficient system leading to optimum utilization of computers in the country, a high powered National Computer Committee (NCC) with a cabinet minister as its chairman was set up by the government in 1983. Later the government has restructured the NCC and constituted the National Computer Board (NCB) with a corporate body and a full-time director. NCB has been further restructured and named as National Computer Council headed by the education minister as its chairman. In 1990 by the BCC Act of the parliament, Bangladesh Computer Council (BCC) was established to perform the following major functions [9].

a. To encourage the use of Computer and Information Technology (IT) for the socio-economic development of the country.

b. To help build-up Bangladeshi nationals to compete in the growing IT industry in the international market.

c. To encourage in developing human resources in the field of IT and organise manpower export in the international market.

d. To formulate and implement national strategies and policies related to IT.

e. To organise workshops, seminars and training courses on subjects related to IT.

f. To give grants to initiate or conduct research, study or training on subjects related to IT.

2.2 Computer Resources in Bangladesh

There are mainly three types of Computers in Bangladesh. These are mainframe computers, minicomputers and microcomputers. Uses of Local Area Networks (LANs) and Unix based multiuser systems are also increasing day by day.

Mainframe Computers

Twelve organization have mainframe computers. Among different organizations, Bangladesh Power Development Board and BUET each has two mainframes. So, in total there are fourteen mainframes in the country. Out of the different mainframe computers three computers owned by Bangladesh Bank, Adamjee Jute Mills Ltd. & BUET are of old model. The model number is 370/115. This model has only data entry stations but no terminals.

The name of the organizations which are the owner of mainframe computers and concerned brand and model are given below:

1. Bangladesh Atomic Energy Commission - IBM 4341.
2. Adamjee Jute Mills Ltd - IBM 370/115.
3. Bangladesh University of Engineering and Technology-IBM 370/115 and IBM 4331
4. Bangladesh Bureau of Statistics (BBS) - ES 9000.
5. International Centre for Diarrhoeal Disease and Research, Bangladesh(ICDDR'B) -IBM 4361
6. Bangladesh Bank - IBM 370/115

7. Dhaka University - IBM 4331

8. Sonali Bank - IBM 9373

9. Power Development Board - IBM 9375 and IBM 9373

10. Bangladesh Biman -IBM 9375

11. Islamic Centre for Technical and Vocational Training and Research(ICTVTR) - IBM 9373

12. American Express Bank - ES 9000

Out of the above fourteen Mainframe computers one computer owned by power development Board is in Chittagong.

There is a lot of uses of Minicomputers in our country. At least the following organizations, private companies and public sectors are using Minicomputers.

1. Arab Bangladesh Bank Ltd.

2. Agrani Bank.

3. Bangladesh Management Development Centre (BMDC).

4. IBM World Trade Corporation.

5. Eastern Bank (previous BCCI BANK).

6. IBCS-PRIMAX Software (Bangladesh) Ltd.

7. Beximco Computers Ltd.

8. Bangladesh Bureau of Statistics.

9. International Centre for Diarrhoeal Disease and Research, Bangladesh (ICDDRB).

10. Bangladesh Chemical Industries Corporation (BCIC).

11. Directorate of Primary Education.

12. Bangladesh Rural Advancement Centre (BRAC).

13. Phillips.

14. Lever Brothers, Chittagong.

15. Bangladesh Oxygen Ltd. (BOL).

16. Bangladesh Tobacco Company (BTC).

17. Bangladesh Internal Water Transport Authority(BIWTA).

18. Directorate of family Planning.

19. Grindlays Bank.

20. Jiban Bima Corporation.

21. Titas Gas Ltd.

22. American Express Bank.

23. Export Processing Zone (EPZ), Chittagong.

24. Jamuna Oil Company Ltd., Chittagong.

25. Padma Oil Company Ltd., Chittagong.

26. External Resource Division (ERD), Ministry of Planning.

27. Implementation, Monitoring and Evaluation Division (IMED).

28. Establishment Division, Ministry of Establishment.

29. House Building Finance Corporation.

30. Space Research and Remote Sensing Organization (SPARRSO).

31. Meteorological Department.

32. Pubali Bank Ltd.

33. Bank Indosuez.

34. American Embassy

35. USAID.

36. Hotel Sonargaon.

37. Investment Corporation of Bangladesh (ICB).

38. Social Marketing Company.

Some of the above organizations, like BBS, Bank Indosuez, SPARRSO, Meteorological department etc. have more than one miniframe installations. The IBM System/36 and system/34 are occupying the major field of mini computer world in our country.

Without the above two systems other brands include NCR 9400, IBM AS400, Honeywell HVS6PLUS, WANG VS100, VAX-11, MICROVAX 9000 etc.

Due to technological development and reduction of cost in PC field, avoiding tendency of mainframe or mini computers to the users is being observed now-a-days. Demand of local area networks and PC based multiuser systems are increasing day by day. At least the following organizations / companies are using LAN.

1. UNDP
   House # 60, Road # 11A
   Dhanmondi, Dhaka.

2. US-Aid
   Baridhara, Dhaka.

3. Standard Chartered Bank
   Motijheel, Dhaka.

4. ActionAid Bangladesh
   House # 9/4, Street-2, Shyamoli, Dhaka.

5. CSE Department, BUET.

6. Computer Science Department, DU.

7. SEDI S. A. Ltd.
   35 B/1, Indira Road, Dhaka.

8. British High Commission
   Baridhara, Dhaka.

9. Hotel Sheraton
   Shahbag, Dhaka

10. HRC Group.
    19th Floor, Senakallyan Bhaban.
    Motijheel, Dhaka.

11. Financial Sector Reformation Project (FSRP)
    9th Floor, Senakallyan Bhaban.

12. Millitary Directorate General of Medical Services
    Dhaka Cantonment, Dhaka.

13. Unidev Ltd.
    65-66 Motijheel C/A, Dhaka

14. EDP (Export Development Project)
    EPB, Metropolitan Chamber building.
    Motijheel, Dhaka.

15. SWMC (Surface Water Modelling Centre)
    House # 25, Road # 114, Gulshan, Dhaka.

16. World Vision of Bangladesh
    House # 27, Road # 16, Dhanmondi, Dhaka.

17. Continental Ltd.
    Islam Chamber, 125/A, Motijheel, Dhaka.

18. Leather Boards Ltd.
    65-66, Motijheel C/A, Dhaka.

19. Com Textile (H. K.) Ltd.
    House # 50, Road # 7, Banani, Dhaka.

20. Applied Computer Technologies Ltd. (ACT).
    23, New Eskaton Road, Dhaka.

21. Beximco Computers Ltd.
    House # 9A, Road # 2, Dhanmondi, Dhaka.

22. Bangladesh Public Administration Training Centre
    Savar, Dhaka.

23. International Fertilizer Development Corporation
    10, Dilkusha C/A, Dhaka.

All the above organizations/companies are using Novell Netware, except in US-AID where Banyan Vines is being used. Applied Computer Technologies Ltd. (ACT) is the authorized dealer of Novell Netware in the country.

There are more than 65 installations of Unix based multiuser systems. Some of the major clients/customers of Unix based multiuser system are as follows:

1. Tariff Commission.
2. Ministry of Defence.
3. Comptroller and Auditor General
4. Bangladesh Railway.

5. CSE Department, BUET.
6. Surface Water Modelling Centre (SWMC).
7. BSB (Bangladesh Shilpa Bank).
8. Ministry of Irrigation.
9. World Meteorological Organisation.
10. Bangladesh Computer Council.
11. Development Design Consultant (DDC).
12. Bata Shoe Company Ltd.
13. Square Pharmaceuticals Ltd.
14. Desktop Computing Ltd.
15. Computer Solution Ltd.
16. Flora Ltd.
17. The Computers Ltd.
18. Beximco Computers Ltd.
19. IBCS Primax Software (Bangladesh) Ltd.
20. Technohaven Co. Ltd.
21. Bangladesh Rice Research Institute (BRRI).
22. Institute of Scientific Instrumentation.
23. Bangladesh Forest Industries Corporation.

Technohaven Co., 4/2, Block-A, Lalmatia is the authorized dealer of Unix in the country.

Unlike mainframe and minicomputers, it is extremely difficult to find out the exact number of micros being operated in the country. There are many orgainzations in the private sectors including some foreign consulting engineering firms, who import it directly from foreign countries. However, a rough estimate would put the number of micros in the country at about seven thousand. A few companies are related to Software export. Software for export purpose are being developed in microcomputers. Mainframe and minicomputers in the country are normally maintained only by local representatives of the concerned company at a high rate of maintenance cost. The microcomputer scene in Bangladesh is at present dominated by different models of IBM PC or compatibles. The easy adaptability of apple macintosh micros of Bangla Wordprocessing has made it quite popular, particularly in Desktop publishing. Their number is growing fast. Different organizations, commercial people, educational institutions, research centres are increasing their use of microcomputers. Even many students in the country have their personal microcomputer for their study purposes. There are a lot of microbased network and multiuser systems in the country. Novell is dominating in PC LAN (Local Area Network) field. PC based multiuser systems are dominated by UNIX. A lot of organizations like national board of revenue, Bangladesh computer council, FAO, Prime Minister's secretariat, IFIC Bank, UNDP, British Council, Hotel Sheraton etc. have more than ten microcomputers. Software resource in the country is also getting rich day by day. Network software, multiuser software, 4 GL (Cross System Product-CSP is a 4th generation language (GL), being used by PDB) and 4 GL RDBMS (ORACLE is a 4 GL relational data base management system (RDBMS), being used by Biman) are being used by different organizations. These software are being marketed by local vendors. Banks, airlines, different government and autonomous bodies and different foreign organizations are developing and using efficient application softwares.

2.3 Applications of Computers in Bangladesh

At present there is no national level information system at the inter-ministerial level, any such system has not yet been planned for the near future. There are, however, several national level information systems at the ministerial /departmental level. In a strict sense very few of this systems can be recognized as information systems that support decision making directly like artificial intelligence or expert system. But information is available on hard copies and these are used in national planning, project planning, system planning, project management and also in decision making process.

Computer uses in public sectors :

Most applications in the public sector are concerned with the sophisticated administrative systems such as computer -billing, accounting, inventory control, pay roll, personnel and record management. The computer mainly functions primarily as a high speed tabulating equipment. A few public sector agencies have, however, moved into advanced computer applications in the fields of engineering, statistics, project planning, system planning, control and very recently computer aided design. Banks in the country are rapidly going for computerization. Many banks, such as, American Express Bank, Arab Bangladesh Bank, Eastern Bank (Previous Bank of Credit and Commerce International(BCCI)), Islami Bank, Agrani Bank have already started on line banking service with their customers. Some airlines and travel agencies are moving fast towards computerization. A few uses of computer in the public Sectors are illustrated as follows:

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY (BUET):

All Departments of BUET have their own microcomputers. Computer science and Engineering Department has about 100 microcomputers. The Department has recently installed a local area network (Novell Netware 3.11). All the microcomputers remain always busy by the undergraduate, postgraduate students and teachers of the department for their thesis, research and home works. Normally different programming languages like Assembly, Pascal, C, Fortran, Prolog and different package programs are used. BUET has two mainframe computers (Model No 370/115 and 4331), a RISC 6000 and a number of microcomputers in its computer centre in Civil Engineering building. The Mainframe computers in the computer centre is mainly used for different administrative work of the university, research and thesis works of the fourth year and postgraduate students. Different organizations outside BUET are also getting services from BUET Computer centre through the Bureau of Research and Technical Consultation (BRTC) of the university. By doing such work the university earns a lot of money from different public and private organizations. BUET computer centre also offers different short courses to outside people.

DHAKA UNIVERSITY

Dhaka University has a mainframe computer (Model No: 4331) under the management of the computer centre and the university has numerous microcomputers in its Institute of Business Administration and department of Science and Biological Science faculties. The mainframe computer is mainly used for the research work of the university. The students also work on different high level languages. The Institute of Business Administration offers different courses on application packages at times. The MBA students are to use computers to solve their assignments for the fulfillment of requirements of their Degree. Dhaka university has recently opened Computer Science Dept.

BANGLADESH BUREAU OF STATISTICS (BBS)

The Bureau of statistics is one of the pioneering Government Organizations having computerized data processing centre in the public sector. BBS has recently upgraded their IBM Mainframe 4341(which replaced the IBM 370 installed at 1973) to ES 9000. BBS has some mini computers also, the Bureau processes the census data and is also responsible for providing statistics related to population, labour, agriculture, national accounts etc. to meet the needs of planning and policy decisions in the government, semi government and autonomous organizations.

BANGLADESH BANK

In 1980 Bangladesh Bank installed an IBM 370/115 computer. The Bank also has some microcomputers. The Bank uses the computers for a variety of jobs that include accounting and reconciliation for nationalized banks, banking information system, personnel information system, credit information system, provident fund, salary etc.

ESTABLISHMENT DIVISION

The Establishment Division under the ministry of establishment has installed a Honeywell DPS6/85 minicomputer system to maintain personnel information of the civil servants in the country. The first phase of the computerization of data covered 4000 officers under the ministry of establishment.

IMPLEMENTATION, MONITORING and EVALUATION DIVISION(IMED)

This Division of the ministry of planning is entrusted with the responsibility of monitoring all public sector projects in the country. IMED was created in 1975 as project implementation Bureau. An IBM system 34 and some microcomputers are currently being used to process data related to all projects included in the Annual Development Programme. IMED supplies necessary information about financial and physical progress of the projects, unapproved spendings, implementation difficulties etc. for reviewing in meetings. The division also supplies similar information to the national economic council to review the progress of the Annual Development Programme. A recent study has suggested that a large and faster computer would be necessary.

EXTERNAL RESOURCE DIVISION (ERD)

The external resource division is responsible for dealings with mobilization, co-ordination and monitoring of all external aid in Bangladesh. ERD has developed a computer based accounting of aids and monitoring system using minicomputer and microcomputers with UNDP assistance. The system is used to maintain information on commitments of loans, grants, their actual disbursement by donors to executing agencies, outstanding debt, interest due and actual debt payments. The system is also used to prepare budget for annual utilization of aid, debt servicing, for making projections of debt payments and outstanding debts. An IBM System 34 and some microcomputers are being used for these jobs.

SPACE RESEARCH AND REMOTE SENSING ORGANIZATION (SPARRSO)

SPARRSO uses its minicomputers (Model VAX-11/750 and MICROVAX 3400) and microcomputers for the processing of remote sensing data obtained from satellites. These provide valuable information for planning and design of different development projects in the country.

METEOROLOGICAL DEPARTMENT

Meteorological department has two minicomputers and a number of microcomputers. They receive different data through satellite and radar, process these and provide weather and flood forecast information.

BANGLADESH BIMAN

Bangladesh Biman has a mainframe at its Motijheel Head office. The model number is IBM 9375. Biman has recently bought a RISC 6000 for inventory control. The application software for inventory management is being developed with Oracle by IBCS-Primax. The organization is maintaining its reservations, personnel, accounting jobs by the computer. Biman is also getting computer service from an international agency, **SITA** (Society de International Telecommunications Aeronautics).

JUTE INDUSTRY

Jute industry is the largest sector of industry and it introduced computerization with the installation of an IBM 1401 in the Adamjee jute mills ltd in 1970. The company now uses an IBM 370/115 computer. Besides the usual applications in financial accounting, salary and provident fund statements, computer uses have been extended to inventory control for about 70 jute mills. The computer is also used for management of export system, production efficiency, quality control and management information system. The computer centre is also shared by other public sector agencies.

MINISTRY OF IRRIGATION, WATER DEVELOPMENT AND FLOOD CONTROL

The planning cell in the ministry uses microcomputer based system for project planning and monitoring. Data on all projects and subprojects included in the annual development programme are maintained. An on-line database for monitoring the progress of food- for- work scheme is also maintained. Water development board under the ministry has a separate microprocessor based information system for monitoring the progress of food- for-work schemes under the administrative control of the board. The Board has recently installed a large number of micros under the CIDA grant. These micros are linked through a LAN, which acts as a nucleus for the Data Processing centre. Different Foreign consultants are working on the FAP (Flood Action Plan) project under the guidance of the ministry. These firms are involved in huge computer use for their research works. SWMC has about 40 pcs which are interconnected by six servers.

LOCAL GOVT. AND ENGINEERING BUREAU (LGEB)

The local government each year allocates grant to the 460 thana parishads of the country to carry out local level development works. A major share of the grant is spent for different types of public works. The LGEB with the micro based system at Dhaka maintains a data base for these works for the purpose of monitoring the projects.

HOUSE BUILDING FINANCE CORPORATION

House building finance corporation has a minicomputer (model no. NCR tower 32-700) with 12 terminals. Different important uses include provident fund, financial and accounting applications, house building advance etc..

JIBAN BIMA CORPORATION

Jiban bima corporation has an IBM System/36 minicomputer. Different programming languages used here include Fortran, Cobol, RPG-II etc.. Different applications of computer are: payroll system, personnel/leave database system, provident fund system, collection system, house building loan, policy loan, fixed deposit, bank reconciliation etc.

NATIONAL BOARD OF REVENUE (NBR)

National Board of revenue has about 40 PCs in their Segunbagicha office. Different reports regarding collection of revenue are prepared by these computers. They also maintain revenue collection related databases.

DEPARTMENT OF NARCOTICS CONTROL

This department has a unix based multiuser system with one server and about 14 terminals. Out of these 14 there are 3 intelligent terminals. These computers are used for maintaining statistical database regarding narcotics control and for providing management query.

BANGLADESH POWER DEVELOPMENT BOARD (PDB)

PDB has been using microbased information system from the very beginning of availability of microcomputers in the country for load flow study and other technical purposes. In 1990 PDB has installed two mainframe computers in its Dhaka and Chittagong office with 29 and 15 terminals respectively. These two mainframes (IBM 9375 and IBM 9373) are mainly used for billing and personnel management system. PDB has its future plan to computerize its billing system, payroll, Inventory, Accounts, Finance etc. in other major divisional and district towns.

In addition to the above mentioned organizations almost all public sectors have started computer information and management system. Our government is also taking proper steps for the development of computer technology in the country. BCC has recruited different computer personnel and offers different computer related courses to government officers of different departments. Bangladesh Computer Council formulates strategies and policies to develop computer application in the country. It is expected that utilization of computer would increase in public sectors day by day. There is a possibility of local and foreign investments in computer industry in Bangladesh for setting up export oriented computer industry in the country. Some of other public sectors, where computer is being used, are:

1. Tariff Commission
2. Controller and Auditor General of Bangladesh
3. Banga Bhaban
4. Parliament Secretariat
5. Bangladesh Railway
6. Ministry of Land Administration
7. Bangladesh Public Service Commission
8. Bangladesh Rice Research Institute
9. Bangladesh Forest Industries Corporation
10. Bangladesh Shipping Corporation
11. Bangladesh Planning and Development Academy.
12. Ministry of Defence
13. Trading Corporation of Bangladesh
14. Bangladesh Trade Mark Registration
15. Public Administration Training Centre.
16. Bangladesh Navy

17. All Universities/ BITs

18. BADC

19. Bangladesh Airforce

20. National Security Intelligence

21. BOGMC (Bangladesh Oil Gas and Mineral Corporation)

22. Janata Bank

23. Rural Electrification Board

24. Bangladesh Fisheries Development Corporation

25. Security Printing Press

26. Forest Research Institute, Chittagong

27. Bangladesh Forest College, Chittagong

28. Bangladesh Food and Sugar Industries Corporation

29. Bangladesh Shilpa Rin Sangstha

30. Institute of Chartered Accounts of Bangladesh

31. Bangladesh Krishi Bank

32. Chittagong Port Authority

33. Dhaka WASA.

Applications of computers in international and foreign organizations and in NGOs:

Different International organizations like UNDP, WHO, FAO, ADB, World Bank, International Jute Organization, International Labour Organization(ILO), International Civil Aviation Organization, ICDDR'B etc.; different foreign organizations like British Council, United States Information Services, American Life Insurance Co., different airlines, different embassies etc.; different NGOs like BRAC, The Ibn Sina Trust, CARE, Rabeta, Social Marketing Company, South Asian Partnership, World Vision of Bangladesh, Swanirvar Bangladesh, Comilla

Proshika etc. are using computers for office automation, to follow up progress in different projects, to retrieve and update different statistical information for decision and policy making. Most of them are users of microbased systems. But some of them (ICDDR'B) have mainframe computers, while others e.g. BRAC, USAID, US Embassy, Social Marketing Company have mini computers.

Applications of computers in private sectors:

A major usage of computers in private sector is in private commercial Banks and different consulting firms. These applications include business application, engineering drawing, accounting, wordprocessing application etc. All the foreign banks and some local private banks have developed mini or microcomputer based systems. Arab Bangladesh Bank is using remote terminals via leased voice grade telephone networks of the telegraph and telephone Board. They are transferring data among their Motijheel branch, Kawran bazar branch, Kakrail branch etc.

There are a lot of local computer firms, like Beximco Computers Ltd., Concept, Datec, Unidev Ltd., Technohaven Co., Desktop Computer Connection Ltd. etc. who are selling computers and softwares. They also provide maintenance services and training to the customers. These firms are using computers for software development for their customers and for training purpose. Hundreds of people are obtaining training in these computer firms on different package programs and programming languages.

Recently computers have found their applications in the private industries as well. some of the jute and textile mill owners have introduced microcomputers in their factories mainly for personnel management and accounting. Micros are also being increasingly used in managing the garment industries. BGMEA (Bangladesh Garments Manufacturers and Exporters Association) has established a computer communication facility with different international trade organizations to know their requirement status, to inform them present stock condition and other garments export related information. Some of the multinational companies, particularly the pharmaceutical sectors have computerized their management operations. Some engineering product manufacturing firms have recently made efforts to improve the quality of products through computer aided design. Maximum users in the private sector are the users of microcomputers.

Marketing of Computers

Marketing of mainframe computers are mainly dominated by IBM World Trade Corporation. Minicomputers are marketed by IBM, NCR corporation, Techvalley corporation etc.. Recent developments in microcomputers have decreased the tendency of users to buy mainframe or minicomputers. Users are being attracted to microcomputer based multiuser systems, micro based local area networks and stand alone PCs. There are dozens of vendors in microcomputer field. Among the vendors some are: Beximco computers Ltd, IBCS-PRIMAX, Technohaven Co. Ltd., Desktop Computer Connection, Flora ltd., Datec Ltd. etc.. From the beginning of microcomputer applications, vendors were mainly involved with hardware sales and application software development. There were no authorized dealer for most of the system software. Recently, interests are being observed on marketing of system software. Technohaven company is authorized dealer of UNIX operating system, IBCS is selling ORACLE software. ACT (Applied Computer

Technologies) is marketing Novel operating system. Some vendors have developed Bengali Softwares (Anirban, Abaha, Shahid lipi, Basundhara, Barna, Bijoy etc.) also and they are marketing these products. Spreadsheet with limited facility in Bengali language is already available. Works on development of database language in Bangla is going on. Publication and printing companies are using computers for compose and printing of books, journals, newspapers etc.

Computer Education

Formal academic education started first in BUET in postgraduate level from 1984. Now there are undergraduate programs in BUET, Khulna University, Jahangirnagar University, Sylhet University and in North South University. The first batch in Computer Science and Engineering department of BUET will complete their B.Sc. Engg. degree in or about November '93. Dhaka University has started postgraduate courses in Computer Science department. Courses on Computer are being taught in many institutions as special subject. Education Board has introduced optional courses on Computers in S.S.C. and H.S.C. level also. Besides these some private organizations are offering different diploma courses and short courses on computer.

CHAPTER

THREE

PRESENT STATUS OF TELECOMMUNICATION IN BANGLADESH

PRESENT STATUS OF TELECOMMUNICATION IN BANGLADESH

Information plays a vital role in socio-economic development. Information has been identified as knowledge or human capital. Telecommunication as a means of information transfer contributes to the socio-economic development of the country. Moreover, Present status of telecommunication in a country plays an important role to the development and establishment of computer communication network in that country. So, the importance and necessity of adequate and efficient telecommunication system need no explanation. It is a precondition to any development activity of a country. Most of the countries have given very high priority to telecommunications in their national life. To plan about the establishment of a widearea computer communication network, it is required to consider the existing telecommunication facilities and future plan or projects in telecommunication field. A study regarding utilization of telecommunication facilities in computer communication should also be investigated.

3.1 Chronological Developments in Telecommunication in the country [11]

At present there are only two telephones per thousand people in the country [10]. This is one of the lowest in the world. From the example and experience of other developed countries it is clear that the telecommunication sector in Bangladesh should be given proper importance and priority in its national life and national investment plan. In that case not only the telecommunication of the country will improve, but it will enhance the human development and total development of the country. The present status of telecommunications should be developed in a rapid way to fill the gap between the demand and supply of telecommunication facility. However, this present position is achieved in step by step and the chronological evolution of telecommunications in Bangladesh is as follows[11]:

* The first Telegraph line between Dhaka and Calcutta was established in 1858 and the telephone act was promulgated in 1885.
* The first manual telephone exchange in Dhaka was installed at Ramna in 1920 which was expanded to 200 lines in 1940 and to 360 lines by 1947.
* The first automatic telephone exchange of 2000 lines capacity was installed in 1954 by replacing the manual exchange at Ramna, Dhaka.
* With the installation of a 3000 lines EMD (Edel Metal Dewheeler - Rotary Analog) exchange at Sher-e-Bangla Nagar in 1969, Dhaka came under multiexchange system.
* The first satellite earth station of the country was established in 1975 at Betbunia.

* The number of telephone lines in the country was 60,000 in 1971, which was expanded to 109,000 lines by 1982.
* Coin Box public telephone system was installed in 1980.
* The digital technology was first introduced in the country with the installation of digital telex exchange in Dhaka in 1981.
* The second satellite earth station of the country was established in 1982 at Talibabad.
* Three digital trunk exchanges and one international Trunk exchange (ITX) was installed in 1983.
* The digital telephone exchanges with fiber optics multiexchange junction network was first commissioned at Dhaka in 1990.
* Paging system and mobile telephony has been introduced in limited capacity by private enterprises in 1990-91.
* The first long distance digital microwave link was installed in the Dhaka-Khulna route in 1991.
* Magnetic card pay phone with ISD (International Subscriber Dialling) facilities was first installed in 1992 at Dhaka and with gradual expansion in all major cities of the country by TSS (Telephone Shilpa Sangstha) in joint collaboration with BTTB (Bangladesh Telegraph and Telephone Board).
* Cellular telephone is inaugurated in august'93.
* The present installed capacity of the telephone exchanges in the country in 1993 is 264,000 lines and the working connections is about 241,000 lines. The capacity of the telex exchanges in the country is 8800 lines of which 2400 lines are in operation [11]. Data transmission circuit has been commissioned with some overseas countries. A modern high capacity satellite earth station is going to be installed at Mohakhali, Dhaka.

3.2 Present status of telephone network in Dhaka city [12]

The total installed capacity of telephones in Dhaka multiexchange area is, at present little over 131000 lines in 10 exchange areas. The exchanges are nearly full and large demands are pending in almost all the exchanges. The present status of the exchanges with actual connections and demands are given below:

Sl. No.	Name of the Exchange	Capacity in lines	Type	Working Connections	Pending demand
1	Central	13,000 20,000	F1* EMD	32,892	28,175
2	Moghbazar	19,500 5,120	EMD Digital	19,400 5,047	14,398
3	S.B. Nagar	17,000 6,500	EMD Digital	16,719 6,036	8,613
4	Nilkhet	10,000 6,000	EMD Digital	9,912 5,441	4,320
5	Gulshan	10,000 5,500	EMD Digital	9,663 5,047	5,152
6	Mirpur	4,000 4,000	EMD Digital	3,468 3,998	6,959
7	Uttara	4,000	Digital	3,596	355
8	Tongi	1,100	EMD	954	416
9	Narayanganj	4,000 1,000	F1 EMD	4,200	2,183
10	Zinjira	450	C.B.**	448	
	Total	131,170		126,901	70,562

* F1 = Rectangular motion analog switches
** C.B. = Central Battery

Out of the above 4000 lines in Narayanganj and 13000 lines in Central exchange using F1 switches were installed at various times from 1954 to 1971. The C.B. exchange at Zinjira came into operation from 1972 with 100 lines which was subsequently extended to present 450 lines. The old analog switches of the above exchanges are constantly under heavy pressure, the resultant wear and tear on the contact banks and on the moving parts, wrong speed of switches, noncontact or no contact on the contact banks, burning of magnet and relay coils are quite inherent. Maintenance personnel are constantly engaged in removing the faults or repairing/replacing the faulty parts. Moreover the traffic generated by the subscribers are quite high. As a result congestion exists in almost all the exchanges during busy hours. Introduction of limited NWD (Nation Wide Dialling) systems in a number of stations with insufficient NWD circuits, also causes repeated call attempts, adding further rise to the existing congestion problem. The solutions to these problems are large scale expansion of telephones preferably by systems with nonmoving parts, i.e. digital system, timely replacement of old exchanges, provisions of adequate NWD ckt, improvement and expansion of inter-exchange junction circuits etc.

3.3 Advantages of Digitalization [13]

In comparison to analog system there are a lot of advantages in digital system. The modern world is advancing towards cost effective and compact digital system from previous analog system. It is a news of pleasure for Networking in Bangladesh that BTTB has bought NEAX-61E digital local exchange. It has been installed at Sher-e-Bangla Nagar. BTTB has started to arrange data communication channels for networking in the country. Arab Bangladesh Bank (AB Bank) has already established a data communication network among their Motijheel branch, Karwan Bazar branch, Kakrail branch etc. with the help of telecommunication facility of BTTB. IBM world trade corporation has established their network line with Singapore and other foreign branch offices of IBM using the telephone line of BTTB. Recently American express bank has established data communication link between their Dhaka branch and Singapore branch through leased line from BTTB. Bangladesh Garments Manufacturers and Exporters Association (BGMEA) transfers data and files to different foreign trade companies and receives the same utilizing T&T line. SITA and Some international organizations like UNDP, World Bank are using dedicated international channels from BTTB for data transmission. Data transmission technique using T&T line is briefly described in section 3.5.

BTTB has a plan to move towards digitalization by removing present analog control in step by step. The problem of ghost billing can very effectively be combatted by digital technology. In the digital exchanges there can not be any meter tampering as there is no physical meter at all. The details of a call are recorded in a computer which can not be easily accessed for tampering and have a built in security system and passwords to prevent any misuse. Due to the following main points in favour of a Digital exchange in comparison to a electro-mechanical exchange, BTTB is trying to move towards digitalization.

1. Less space requirement.
2. Higher reliability and speed.
3. Easy operation and maintenance.
4. Due to the extensive use of digital exchanges, the cost of the exchange tends to be cheaper than its counter part.

5. Traffic data are available to understand the loading of the exchange; e.g. in which route how many calls are handled, how many calls fail for what reason etc. Exchange records the details of any call and that can be printed.

6. Using password, subscriber can easily prevent his/her telephone set from different types of calls by unauthorized person.

7. The digital exchange is very accurate and completed. Normally a fault of fundamental nature is not expected.

8. Automatic checking of subscribers' lines is possible.

9. Flexibility in Operation is easy. Different types of announcement like wrong code dialling, Route busy etc. can be made available. Different facilities (like ISDN, ISD, NWD) can easily be provided and revoked.

10. More detail information about a subscriber's outgoing and incoming call can be obtained. From the subscriber's premises BTTB staff can test some items like ringing function, Dial speed, insulation resistance, Push button dial speed etc.

11. Call completion to some important busy number is possible. A digital subscriber dialling 17, 18, 12 (Police), 13 (Fire Brigade) etc. may find the line busy but can hold on. When the line becomes free he will be automatically connected. In case of overload on the exchange, priority subscriber can get preference.

12. Controlling is very much easy. Multimetering can easily be introduced. Numbering plan can be very easily changed simply by software. By simple command, Subscribers' facilities /attributes can be changed. Charge data can be easily dumped.

13. Calls can be easily routed to the alternate routes.

14. There are other special facilities (abbreviated dialling service, hot line, call transfer service etc.) which can be provided to only some limited subscribers at higher rate of payment.

3.4 Status of Digitalization [13]

Dhaka north has 26000 digital lines in seven exchanges out of which one is tandem that connects the other six exchanges. This 26000 line project is commissioned in 1990. In future when traffic will increase, direct connection between exchanges may be done and the tandem may be used to cater for only the traffic of alternate route. Digital to digital, digital to analog, analog to digital calls are in general routed through the tandem. For digital to analog calls, when both exchanges are located in the same building, are routed directly.

Final capacity of different exchanges has been decided to be as following although more will be possible by increasing the number of CPUs [13].

Exchange Name	Initial	Final
Moghbazar	4000	30000
Nilkhet	5000	20000
Shere-Bangla Nagar(SBN)	5000	30000
Mirpur	4000	20000
Gulshan	4000	20000
Uttara	4000	20000

Digital exchanges are connected through optical fibre. At present the optical fibre can carry 140 M bits/sec. BTTB has a future plan to transmit between exchanges at a speed of 565 M bits/sec. The fibre network data are as follows[13]:

Route		length (km)	No of cores Act	SBy	Spare	Remarks
SBN	-Uttara/Tongi	17.9	(1+1)	(1+1)	8(4 Tongi)	One core
	-Mirpur	6.3	(1+1)	(1+1)	4	Carries
	-Gulshan	5.6	(1+1)	(1+1)	4	140 Mbits
	-Moghbazar	3.7	(1+1)	(1+1)	8	i.e.1920
	-Nilkhet	4.4	(1+1)	(1+1)	4	channels
	-Central	7.2	(1+1)	(1+1)	6	
			(1+1)			

To cope with the larger number of accelerate pending telephones subscriber demand in southern part of Greater Dhaka Metropolitan area and to complete the Greater Dhaka Junction Network another project has been taken by BTTB. The project is expected to be completed within 1996 and will provide digital exchanges of 60,000 lines to be installed in seven local exchanges. Name and capacity of these exchanges are mentioned as follows:

Name of Exchanges	Capacity(Lines)	
Central V	12,000	
Narayanganj	10,000	
Zinjira	5,000	
Chowkbazar	10,000	
Gandaria	10,000	
Savar	3,000	
Bashaboo	10,000	
Central Tandem	12,000	(Trunk lines)
60,000 lines +12,000 Trunk lines		

Digital Switching system was first introduced in Nation wide Dialling in December 1983 in Bangladesh. For the purpose four computer controlled Trunk Automatic Exchange (TAX) were installed at Dhaka, Bogra, Khulna and Chittagang. Dhaka TAX can now handle 4200 voice circuits and four (duplicated) CPUs are in it's hardware. Similarly Chittagang, Bogra and Khulna handle 1800, 1300 and 1100 voice circuits respectively and each TAX has 1 (Duplicated) CPU. Also International Trunk Exchange(ITX) having digital switching system was set to work from December 1983. This exchange is in Moghbazar Telephone House. At present it is equipped for 550 circuits. The system has two CPU (Duplicated).

Throughout the world the digital technology is gradually replacing the analog technique because it can cater multifarious services and activities in telecommunication field which could not be even imagined earlier. With this view BTTB has taken up to install initially 20,500 lines digital switching system having ISDN compatibility in greater Chittagang city. The proposed digital switches and Tandem will be installed in five switching centres in the multiexchange area with several remote switching units. The exchanges and the remote switching units will be connected by optical fiber cables. ISDN compatibility shall widen up the future opportunity to integrate telephone, data transmission, facsimile and other audio and video telecommunication services etc. The project is expected to be completed within 1996.

BTTB also plans to install digital switching network in Rajshahi region making a provision for 50,000 subscribers lines. Under the guidance of BTTB rural area is also being provided by digital switching system and three private organizations have undertaken this work. Cellular telephone system is already introduced.
In order to improve telecommunication system for the rural area, BTTB identified the necessity of improving transmission network first as a prerequisite for stable communication. BTTB experienced difficulty in maintaining land lines in rural areas. Maintenance of physical lines is difficult as no good road is available. During flood, road communication is cut-off and long period of interruptions are observed. Man made damage and damage due to storm and other natural forces also cause long interruptions. Cost of constructing metallic land line has also gone up quite high. Therefore, BTTB could not choose land line for stable communication. Similarly underground cable could not be chosen due to river, canals etc. So radio mode communication remained as the only option for rural transmission network. BTTB has undertaken different projects with digital transmission system. These are mentioned below[13]:

1. **Rural project :** Under the project 135 thanas will be connected with their 24 district towns by digital UHF radio links. Bell ITT is supplying the digital UHF radio links of 8 MB (120 Channels) system in 1.9 — 2.1 GHZ and 2.1—2.3 GHZ bands. Work under this project is progressing rapidly and expected to be completed by the end of 1993.

2. **Upazilla Project :** Under the project 135 thanas in 27 districts will be connected with their district towns by digital UHF radio links. NOKIA Co. LTD. of Finland is supplying the radio equipment. The radio has a capacity of 60 channels(4 MB). The radio will work at 2.4-2.6 GHZ. The project work of this project is also progressing rapidly and will be completed by 1993.

3. **89 Upazila Project :** Under the project 71 thanas in 11 districts and 18 important places in 17 districts will be connected with their district towns by digital UHF link. The project work is under progress and will be completed within June' 1994. This project is being financed from a French Credit.

4. **Dhaka-Khulna M/W Project :** Under the project digital M/W link will be established between Dhaka-Khulna and Magura-Kushtia. This will be a 140 MB system with the possibility of 565 MB in future and this project will be completed within 1993.

5. **Dhaka-Sylhet M/W :** Under the project Dhaka-Sylhet digital M/W link and Dhaka – Mymenshing Bogra digital M/W link will be established. These will be also 140 MB/sec system and the project will be financed from French Credit. It is expected that the project will be completed within June'94.

In the northern part of Dhaka 26,000 line digital telephones were installed 3 years back and addition of another 5000 line have recently been done, provision has now been made to expand the six digital exchanges by another 18,500 lines including additional CPU where necessary and additional inter-exchange junction equipment [12]. The work is being funded and executed from Renewal and Replacement (R&R) programme. Public data network project and Computer project are in the very preliminary stage of BTTB.

Telephone Shilpa Sangstha (TSS) has drawn up a scheme to expand telephones in the country on Built Lease Transfer (BLT) basis. On this scheme provision has been made to expand telephones by 130,000 lines in the country out of which 80,000 are in Dhaka [12]. The five out of six existing digital exchanges except Uttara have been brought under this scheme. For this, tender has been floated and offers are received. Formalities for awarding the contract is going on. Similarly there is also an active consideration to take up a crash programme to replace existing Central exchange switches by digital system. However the methodology and funding of this proposal is yet to be worked out.

3.5 Data transmission technique using T&T line

A modem is required to communicate between the terminal/computer and the telephone system. A modem (for modulator-demodulator) is a device that accepts a serial stream of bits as input and produces a modulated carrier as output (or vice versa). The modem is inserted between the computer and the telephone system. The interface between the computer or terminal and the modem is a physical layer protocol. Well-known physical layer standards are RS-232-C and RS-449. In these standards the terminal or computer is known as DTE (Data Terminal Equipment) and the modem is called a DCE (Data Circuit-Terminating Equipment). The block diagram of data transmission between two terminal/computer via T&T line is shown in figure 3.1 and some main RS-232-C circuits are shown in figure 3.2 [1].

Different available modems in the market have different maximum speed (bps). The common values are 1200, 2400, 4800, 9600, 14,400, 19,200. Different modulation techniques used are amplitude modulation, phase

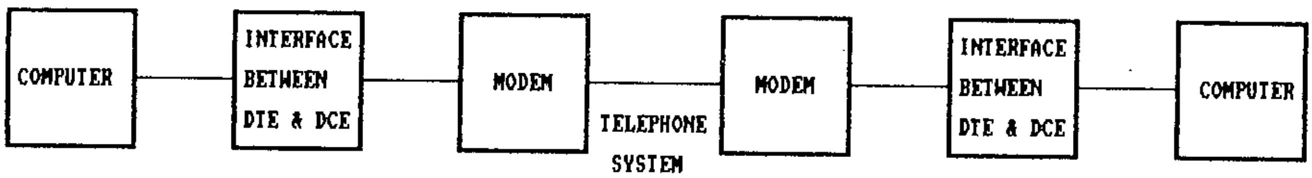


FIG 3.1 : BLOCK DIAGRAM OF DATA COMMUNICATION BETWEEN TWO COMPUTERS VIA T & T LINE.

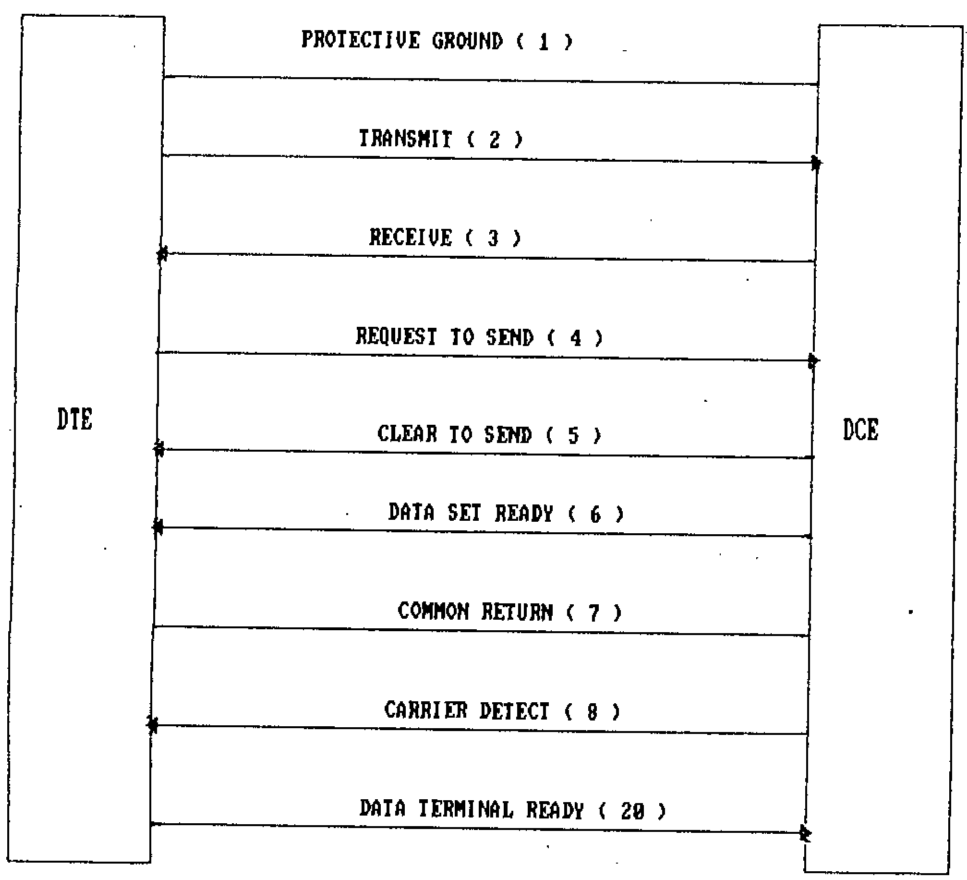


FIG 3.2 : SOME OF THE PRINCIPAL RS-232 CIRCUITS. THE PIN NUMBERS ARE IN PARENTHESIS

modulation and frequency modulation. Some advanced modems use a combination of modulation techniques [1]. QAM (Quadrature Amplitude Modulation) is the combination of amplitude modulation and phase modulation. This technique is most popular in modems of 9600 bps.
The RS-232-C Standard has mechanical, electrical, functional and procedural interface[1]. The mechanical specification includes 25 pins. The top row has pins numbered 1 to 13 (left to right), the bottom row has pins numbered 14 to 25 (left to right). The electrical specification for RS-232-C is that a voltage more negative than -3 volts is a binary 1 and a voltage more positive than +4 volts is a binary 0. The functional specification tells which circuits are connected to each of the 25 pins and what they mean. Figure 3.2 shows 9 pins that are frequently used. The procedural specification is the protocol, that is, the legal sequence of events.
If a T&T line is not used as dedicated or leased line then the cost is just like normal telephone line and the bill is made against the telephone number used. In that case due to higher traffic the line is not always available. If a line is leased then the cost is as follows (These data are collected from ITS (International Telecommunication Services) department of BTTB on 01.10.92):

a. Application fee TK. 2000.00

b. Establishment fee TK. 10,000.00

c. Royalty TK. 20,000.00

d. Annual line rent TK. 800.00 per km (8000.00 minimum).

For these leased lines high bit rate can not be used due to inductive and capacitive effect of lines. If high data rate is used then attenuation of the line becomes high and signal to noise ratio becomes worse. In practice it is seen that if bit rate is allowed more than 9600 bits/sec then signal to noise ratio becomes unacceptable, this is why BTTB does not recommend a data rate above 9600 bps (bits/sec).

CHAPTER

FOUR

Optical Communication

Optical Communication

For high speed data communication optical fiber is a very prominant name in the data and telecommunication world. Optical communication system avoids electrical losses and hence higher repeater spacing and as a result less investment for line equipment in transmission lines.

4.1 Fundamentals of optical communication

Optical communication system is based on the concept of total internal reflection. According to Snell's law, if light passes from a medium of higher refractive index to a medium of lower refractive index it is bent back to the original medium. If the angle of incidence is greater than the critical angle total internal reflection occurs. On the basis of this principle optical fiber is composed of two concentric cylinders of glass. The inner cylinder is called core having higher refractive index surrounded by clad having lower refractive index. The basic optical communication system is shown in figure 4.1 and the main components are:

1. The optical source.
2. A means of modulating the optical output from the source with the signal to be transmitted.
3. The optical fiber as transmission medium.
4. The photodetector which converts the received optical power back into an electrical waveform.
5. Electronic amplification and signal processing required to recover the signal and present it in a form suitable for use.

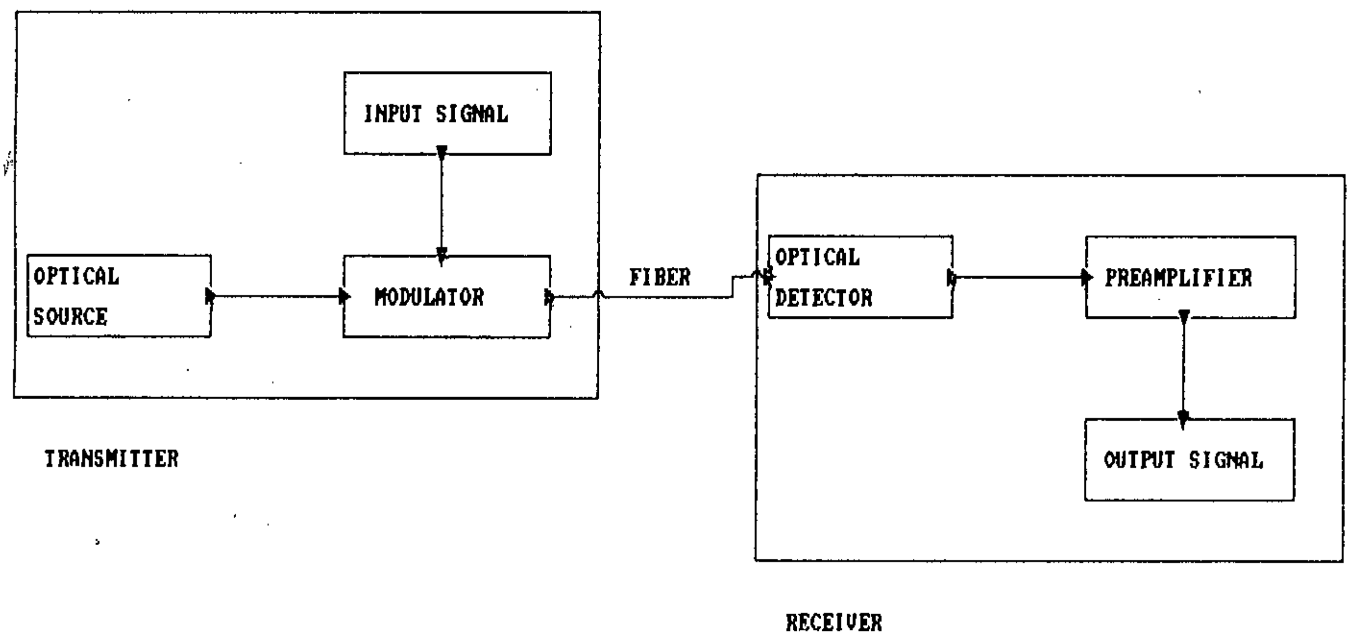


FIG : 4.1 : BASIC OPTICAL COMMUNICATION SYSTEM

A measure of the information capacity of an optical fiber is usually specified by the bandwidth-distance product in MHz-Km. This value depends on types of optical fibers. For graded-index fiber typical value is 2.5 GHz-Km and for step-index fiber the typical value is 20 MHz-Km [15]. Information capacity of optical fiber is limited by signal distortion in fiber. Signal distortion phenomena causes optical pulses to broaden as they travel along fiber. If these pulses travel sufficiently far, they will overlap with neighbouring pulses, thereby creating errors in receiver output. The signal distortion phenomena thus limits the information carrying capacity of optical fiber.
Some important characteristics related to fiber structure and refractive index of fiber material include index difference, numerical aperture, normalized frequency.

Index difference:

If n_1 is the refractive index of core and n_2 is that of clad, then the core-cladding index difference or simply the index difference for step-index fiber is defined as

$$\Delta = \frac{n_1 - n_2}{n_1}$$

The index difference for graded index fiber is given by

$$\Delta = \frac{n_1^2 - n_2^2}{2n_1^2} \approx \frac{n_1 - n_2}{n_1}$$

Typical value for n_1 is 1.48, n_2 is chosen so that index difference is 0.01 [15].

Numerical Aperture

Numerical aperture in step-index fiber is defined as

$$NA=\sqrt{n_1^2-n_2^2}\approx n_1\sqrt{2\Delta}$$

In graded-index fiber NA is a function of position across the core and is defined as

$$NA(r)=\sqrt{n(r)^2-n_2^2} \qquad \text{for } r \le a$$

$$= 0 \qquad \text{for } r > a$$

where n(r) is the refractive index at radial distance r from the fiber axis and a is the core radius.

Axial numerical aperture is defined as

$$NA(0)=\sqrt{n(0)^2-n_2^2}=\sqrt{n_1^2-n_2^2}\approx n_1\sqrt{2\Delta}$$

The numerical aperture is a dimensionless quantity which is less than unity. Its value is normally between 0.14 to 0.50.

Normalized frequency

Normalized frequency is defined as

$$V = \frac{\omega}{\omega_0}$$

where

$$\omega = 2\pi f$$

and

$$\omega_0=\frac{C}{a\sqrt{n_1^2-n_2^2}}$$

So,

$$V = \frac{2\pi f a\sqrt{n_1^2 - n_2^2}}{\lambda f}$$

$$= \frac{2\pi a\sqrt{n_1^2 - n_2^2}}{\lambda}$$

$$= a\sqrt{\beta_1^2 - \beta_2^2}$$

where β_1 and β_2 are the propagation constant in the material of fiber core and clad respectively, c is velocity of light, f is frequency of the wave, λ is wavelength of light.

4.2 Background of fiber optic technology

The modern era of optical communication may be said to have originated with the invention of the laser in 1958 and the fast developments soon followed the realization of first lasers in 1961 [6]. In the context of optical fiber systems the first generation system is one using multimode graded index fiber with wavelength between 800 and 900 nm, gallium-aluminium-arsenide diode lasers or LED sources and Si-APD detector. It was discovered that as wavelength is increased, scattering loss in silicon fibers is decreased. It follows that dispersion losses will approach zero if the wavelength is made long enough (1300nm) [5]. The major problem with lasers that produce a long wavelength was their fabrication. Present-day technology, however, produces two long wavelength lasers, both of which are becoming more common. These are 1300 nm and 1550 nm devices. Losses at these wavelengths have been recorded as 0.5 db/km and 0.18 db/km respectively [5]. Such low attenuation allows for long transmission distances.

Second generation optical fiber systems fall into two categories: those using multimode fiber and operating at the material dispersion minimum around 1.3 micrometer and those using monomode fiber at one of the wavelengths of minimum attenuation [6]. Both offer prospects for links significantly longer than those of first generation systems and this fact has accelerated the development of long wavelength sources, detectors and low loss fiber. Such links will be of particular value in the long-haul parts of trunk telephone systems and in submarine applications.

4.3 Types of optical communication

On the basis of the variation of the refractive index in the core, optical fiber is classified in two categories. These are (a) step-index fiber and (b) graded-index fiber.

Step-index fiber: If the refractive index of the core is uniform throughout and undergoes an abrupt change at the cladding boundary then the fiber is called Step-Index.

Graded-index fiber: On the other hand if the core refractive index is made to vary as a function of the distance from the centre of the fiber then the fiber is called gadded-Index.

On the basis of the number of modes of propagation both step-index and graded-index optical fiber is again divided into two classes. These are i) Monomode and ii) Multimode fiber.

A single mode fiber sustains only one mode of propagation, whereas multimode fibers contain many hundreds of modes. The single mode fiber has a typical core diameter of 10 micrometeter and the cladding diameter of 125 micrometer. In case of multimode fiber the cladding diameter is the same but the core diameter is 50 micrometer.

The selection of monomode or multimode fiber depends on the specific application. A comparison of monomode and multimode fiber is given below:

a. A fiber which can only propagate one ray i.e. a fiber which sustains only one mode of propagation is called a monomode fiber, whereas multimode fibers contain many hundreds of modes. Each of the modes that can propagate in a multimode fiber, travels at a slightly different velocities. As a result in case of multimode transmission, intermodal dispersion occurs. This is why higher bandwidth is possible in case of monomode fiber where intermodal dispersion is absent.

b. Core diameter of multimode fiber is larger than that of monomode fiber. In case of multimode fiber the core diameter is greater than or equal to 50 micrometer. A single mode fiber is more difficult to couple into due to its small core diameter.

c. Light can be launched into a multimode fiber using a light emitting diode source, where as single mode fibers must be excited with Laser Diodes. Although LEDs have less optical output power than Laser diodes, they are easier to fabricate, less expensive, require less complex circuitry and have longer lifetimes than laser diodes.

d. Both bandwidth and repeater spacing are larger in case of monomode transmission than that of multimode transmission. For same repeater spacing, with single mode technology the bandwidth limit is approximately 60 times greater [5].

4.4 Optical transmitter:

To construct an optical communications system one requires a source of optical power and a means for modulating that source. The combination of the source and the modulator is called a transmitter. A transmitter in block diagram is shown in figure 4.1. A suitable source for an optical fiber communication system should have certain characteristics as follows [16] :

1. Emission at a wavelength within a window of low fiber transmission loss.
2. Efficient conversion of the signal to be transmitted to light coupled into the fiber.
3. High reliability.
4. Ease of modulation.
5. Modulation speed capability.
6. Low noise.
7. High linearity of modulation.
8. Temperature stability.
9. Low cost.
10. Long life.

Both light emitting diode (LED) and injection laser diode(ILD) meet most or all of the requirements listed above. Both LED and ILD can be modulated by varying electrical current used to power the devices. Modulation is accomplished by varying the drive current. The varying drive current causes the emitted output power to vary in response. If we vary the drive current slowly the output power will vary faithfully. Although the amount of light power coupled into the fiber is typically a small fraction of the device output power, this electrical to optical conversion efficiency is adequate in most applications. In order for an LED or laser to be useful in a system it must be successfully interfaced to the electronic terminal which is generating the modulating signal. Important considerations in the design of a transmitter module are power consumption, modulation bandwidth, available power supply voltages, transient and over voltage protection, impedence matching, stabilization against temperature etc.

4.5 Optical receiver

In the optical communication system information is extracted from the optical signal by converting it to an electrical signal and then performing the electrical signal processing functions. The device which converts the optical signal into a voltage or current is called the optical detector. The electronic circuit which interfaces the detector to conventional electronic terminal equipment is called a preamplifier. The combination of the detector and the preamplifier is called a receiver. An ideal receiver should have the following characteristics [16]:

1. Efficient optical to electrical conversion.
2. Fast response.
3. Low noise.
4. Temperature stability.
5. Low cost.
6. Long life.
7. High sensitivity.
8. Dynamic range.

9. Adequate bandwidth.

10. A proper interface to the remaining electronics beyond the receiver

The two types of photodetectors commonly used are

(1) Pin photodetectors and

(2) APD(Avalanche Photodiode).

A pin photodetector consists of P and n regions separated by a very lightly n-doped intrinsic region. In normal operation a sufficiently large reverse bias voltage is applied across the device so that the intrinsic region is fully depleted of carriers. When an incident photon has an energy greater than or equal to the band gap energy of the semiconductor media, the photon can give up its energy and excite an electron from the valence band to the conduction band. This process generates free electron- hole pairs which are known as photocarriers. These photocarriers cause a current flow known as the photocurrent. Avalanche photodiodes internally multiply the primary signal photocurrent before it enters the input circuitry of the amplifier. This increases the receiver sensitivity since the photocurrent is multiplied before encountering the thermal noise associated with the receiver circuit.

4.6 Signal losses in optical communication

In the early days of optical communication the tremendous problem was signal loss or attenuation in optical communication. Even in the decade of sixty the minimum available attenuation was 1000 db/km from the best available glass [6]. It was decided that if this loss could be reduced to 20 db/km, then practical fiber-optic communication system could be developed. Glass manufacturer led by Corning in the USA succeeded in reducing fiber attenuation to this level by 1970 and to 2 db/km by 1975. Japanese workers produced fibers with attenuation of 0.5 db/km in 1976 and 0.2 db/km in 1979. Signal loss or attenuation determines the maximum repeater less separation between a transmitter and a receiver. Since repeaters are expensive to fabricate, install and maintain, the degree of attenuation in a fiber has a major influence on system cost.

Attenuation of a light signal has three components. These are : absorption, scattering and radiative loss.

In absorption the propagating light interacts with impurities in the silica glass, or with the silica glass itself at some wavelengths to cause electrons to undergo transmission. Later these electrons give up this absorbed energy by emitting light at other wavelengths or in the form of mechanical vibration (heat). Thus in absorption, energy is removed from the propagating pulse and given up later in some other form.

Scattering occurs due to geometrical imperfections in the fiber which causes light to be redirected out of the fiber. Thus in scattering the propagating energy leaves the fiber at the same wavelength at which it arrives at the geometrical imperfection.

Radiative losses occur whenever an optical fiber undergoes a bend of finite radius of curvature. This can arise from bends when a fiber cable turns a corner or from bends of fiber axis occurring during fiber cabling.

CHAPTER

FIVE

POINT TO POINT NETWORKS

POINT TO POINT NETWORKS

For establishment of any network it is the primary and basic task to fix up the topology. Network topology is a graph of the network nodes and the transmission links to connect the nodes. A network may be represented as a graph G = (V, A), where V is the set of nodes and A is the set of arcs that joins the nodes in V. The goal of the topological design is to achieve a specified performance at a minimum cost. The topology design problem can be characterized as follows [1]:

Given :

Locations of the hosts and terminal

Traffic matrix

Cost matrix

Performance constraints :

Reliability

Delay/ Throughput

Variables :

Topology

Line capacities

Flow assignment

Goal :

Minimize cost

5.1 Selecting network nodes:

Selection of network nodes depends on the number of terminals to be attached to it, the amount of traffic generated at each terminal, and the number of node and link capacity. Each mainframe installation, miniframe installation and important PC based multiuser installations may be considered as a node. For the time being and for the simplicity of calculation and analysis, in this thesis only some important installations are assumed as nodes in the network. If mutual distance among two or more installations is considerably low, these installations may be considered as a single node. Main characteristics of these nodes are given in Table-5.1.

5.2 Functions and Components of network nodes [3]:

The term network node has a variety of meanings and implies several interpretations. Network nodes are used to describe front-end processors, network controllers, Communication processors, concentrators and the like. Actually these terms represent the corresponding aspects of services provided by the network node. Network nodes encompass nearly all the functions needed to operate and control the network and to provide communication between network users. Different types of requirements for a network node may be grouped into three categories.

i) **The source/destination functions:** The source/destination functions pertain in providing an interface to the network users, such as terminals, terminal controllers, host processors etc. These functions also include the management of end to end message transmission between a source node and a destination

AS ON FEBRUARY'93

NODE NO.	NAME OF THE INSTALLATION/INSTALLATIONS	MODEL NO.	OPERATING SYSTEM	MEMORY SIZE	NO. OF TERMINALS	NO. OF PCS	TOTAL NO. OF USERS
1	BANGLADESH COMP. COUNCIL					10	10
2	SPARRSO	VAX-11/750	VAX-VMS 4.5	8 MB	2*16	8	104
		MICROVAX-3400	VAX VMS 5.3	36MB	2*16		
	METEOROLOGICAL OFFICE	MICROVAX-II	VAX-VMS 5.2	15MB	2*8		
		MICROVAX 9000	VAX-VMS5.4-2	18MB	2*8		
3	BEXIMCO	AS/400	OS/400	8 MB	14		14
4	IBCS-PRIMAX	AS/400	OS/400	8 MB	10	25	35
5	PRIME MINISTER'S SECRETE-RIATE	TOKEN RING			10	3	13
6	BUET	IBM 4331	VM/SP	4 MB	30	80	110
7	TITAS GAS T & D COMPANY	HVS6PLUS	HVS6	4 MB	10	4	14
8	DHAKA UNIVERSITY	IBM 4331	DOS/VSE	1 MB	5	5	10
9	ICDDRB	IBM 4361	VM/SP	8 MB	46	100	146
10	BBS	ES/9000	VM/SP	16 MB	50	10	60
11	BANGLADESH SHILPA BANK	MULTIUSER SYSTEM	UNIX			20	30
	EASTERN BANK (EX BCCI BANK)	NCR 9400	ITX	4MB	10		
12	IBM WORLD TRADE CORP.	SYSTEM 36	SSP	512 K	5	7	12
13	BIMAN	IBM 9375	VM/SP	8 MB	15		62
	ANZ GRINDLAYS BANK	NCR 9400	ITX	4MB	22	25	
14	SURFACE WATER MODELLING CENTRE	MULTIUSER SYSTEM	UNIX		40		40
15	SONALI MANK	IBM 9373	VM/SP	4 MB	14		46
	AMERICAN EXPRESS BANK	ES 9000	VM/SP	16 MB	32		
16	POWER DEVELOPMENT BOARD	IBM 9375	VM/SP	8 MB	29		29

MAIN CHARACTERISTICS OF THE NODES

TABLE : 5.1

node. Such functions may be visualized by assuming that there is a logical communication channel between the two end nodes that are communicating. The interface of this channel to the network users and the management to provide error free transmissions are the subject of this class of functions. These functions provide the protocols required between the source node and the destination node in order to permit communication between network users.

ii) **Store and forward functions :** This type of functions provide the services for message transmission through a network node. This node is known as transit node or intermediate node. An intermediate node receives a message, stores it and then forwards it to the next node on the route. Route is defined as the best transmission path of a message through the network to reach its destination node. These functions also include message acknowledgement between adjacent nodes and flow control mechanisms to protect node resources from being exhausted.

iii) **Network-wide functions :** The third class of functions, network wide functions pertain to the management and maintenance of the network, and the measurement of its behaviour. These functions include preventing network-wide congestion, maintaining topological awareness, bringing up or taking down network nodes or links, managing network configuration and measuring network performance. These functions may be centralized in a single node of the network, in this case a control node performs all these functions with minimal interference with other nodes.

Alternatively, each node may individually perform most of the functions and periodically update the control node, if required.

The above two approaches are often called centralized network management and decentralized network management respectively. An efficient design of network nodes is an important step towards development of a viable network. A network node is composed of the following components.

i) Software system

ii) Node processor

iii) Node memory

iv) Interface hardware

Software system :

A communication network is operated, controlled and managed through control programs that reside in various components of the network. The host processor may contain application programs, data bases, files and communication access methods. The communication access method may be viewed as the host interface for network nodes, terminals or terminal equipment. A communication access method, such as IBM's virtual telecommunications access method is a set of software routines used by a host operating system to interface with telecommunication equipment. Different software routines in a network node are as follows:

a) **Error handling routines :** Handles error in software, memory or processors.

b) **Link handling routines :** Provide link controls such as acknowledgments, polling, assemble the bits from the links into characters or segmenting characters into bits for transmission on the links.

c) **Message handling routines :** Stores and forward messages, performs message routing and flow control.

d) **Network protocol routines :** Handle end-to-end protocols, sequence numbers and transit node protocols, flow control and user interface protocols.

e) **Queue management routines :** Handle message queues for links or host processors.

f) **Support programs :** Provide initial program load (IPL), maintenance routines, such as dump, test routines, operator interface and other network-wide functions.

Node processor:

The network node processor executes the software routines and manages the communication links. The node processor may be interrupt driven based on a priority structure. An important performance aspect of node architecture is the processor overhead required to change interrupt levels. This change permits a higher priority task to take over the processor, and at the end of this task, returns the processor to the next lower priority task. The resulting processor overhead may be significant because of the high frequency of changing processing levels in the node processor. The instruction set for a network node should be optimized for character, buffer and address handling. The required capacity of a node processor may be estimated in terms of the number of instructions it executes each second.

Node memory:

The memory of the network nodes should permit fast access by the processor and the interface hardware so as to permit timely operations on the links and host channels. If direct memory access is provided, the interface hardware may save or retrieve data, for links or host computers without assistance from the node processor. If several microprocessors are used, such as one or more for each of the priority levels, the memory may permit access to several processors at the same time in case of multimodule memory system. The problems of contention on the memory and simultaneous write operations may be resolved by such techniques as queuing the requests and permitting memory access only to a single processor at a time. Network nodes may also employ cache memory, in which, more than one memory level is available, with each level offering a different memory access time. The total memory size required for a network node is the sum of the requirements for (1) the control program, (2) the transaction processing routines, (3) the message buffers and (4) Network protocol.

Interface Hardware:

The interface hardware of a network node provides connection to the network users, such as terminals and host processors, and to the other nodes in the network. The interface for the host processor cooperates with the host access method in executing channel protocols. The link protocols are executed through the link interface. In general, a separate interface may be needed for each type of link protocol. Several functions described as software routines may be included in the form of microcode in the interface hardware. The interface hardware includes the attachment facilities and the appropriate modem interfaces for adjacent terminals, nodes or host processors. It may also include interface buffers, which provide intermediate buffering between links and message buffers.

5.3 Traffic matrix:

To develop a network topology among the nodes a cost matrix and a traffic matrix are needed. Again a distance matrix is necessary for calculation of both the traffic matrix and cost matrix. In this thesis distances are calculated from the Dhaka city map. BUET is considered as the origin and with respect to this origin the x and y co-ordinates of other nodes are measured. Physical locations of the nodes are represented in Figure-5.1. The distance matrix is given in Table-5.2a. It is not possible to lay any cable from one node to another along a straight line. This is why road distances have also been measured and is shown in Table-5.2b. The traffic matrix tells how many packets per sec on the average must be sent between two nodes. Before the establishment of a network it is not possible to exactly calculate the traffics between the nodes. But in this case the common assumption is that it is directly proportional to the product of population of the two nodes and inversely proportional to the distance between them. The proportionality constant is taken to be 2. This constant may be considered as the traffic growth factor. On the basis of this assumption the traffic matrix is developed and shown in Table-5.3.

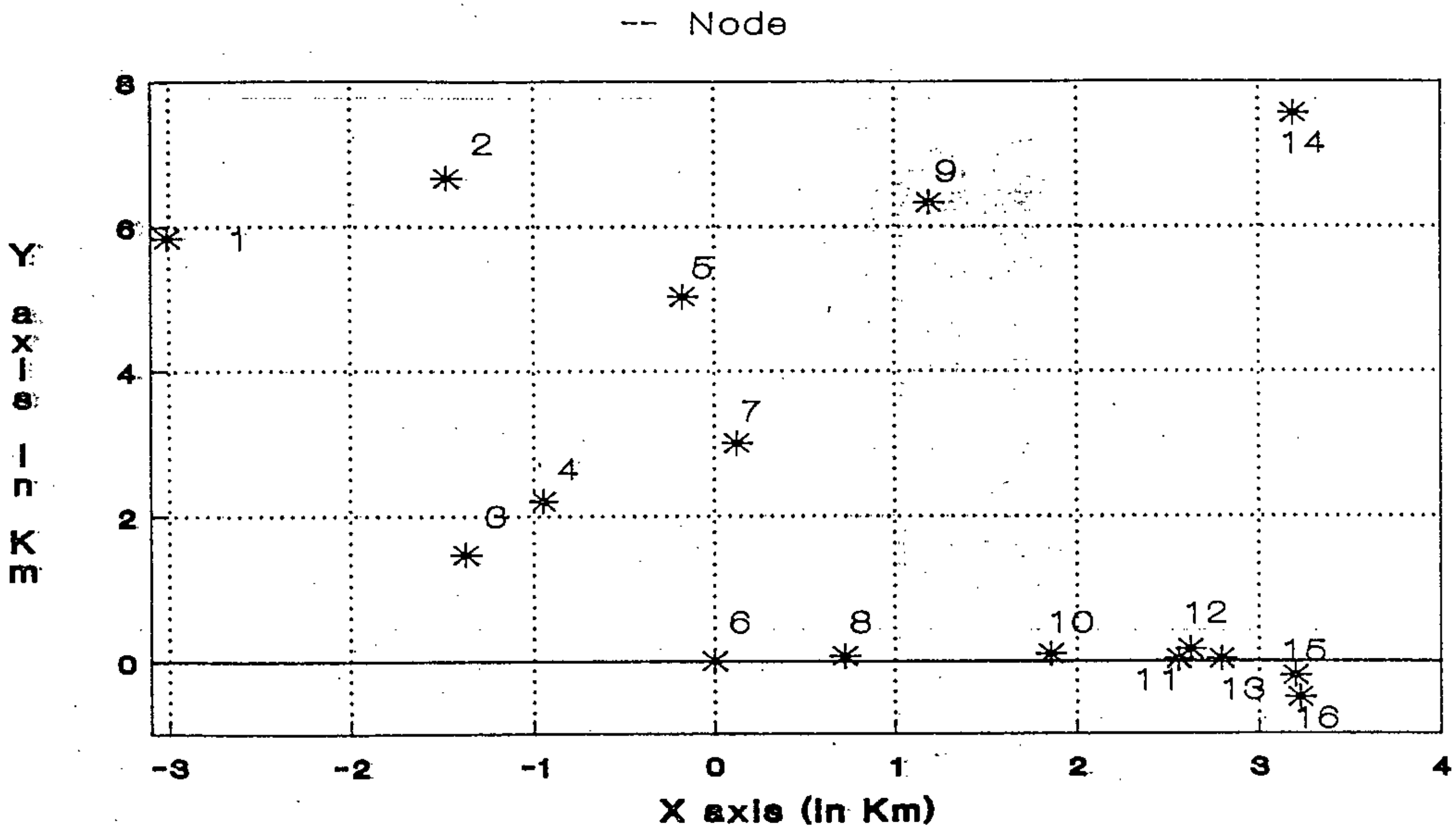


Fig. 51: Physical locations of the nodes

NODE NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	1746	4663	4180	2946	6563	4225	6867	4228	7518	8042	7991	8207	6438	8657	8886
2	1746	0	5201	4498	2090	6827	4000	6953	2686	7362	7765	7685	7891	4752	8306	8570
3	4663	5201	0	852	3761	2010	2145	2522	5499	3507	4187	4206	4410	7620	4869	5003
4	4180	4498	852	0	2932	2393	1334	2705	4648	3498	4118	4106	4321	6773	4787	4965
5	2946	2090	3761	2932	0	5033	2052	5041	1885	5332	5698	5612	5816	4214	6224	6492
6	6563	6827	2010	2393	5033	0	3003	728	6441	1858	2558	2630	2795	8211	3206	3264
7	4225	4000	2145	1334	2052	3003	0	2991	3496	3377	3839	3779	3994	5500	4438	4675
8	6867	6953	2522	2705	5041	728	2991	0	6277	1130	1833	1902	2070	7891	2490	2564
9	4228	2686	5499	4648	1885	6441	3496	6277	0	6265	6447	6329	6501	2352	6832	7127
10	7518	7362	3507	3498	5332	1858	3377	1130	6265	0	706	773	943	7585	1378	1496
11	8042	7765	4187	4118	5698	2558	3839	1833	6447	706	0	152	237	7563	682	852
12	7991	7685	4206	4106	5612	2630	3779	1902	6329	773	152	0	218	7422	682	896
13	8207	7891	4410	4321	5816	2795	3994	2070	6501	943	237	218	0	7546	466	682
14	6438	4752	7620	6773	4214	8211	5500	7891	2352	7585	7563	7422	7546	0	7766	8066
15	8657	8306	4869	4787	6224	3206	4438	2490	6832	1378	682	682	466	7766	0	301
16	8886	8570	5003	4965	6492	3264	4675	2564	7127	1496	852	896	682	8066	301	0

TABLE 5.2A: LINEAR DISTANCES AMONG THE NODES

(VALUES ARE IN METER)

Node No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	2400	5033	4266	4100	7300	4900	7866	6266	9333	9933	9733	9967	9400	10366	10666
2	2400	0	6267	5300	3267	7700	4400	7667	5433	8500	9100	8900	9133	8567	9533	9833
3	5033	6267	0	1233	4067	3000	2700	3567	6233	4733	5067	4867	5100	9367	5500	5800
4	4266	5300	1233	0	3100	3500	1700	4067	5267	5233	5567	5367	5600	8400	6000	6300
5	4100	3267	4067	3100	0	5500	2200	5467	2300	6300	6900	6700	6933	5433	7333	7633
6	7300	7700	3000	3500	5500	0	3367	833	8133	2000	3067	2867	3033	10800	3500	3800
7	4900	4400	2700	1700	2200	3367	0	3333	4367	4167	4767	4567	4800	7500	5200	5500
8	7866	7667	3567	4067	5467	833	3333	0	7700	1300	2367	2167	2400	10767	2800	3100
9	6266	5433	6233	5267	2300	8133	4367	7700	0	7867	8467	8267	8500	3800	8900	9200
10	9333	8500	4733	5233	6300	2000	4167	1300	7867	0	1400	1200	1500	11300	1900	2200
11	9933	9100	5067	5567	6900	3067	4767	2367	8467	1400	0	167	300	11833	767	1067
12	9733	8900	4867	5367	6700	2867	4567	2167	8267	1200	167	0	233	11633	700	1000
13	9967	9133	5100	5600	6933	3033	4800	2400	8500	1500	300	233	0	11867	500	800
14	9400	8567	9367	8400	5433	10800	7500	10767	3800	11300	11833	11633	11867	0	12267	12567
15	10366	9533	5500	6000	7333	3500	5200	2800	8900	1900	767	700	500	12267	0	333
16	10666	9833	5800	6300	7633	3800	5500	3100	9200	2200	1067	1000	800	12567	333	0

TABLE 5.2B : DISTANCES AMONG THE NODES (ALONG THE ROAD)

(THE VALUES ARE IN METER)

Node No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	866	55	163	63	301	57	25	465	128	60	24	124	85	88	54
2	866	0	464	1373	826	2971	661	271	5592	1468	685	280	1412	970	1003	613
3	55	464	0	796	89	1026	145	78	656	355	165	68	340	119	234	139
4	163	1373	796	0	293	2200	576	171	1939	803	377	156	775	333	536	322
5	63	826	89	293	0	520	165	47	1650	247	113	46	232	191	163	98
6	301	2971	1026	2200	520	0	913	2641	3950	6600	2149	919	4501	814	2891	1678
7	57	661	145	576	165	913	0	84	935	402	176	73	361	149	247	147
8	25	271	78	171	47	2641	84	0	379	923	253	110	516	74	328	187
9	465	5592	656	1939	1650	3950	935	379	0	2226	1034	423	2129	3073	1509	920
10	128	1468	355	803	247	6600	402	923	2226	0	2571	1199	4960	424	2905	1581
11	60	685	165	377	113	2149	176	253	1034	2571	0	4311	12399	203	3598	1626
12	24	280	68	156	46	919	73	110	423	1199	4311	0	6386	82	1577	696
13	124	1412	340	775	232	4501	361	516	2129	4960	12399	6386	0	416	11408	4494
14	85	970	119	333	191	814	149	74	3073	424	203	82	416	0	299	184
15	88	1003	234	536	163	2891	247	328	1509	2905	3598	1577	11408	299	0	8012
16	54	613	139	322	98	1678	147	187	920	1581	1626	696	4494	184	8012	0

TABLE 5.3 : TRAFFIC MATRIX (VALUES ARE IN PACKETS/SEC)

5.4 Cost matrix

For simplicity let us assume a linear cost function for line i as in [1]

cost(i) = d(i)*c(i) +p(i) (1)

where cost(i) is the cost for line i.

d(i) is the cost/bps for line i.

c(i) is the capacity in bps for line i.

p(i) is a constant cost associated with line i

The cost d(i) depends on the length of transmission line and transmission media used. So, the cost of the transmission line of the desired capacity is the first term (d(i)*c(i)) of the equation of cost. Again p(i) is a constant cost associated with line i but not depending on the capacity or on the length of the transmission line. The constant term represents the cost of modem, interfacing or other equipment needed for the line. Main cost of optical fiber installations consists of the following components.

i) **Transmitter**

ii) **Receiver**

iii) **Optical fiber**

To develop a cost matrix let t be the cost of the transmitter module, r be the cost of receiver module, f be the cost/km of optical fiber and l be the labour cost/km for installing the cable. These costs t, r, f and l are changing parameters and these values are dependent on the time of implementation, the country of origin of the equipment and the vendor selected for implementation. However, on the basis of present market study, approximate price figures are given below:

a. t = Taka 1,80,000.00

b. r = Taka 1,50,000.00

c. f = Taka 1,35,000.00

l = Taka 50,000.00

Hence sum of Cable Cost and Labour cost is Taka 1,85,000.00 /km.
The capacity of above optical fiber is 140 megabits/sec. Since no repeater is required within 45 kilometers, on the basis of above information a cost matrix is developed using the following equation:

$$c(i,j)=2\{r+t+d(i,j)*(f+l)\} \quad (2)$$

where c(i,j) is the cost to establish a full duplex line between node i and j, and d(i,j) is the distance between node i and j in Table 5.2b. The cost matrix is shown in Table-5.4. The full duplex mode of operation considered here offers better performance, but its operation requires special considerations for buffer management.

5.5 Minimum Cost Spanning Tree

A minimum cost spanning tree is the graphical representation of the network layout so that each node can communicate to each other with a minimum cost and no alternate path is available i.e. there exists one and only one communication path between any two nodes. For more reliability and less delay alternate paths are to be added to the

Node No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	1548	2521	2240	2177	3361	2473	3572	2980	4112	4334	4260	4349	4138	4508	4619
2	1548	0	2980	2621	1870	3509	2288	3498	2669	3805	4027	3953	4038	3831	4186	4297
3	2521	2980	0	1115	2166	1770	1659	1981	2965	2410	2536	2462	2547	4127	2695	2806
4	2240	2621	1115	0	1807	1955	1289	2166	2610	2595	2721	2647	2732	3768	2880	2991
5	2177	1870	2166	1807	0	2695	1474	2684	1511	2991	3213	3139	3224	2669	3372	3483
6	3361	3509	1770	1955	2695	0	1907	968	3668	1400	1796	1722	1781	4656	1955	2066
7	2473	2288	1659	1289	1474	1907	0	1892	2277	2203	2425	2351	2436	3435	2584	2695
8	3572	3498	1981	2166	2684	968	1892	0	3509	1141	1537	1463	1548	4656	1696	1807
9	2980	2669	2965	2610	1511	3668	2277	3509	0	3572	3794	3720	3805	2066	3953	4064
10	4112	3805	2410	2595	2991	1400	2203	1141	3572	0	1178	1104	1215	4841	1363	1474
11	4334	4027	2536	2721	3213	1796	2425	1537	3794	1178	0	722	771	5026	944	1056
12	4260	3953	2462	2647	3139	1722	2351	1463	3720	1104	722	0	746	4952	919	1030
13	4349	4038	2547	2732	3224	1781	2436	1548	3805	1215	771	746	0	5063	845	956
14	4138	3831	4127	3768	2669	4656	3435	4656	2066	4841	5026	4952	5063	0	5211	5322
15	4508	4186	2695	2880	3372	1955	2584	1696	3953	1363	944	919	845	5211	0	783
16	4619	4297	2806	2991	3483	2066	2695	1807	4064	1474	1056	1030	956	5322	783	0

TABLE 5.4 : COST MATRIX (VALUES ARE IN THOUSAND TAKA)

minimum spanning tree. A minimum spanning tree is developed according to Prim's algorithm.

Prim's algorithm[18]: The algorithm will start with a tree that includes only a minimum cost edge of the graph. Then edges will be added to this tree one by one. The next edge (i,j) to be added is such that i is a vertex already included in the tree, j is a vertex not yet included and the cost of edge (i, j), cost(i,j) is minimum among all edges (k,l) such that vertex k is in the tree and vertex l not in the tree.

The generated graph on the basis of the above algorithm is shown in Figure-5.2.

5.6 Capacity Analysis

The minimum required capacity of each link is the total traffic on the link in terms of bps. Based on the minimum cost spanning tree the routing and traffic matrix is shown in Table 5.5. In reality the capacities are assigned at a higher values than the minimum required capacities to satisfy certain delay constraint. Assuming a packetsize of 2000 bits and a mean delay constraint of 1 millisec the optimal capacities of each link of Fig-5.2 is calculated using the following equation [1]

$$C_i = \frac{\lambda_i}{\mu} \left(1 + \frac{\sum_{j=1}^{m} \sqrt{(\lambda_j)}}{\gamma T \sqrt{(\lambda_i)}} \right) \qquad (3)$$

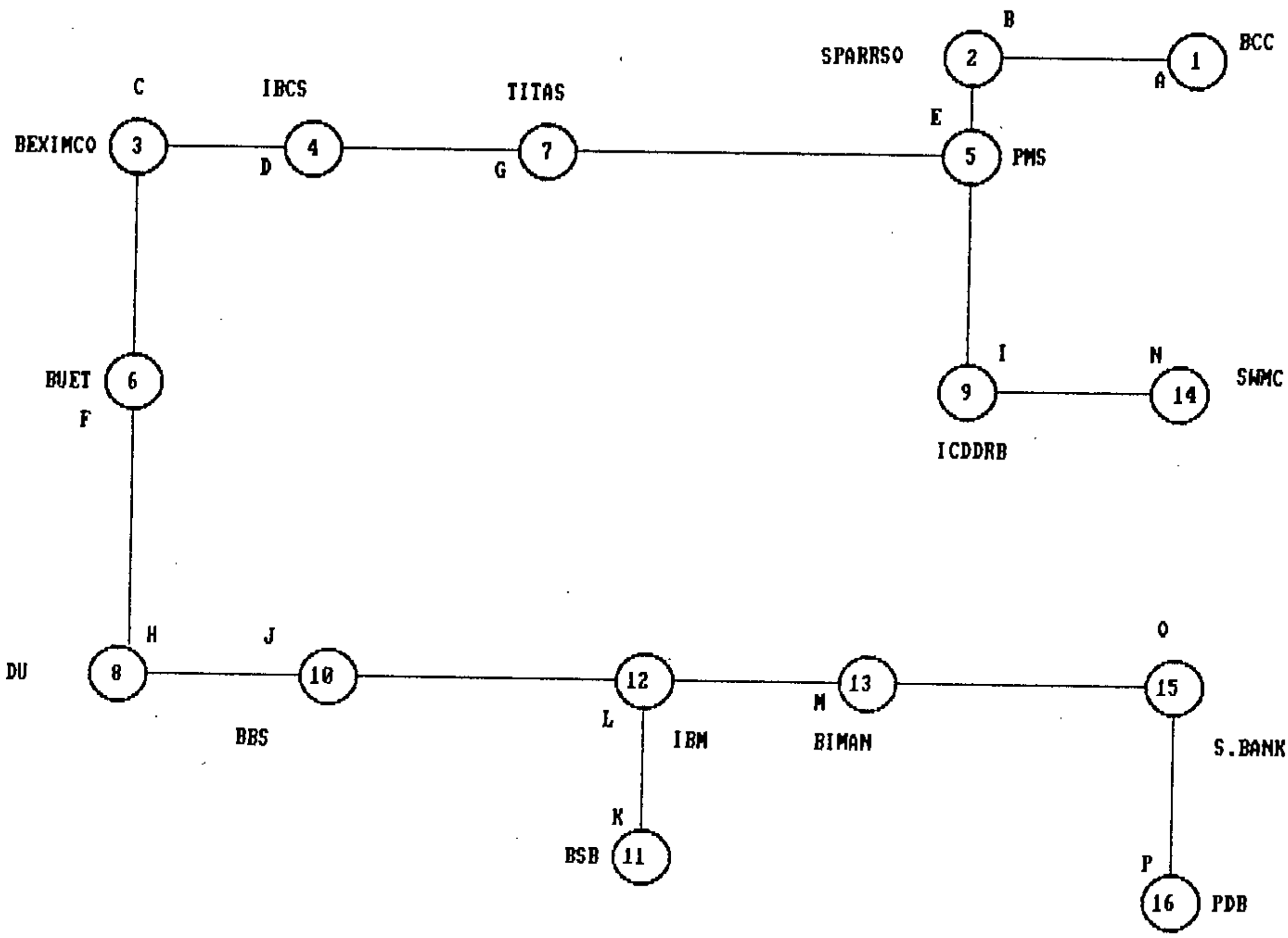


FIGURE 5.2 : MINIMUM COST SPANNING TREE

Node No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	866 AB	55 ABEGDC	163 ABEGD	63 ABE	301 ABEG DCF	57 ABEG	25 ABEG DCFH	465 ABEI	128 ABEGD CFHJ	60 ABEGDC FHJLK	24 ABEGDC FHJL	124 ABEGDC FHJLM	85 ABEIN	88 ABEGDC FHJLMO	54 ABEG DCFHJ LMOP
2	866 BA	0	464 BEGDC	1373 BEGD	826 BE	2971 BEGDCF	661 BEG	271 BEGD CFH	5592 BEI	1468 BEGD CFHJ	685 BEGDCF HJLK	280 BEGDCF HJL	1412 BEGDCF HJLM	970 BEIN	1003 BEGDCF HJLMO	613 BEGDCF HJLMOP
3	55 CDGEBA	464 CDGEB	0	796 CD	89 CDGE	1026 CF	145 CDG	78 CFH	656 CDGEI	355 CFHJ	165 CFHJLK	68 CFHJL	340 CFHJLM	119 CDGEIN	234 CFHJ LMO	139 CFHJ LMOP
4	163 DGEBA	1373 DGEB	796 DC	0	293 DGE	2200 DCF	576 DG	171 DCFH	1939 DGEI	803 DCFHJ	377 DCFH JLK	156 DCFHJL	775 DCFH JLM	333 DGEIN	536 DCFH JLMO	322 DCFH JLMOP
5	63 EBA	826 EB	89 EGDC	293 EGD	0	520 EGDCF	165 EG	47 EGDCFH	1650 EI	247 EGDC FHJ	113 EGDC FHJLK	46 EGDC FHJL	232 EGDC FHJLM	191 EIN	163 EGDC FHJLMO	98 EGDCF HJLMOP
6	301 FCDG EBA	2971 FCDGEB	1026 FC	2200 FCD	520 FCDGE	0	913 FCDG	2641 FH	3950 FCDGEI	6600 FHJ	2149 FHJLK	919 FHJL	4501 FHJLM	814 FCDG EIN	2891 FHJLMO	1678 FHJL MOP
7	57 GEBA	661 GEB	145 GDC	576 GD	165 GE	913 GDCF	0	84 GDCFH	935 GEI	402 GDCFHJ	176 GDCFH JLK	73 GDCFH JL	361 GDCFH JLM	149 GEIN	247 GDCFH JLMO	147 GDCFH JLMOP
8	25 HFCD GEBA	271 HFCD GEB	78 HFC	171 HFCD	47 HFCDGE	2641 HF	84 HFCDG	0	379 HFCD GEI	923 HJ	253 HJLK	110 HJL	516 HJLM	74 HFCD GEIN	328 HJLMO	187 HJLMOP
9	465 IEBA	5592 IEB	656 IEGDC	1939 IEGD	1650 IE	3950 IEGDCF	935 IEG	379 IEGD- CFH	0	2226 IEGD CFHJ	1034 IEGD CFHJLK	423 IEGD CFHJL	2129 IEGD CFHJLM	3073 IN	1509 IEGDCF HJLMO	920 IEGDCF HJLMOP
10	128 JHFCD GEBA	1468 JHFCD GEB	355 JHFC	803 JHFCD	247 JHFCD GE	6600 JHF	402 JHFCDG	923 JH	2226 JHFCD GEI	0	2571 JLK	1199 JL	4960 JLM	424 JHFCD GEIN	2905 JLMO	1581 JLMOP
11	60 KLJHFC DGEBA	685 KLJHFC DGEB	165 KLJHFC	377 KLJHF CD	113 KLJHF CDGE	2149 KLJHF	176 KLJHF CDG	253 KLJH	1034 KLJHFC DGEI	2571 KLJ	0	4311 KL	12399 KLM	203 KLJHFC DGEIN	3598 KLMO	1626 KLMOP
12	24 LJHFCD GEBA	280 LJHFCD GEB	68 LJHFC	156 LJHFCD	46 LJHF CDGE	919 LJHF	73 LJHF CDG	110 LJH	423 LJHFC DGEI	1199 LJ	4311 LK	0	6386 LM	82 LJHF CDGEIN	1577 LMO	696 LMOP
13	124 MLJHFC DGEBA	1412 MLJHFC DGEB	340 MLJHFC	775 MLJH FCD	232 MLJHFC DGE	4501 MLJHF	361 MLJHFC DG	516 MLJH	2129 MLJHFC DGEI	4960 MLJ	12399 MLK	6386 ML	0	416 MLJHFC DGEIN	11408 MO	4494 MOP
14	85 NIEBA	970 NIEB	119 NIEGDC	333 NIEGD	191 NIE	814 NIE GDCF	149 NIEG	74 NIEG DCFH	3073 NI	424 NIEGDC FHJ	203 NIEGDC FHJLK	82 NIEGDC FHJL	416 NIEGDC FHJLM	0	299 NIEGDC FHJLMO	184 NIEGDC FHJL MOP
15	88 OMLJH FCDG EBA	1003 OMLJH FCDG EB	234 OMLJH FC	536 OMLJH FCD	163 OMLJH FCDGE	2891 OMLJHF	247 OMLJ HFCDG	328 OMLJH	1509 OMLJH FCDG EI	2905 OMLJ	3598 OMLK	1577 OML	11408 OM	299 OMLJH FCDG EIN	0	8012 OP
16	54 POMLJH FCDG EBA	613 POMLJH FCDG EB	139 POMLJ HFC	322 POMLJ HFCD	98 POMLJ HFCD GE	1678 POML JHF	147 POMLJH FCDG	187 POMLJH	920 POMLJH FCDGEI	1581 POMLJ	1626 POMLK	696 POML	4494 POM	184 POMLJH FCDG EIN	8012 PO	0

TABLE 5.5 : TRAFFIC AND ROUTE MATRIX FOR FIG. 5.2

where c_i is the optimum capacity for line i in bps.

T is the mean delay constraint in sec

λ_j is the traffic of line j in packets/sec

$1/\mu$ is packetsize in bits/packet and m is number of links.

$$\gamma = \sum_{l=1}^{n} \sum_{k=1}^{n} \gamma_{lk} \quad \ldots\ldots \quad (4)$$

where n is number of nodes.

γ_{lk} is the traffic in the traffic matrix between node l and k. The optimal capacities obtained for different lines are mentioned in next page. For different values of i, the concerned links are AB, BE, NI, IE, EG, GD, DC, CF, FH, HJ, JL, LK, LM, MO, OP respectively. On the basis of these capacities the cost matrix mentioned in Table 5.4 would be revised. In reality link capacities are available in market at discrete values. In case of optical fiber communication the most commonly available link capacities in the range of the above mentioned optimum capacities are 34 Mbps and 140 Mbps. Hence for the link AB and NI assigned capacity is 34 Mbps and for the remaining links the capacity is 140 Mbps. As capacities of links AB and NI are reassigned, r,t and f are assumed to be TK. 75,000.00, 60,000.00 and 1,25,000 respectively. So, in Table 5.4 the cost figure between node 1 and 2 would be replaced by 1110 and that of between node 9 and 14 would be replaced by 1600.

i	Optimal capacity in kilobits/sec	Delay in microsec
1	6852.011	1152.066
2	45450.176	409.151
3	17787.883	676.617
4	62058.926	347.287
5	73261.453	318.398
6	75683.031	313.036
7	78734.164	306.647
8	78903.477	306.303
9	97012.852	275.071
10	93988.156	279.636
11	93238.445	280.802
12	65357.344	337.990
13	124626.789	241.581
14	85873.984	293.084
15	46446.492	404.490

5.7 Delay Analysis

Though it is possible to communicate with different nodes of a network of minimum cost spanning tree configuration but in this case as there is no alternate path for communication, packets from different sources use the same communication line. So, packets must wait for their turn to be sent out on a heavily used line, thereby resulting large queuing delay in the communication line. For poisson's rate of arrival of messages, exponential distribution of packet transmission time and single server system (M/M/1 Queue) the relation among delay, traffic and capacity is [1]

$$T_i = 1/(\mu C_i - \lambda_i) \qquad (5)$$

Where C_i is the capacity for channel i in bits/sec;

λ_i is the traffic in packets/sec

μC_i is the capacity in packets/sec

T_i is the delay of line i in sec

Mean packet delay is defined as

$$T = h \sum_{i=1}^{m} \frac{\lambda_i T_i}{\lambda} \qquad (6)$$

Where $\lambda = \sum_{i=1}^{m} \lambda_i$ (7)

h is number of hops per packet and defined as

$$h = \frac{\lambda}{\gamma} \qquad (8)$$

On the basis of the capacity, packet size (800 bits and 2000 bits) and total traffic, delay for each line of the network in Fig-5.2 is calculated and is shown in Table-5.6.

As delay is one of the main consideration for data communication network, extra arcs are added to minimize delay in network of Figure-5.2 according to the saturated cut heuristic[1]. The arc is added on the basis of maximum traffic to cost ratio. Different network configurations are obtained for different costs. These configurations are shown in Figures 5.3, 5.4, 5.5 and 5.6.

5.8 Routing

Routing is defined as the process of determining the transmission path of a message through the network to reach its destination node. The rules that determine the directed path for each message from its originating node to its destination node is called routing algorithms. Routing algorithm is that part of the network layer software, responsible for deciding which output line an incoming packet should be transmitted on. Several aspects of network design are inseparably related to the routing algorithms. The topological design of a network can be affected by the number of disjoint routes required for each node pair. Routing algorithms can be grouped into two major classes: Nonadaptive and adaptive. Nonadaptive algorithms do not base their routing decisions on measurements or estimates of the current traffic and topology. This procedure is also known as static or fixed routing. The choice of the route to be used to get from i to j (for all i and j) is

i	LINE	TRAFFIC IN PCKTS/SEC		DELAY IN MICRO SEC			
		TOPOLOGY OF FIG. 5.2	TOPOLOGY OF FIG. 5.6	TOPOLOGY OF FIG. 5.2		TOPOLOGY OF FIG. 5.6	
				PACKETSIZE = 800 BITS	PACKETSIZE = 2000 BITS	PACKETSIZE =800 BITS	PACKETSIZE = 2000 BITS
1	AB	2558	2558	25.04	69.24	25.04	69.24
2	BE	20281	20281	6.46	20.11	6.46	20.11
3	NI	7416	7416	28.50	104.34	28.50	104.34
4	IE	28150	28150	6.81	23.89	6.81	23.89
5	EG	33490	33490	7.07	27.39	7.07	27.39
6	GD	34647	34647	7.12	28.29	7.12	28.29
7	DC	36106	36106	7.20	29.50	7.20	29.50
8	CF	36187	36187	7.204	29.57	7.204	29.57
9	FH	44871	3770	7.68	39.79	5.84	15.10
10	HJ	43418	2317	7.60	37.62	5.79	14.77
11	JL	43058	11166	7.58	37.12	6.10	17.00
12	LK	29720	12097	6.88	24.83	6.14	17.27
13	LM	58174	8659	8.56	84.56	6.01	16.30
14	MO	39525	26786	7.38	32.81	6.75	23.14
15	OP	20751	8012	7.48	20.30	5.99	16.13
16	KM		17623			6.35	19.09
17	FJ		41101			7.47	34.60
18	MP		12739			6.16	17.46
19	JM		31892			6.99	26.24
MEAN DELAY IN MICRO SEC				24.82	122.75	18.50	68.25

LINE CAPACITY IS 34 MBPS FOR LINE AB AND NI, 140 MBPS FOR ALL OTHER LINES

TABLE 5.6: DIFFERENT CHARACTERISTICS OF FIG. 5.2 AND 5.6

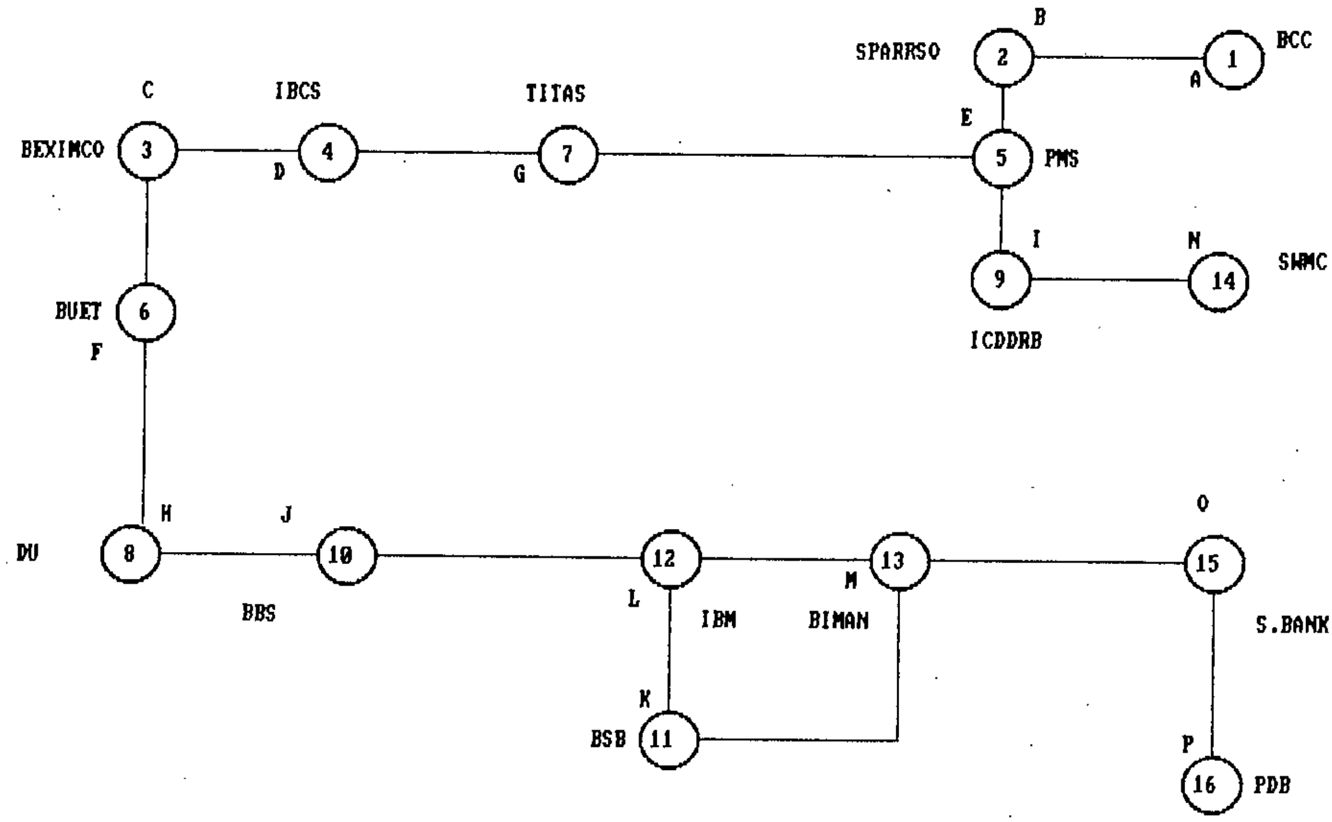


FIG. 5.3 : ARC KM ADDED WITH TOPOLOGY OF FIG. 5.2

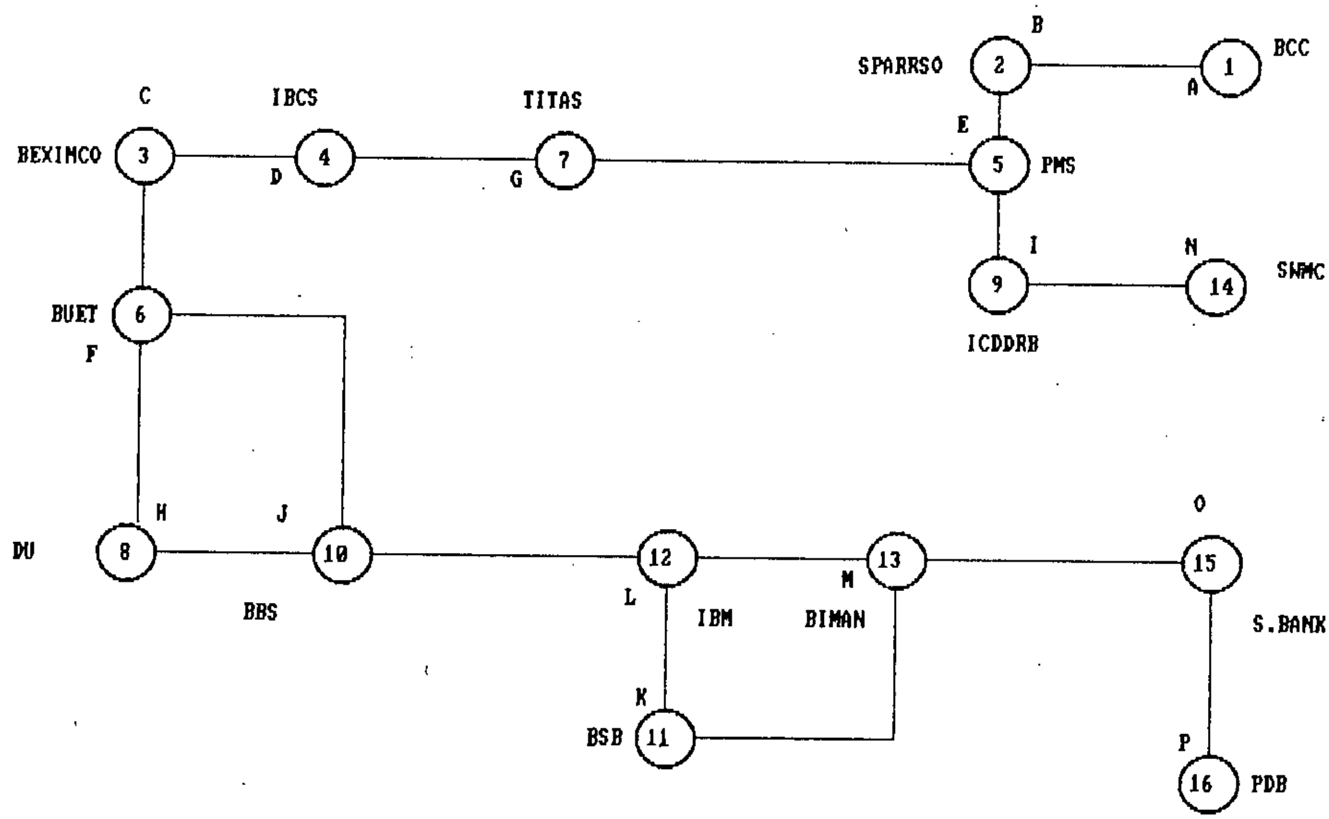


FIG. 5.4 ARC FJ ADDED WITH THE TOPOLOGY OF FIG 5.3

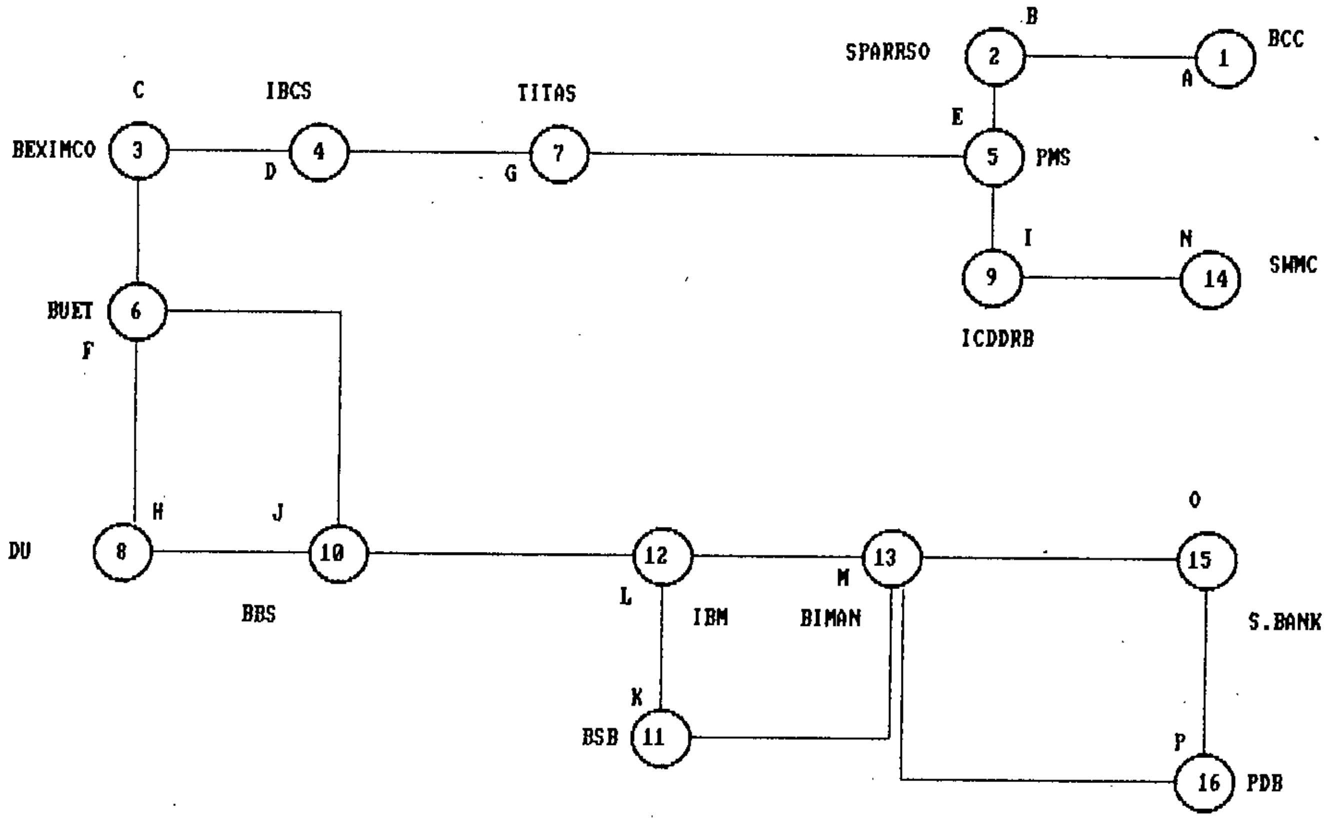


FIG. 5.5: ARC MP ADDED WITH TOPOLOGY OF FIG. 5.4

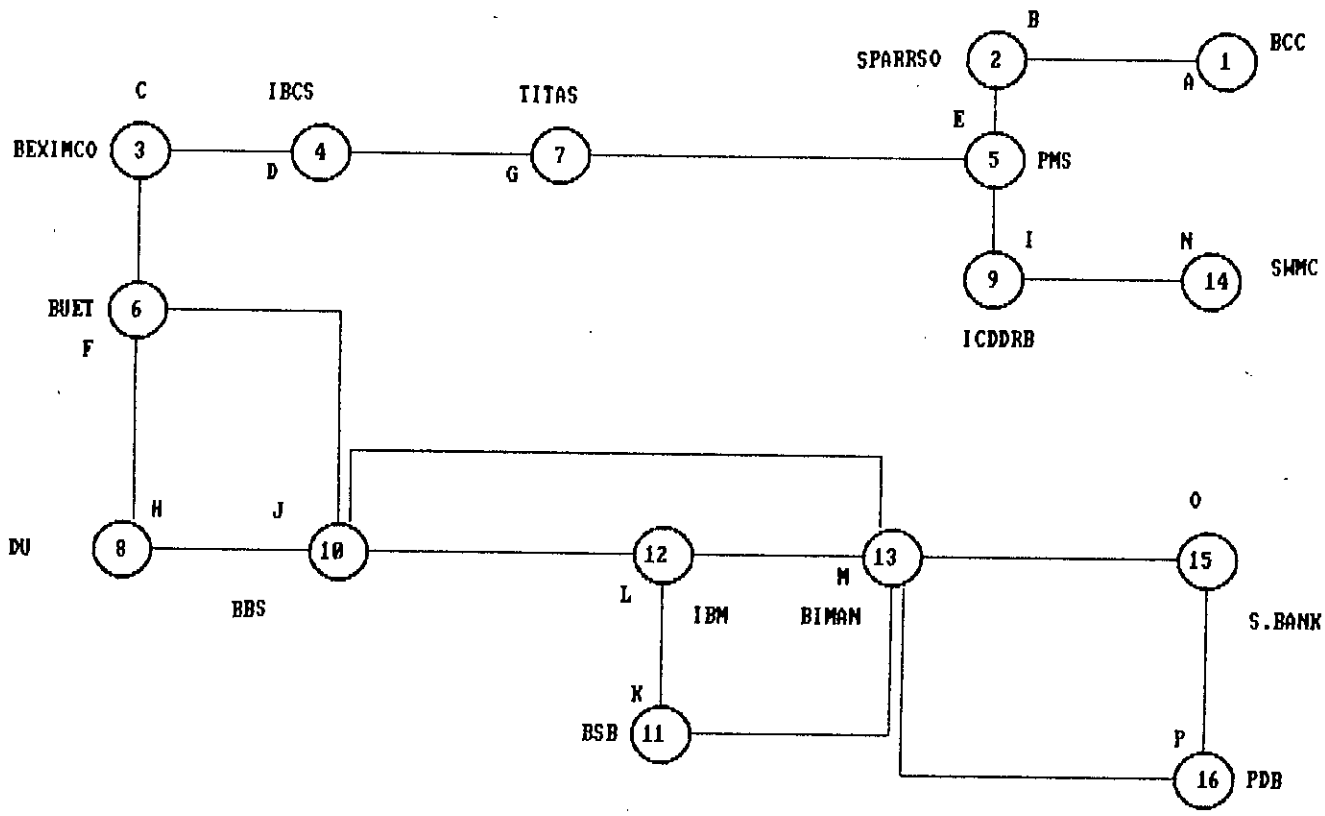


FIG. 5.6 : ARC JM ADDED WITH TOPOLOGY OF FIG. 5.5

computed in advance, and downloaded to the IMPs when the network is booted. In the simplest case, the message routes can be selected to provide shortest distance between two nodes. This approach is simple to implement and provides minimum distance. Adaptive algorithms, on the other hand, attempt to change their routing decisions to reflect changes in topology and current traffic. Three different families of adaptive algorithms exist, differing in the information they use. The global algorithms use information collected from the entire subnet in an attempt to make optimal decisions. This approach is called centralized routing. The local algorithms run separately on each node and use only information available there, such as queue lengths. These are known as isolated algorithms. Finally, the third class of algorithms uses a mixture of global and local information. These are called distributed algorithms. Network routing can be incorporated through a message header or a routing table. In the case of message header implementation, all nodes in the message route are included in the header. Alternatively, the routing information can be stored in a routing table in each node. In this implementation all routes are included in the routing table. The row and column indices of the routing table represent the origination and destination nodes on the route. A routing table entry identifies the link that connects to the next node on the route. At each node, the table is accessed, using the origination and destination node identifications, to determine the link on which to forward the message. In case of lower transmission cost than memory cost, message header procedure is followed. If memory cost is less than transmission cost then routing table procedure becomes cost effective.

On the basis of each of different network configurations of Figures 5.3-5.6, route is determined on the basis of shortest path concept by Dijkstra's algorithm, which is described below.

Dijkstra's algorithm [18]: The Dijkstra's algorithm determines the lengths of the shortest paths from a vertex v to all other vertices in a graph G. Vertices of the graph G are numbered 1 through n. The graph is represented by a cost adjacency matrix. Cost(i,j) is set to a large number if edge(i,j) is not in the graph. Cost(i,j) is assumed zero for i=j. S denotes the set of vertices (including the source) to which the shortest paths have already been generated. For w not in S Dist(w) indicates the length of the shortest path starting from source and going through only those vertices which are in S and ending at w. The destination of the next path generated must be that vertex u which has the minimum distance, Dist(u) among all vertices not in S. During the execution of the algorithm Dist(w) changes and the new Dist(w) becomes the minimum of Dist(w) and {Dist(u) + cost(u,w)}. The edges on the shortest paths from the vertex to all remaining vertices form a spanning tree. This spanning tree is called a shortest path spanning tree.

5.9 Optimization between Delay and cost

For each of the generated topologies of Fig. 5.3 5.6 route matrix and delay are calculated. Ultimately delay and cost for these five different topologies are shown in Fig. 5.7. It is possible to have a compromise on between delay and cost from Figure-5.7.

5.10 Relation between delay and load

Delays of each line of Figures 5.2 and 5.6 are also shown in Table-5.6 for the packet sizes 800 bits and 2000 bits. For the network configuration of Figure-5.2 and 5.6, it is observed that delay is considerably low for a packetsize of 800 bits. With the increase of traffic it may be required to increase the packetsize in future. Both for Fig 5.2 and 5.6, delay is calculated for different packetsizes (expressed as scale factors, 800 bits as scale factor = 1) and the calculated values are shown in Table 5.7. Assuming 800 bits/packet as the base from Table-5.7 it is observed that a maximum available scale factor is about 3 and 4.25 for the topologies of Fig-5.2 and Fig-5.6 respectively.

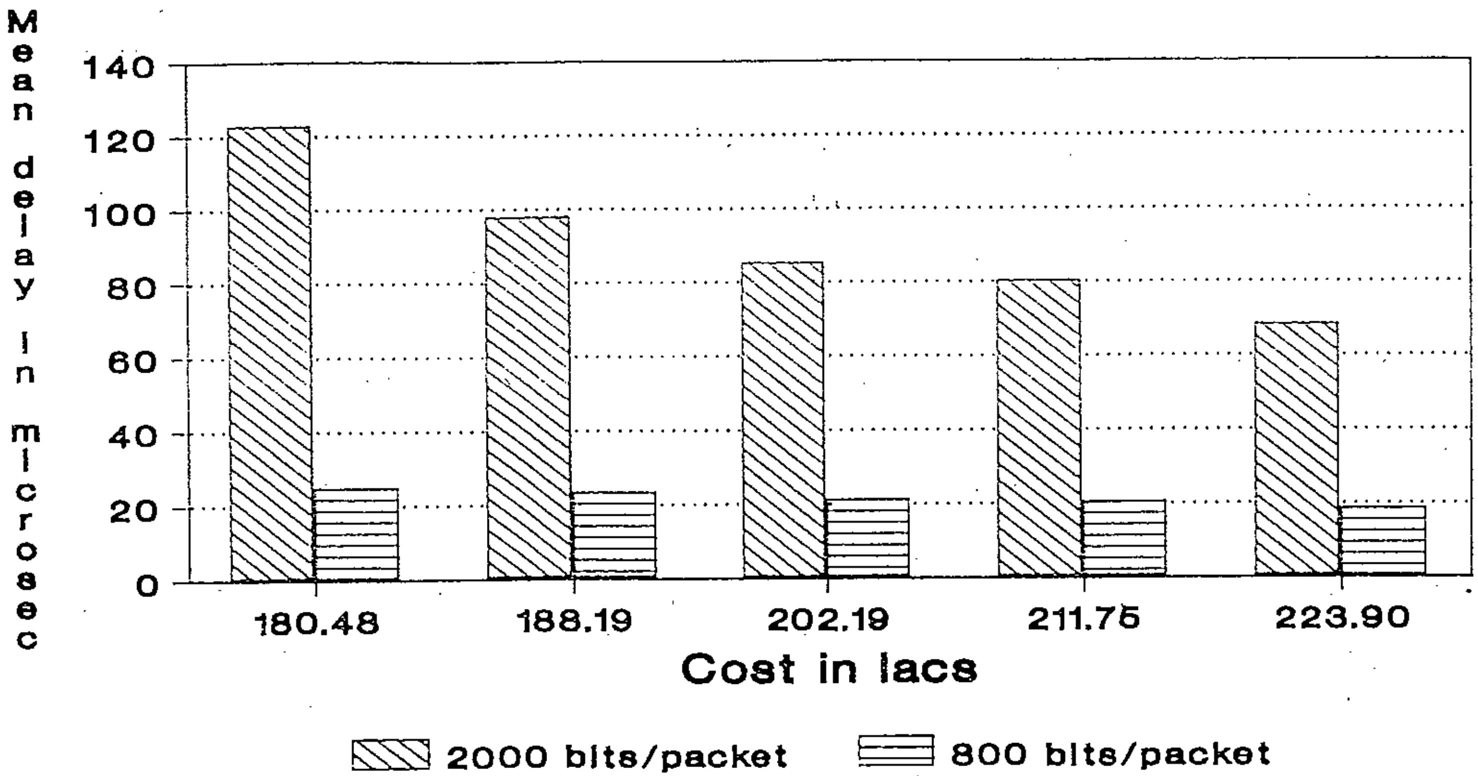


Fig. 5·7: Comparison between Mean Delay & Cost

SCALE FACTOR OF TRAFFIC	MEAN DELAY IN MICRO SEC.	
	TOPOLOGY OF FIG. 5.2	TOPOLOGY OF FIG. 5.6
0.25	5.11	4.02
0.50	10.86	8.4
1.0	24.82	18.5
1.5	43.72	30.95
2.0	71.64	46.86
2.5	122.75	68.25
3.0	2572.05	99.42
3.005	6357.56	99.81
3.008	92369.49	100.04
3.5	UNSTABLE	152.09
4.0	,,	293.24
4.2	,,	722.0
4.25	,,	3877.09
4.2575	,,	93440.09
4.3	,,	UNSTABLE

SCALE FACTOR = 1 FOR 800 PACKETS/SEC

TABLE 5.7: MEAN DELAY OF TOPOLOGY OF FIG. 5.2 AND 5.6 FOR DIFFERNT SCALE FACTORS

5.11 Some standard configurations - Ring, Bus, Star

These are special type of point to point networks. To form a ring network a particular node is considered as origin. The nearest node close to the origin is first accepted. If S is origin and A is the nearest node to S, the arc SA is first chosen and A is assumed as new origin. If there are n nodes, n-1 arcs are included in this way. Then the first origin and the last destination is connected to form the ring. If different nodes are selected as S, cost involvement is different. Out of these, the ring for minimum cost is chosen. This topology is shown in figure 5.8. A bus is same as a ring, except that the connecting arc which joins the first origin and last source is absent. The bus is shown in figure 5.9. In a star network, the network controller can directly communicate to all other nodes. The network controller should be that node for which the total network cost is minimum. The star topology is shown in figure 5.10. Cost and performance characteristics of these topologies are analyzed in section 6.3.

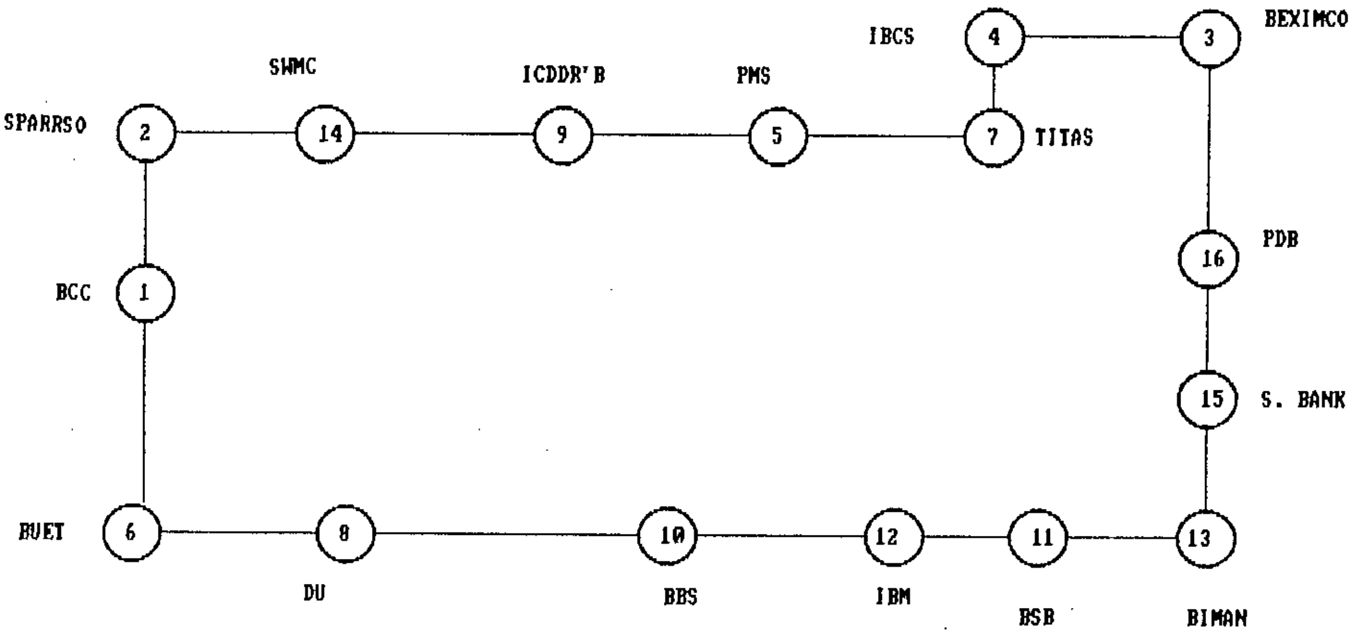


FIG.5.8 : RING CONFIGURATION WITH 16 NODES.

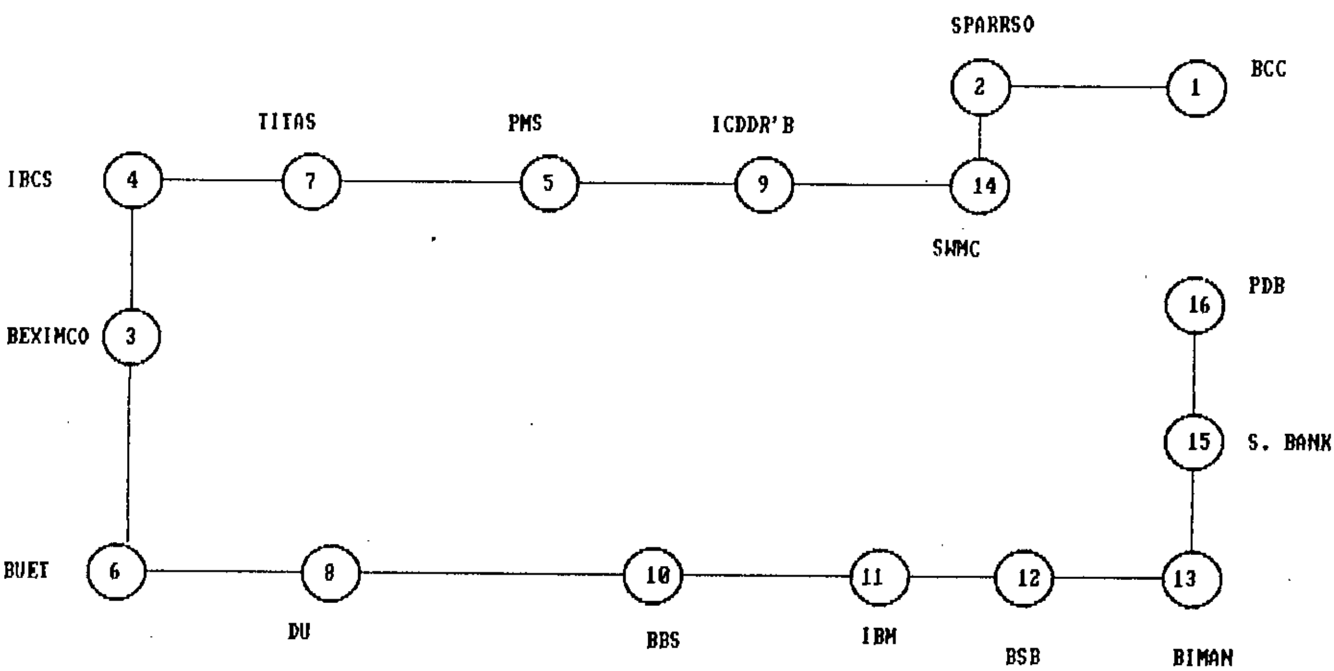


FIG. 5.9 : BUS CONFIGURATION WITH 16 NODES.

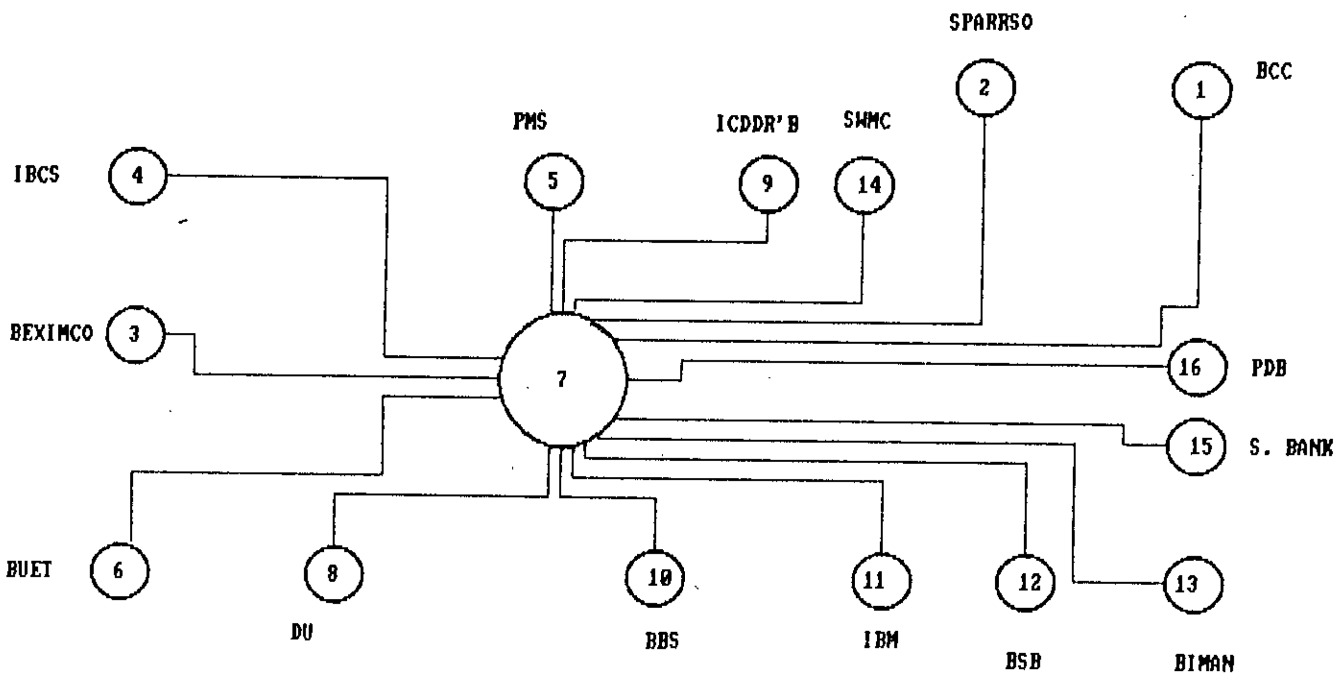


FIG. 5.10:STAR CONFIGURATION WITH 16 NODES.

DISCUSSIONS ON POINT TO POINT NETWORKS

For a network with a large number of nodes point to point networks is formed with nodes in different regions and these clusters are then brought under the control of a hierarchical network. Only 16 nodes have been considered in the point to point network. There are two mainframe computer sites outside Dhaka city. These computer centres are located at ICTVTR, Gazipur and Atomic Energy Research Centre, Savar. It is not cost effective to connect these two installations to the proposed backbone network with fiber optics. These two installations may be included to the network through modem and available telecommunication facility. Each proposed node is surrounded by other smaller organizations, departments or regional offices of a large organization. Also a number of Local Area Networks (LANs) would be established within next few years. These computing facilities with smaller machines or LANs could be considered as lower level of network and it is possible to connect these LANs or smaller computer centres to the backbone network through gateways or bridges. Individual PC users at different locations also can get access to the network through telephone lines or standard cables and appropriate cards. This leads to a hierarchical network topology and such topological design issues are discussed in chapter 6. The proposed network for Dhaka city may be connected through a suitable node to an international network via satellite and telephone line.

The delay of the network (Fig-5.2) shown in Table-5.6 is in the range of micro sec. The traffic will increase gradually and at a stage the delay would reach to tens of millisec range. If due to this increase, delay increases to an unsatisfactory level then it is possible to control delay by adding sufficient arcs to the network. Decrease in delay is accompanied by increase of cost. One can make a compromise between cost and delay according to Fig. 5.7. Different network configurations for different budgets are shown in Figure-5.2, 5.3, 5.4, 5.5 and 5.6 and their required budgets are TK.1,80,48,000.00, 1,88,19,000.00, 2,02,19,000.00, 2,11,75,000.00 and 2,23,90,000.00 respectively. The corresponding mean delays are 24.82, 23.4, 21.18, 20.39 and 18.5 microsec for 800 bits/packet; 122.75, 97.92, 85.24, 80.28 and 68.25 microsec respectively for 2000 bits/packet. Here ratio of packetsizes (2000:800) is 2.5, but ratios of mean delays (4.95:1, 4.18:1, 4.02:1, 3.94:1, 3.69:1) are between 5 and 3.5.

From Table 5.6 it is observed that line LM (between IBM and Biman) of Fig. 5.2 saturates first. In Figure 5.6 some alternate paths are added. As a result the scale factor has increased from 3.0 to 4.25. If more arcs are added higher scale factor will be obtained. Total traffic and delay of each line for Figure-5.6 is also shown in Table-5.6. Here Line FJ (between BUET and BBS) saturates first. For all the lines 1-8 of Fig. 5.2 and Fig. 5.6 delay is identical, because the traffics in these arcs are same for both the figures. The ratio of delays for packetsize 2000 bits and 800 bits is highest for line LM of Figure 5.2, and for line FJ of Figure 5.6. Because traffic of these two lines are very near to saturation level. The highest delay in Figure 5.6 is 104.34 microsec in arc NI, because this is one of the arcs whose capacities were assigned 34 Mbps and its traffic is about 3 times than the other arc AB having 34 Mbps capacity.

From Table 5.6 it is also observed that for Figure 5.6 the total traffic of link FH, HJ, LM and OP is considerably low, it was possible to assign the 34 Mbps capacities for these links, but this is not done for the following reasons [19].

(a) Normally monomode fiber is not available at a transmission rate of 34 Mbps. Monomode fibers are manufactured to support higher transmission rates upto gigabits/sec. Graded-index multimode fiber is to be used for 34 Mbps transmission rate. In this case the core diameter of the fiber is higher than that of monomode fiber [6] and the core material is expensive [16]. This is why ratio of cost of fibers at 34 Mbps to that of 140 Mbps is not as much low as the ratio of the transmission rates(140:34).

(b) The arcs added by saturated cut heuristic method are in mostly well populated areas where traffic rate is high. So, if any link fails then the alternate path would exist for communications, in that case higher transmission rate of the link working as alternate path would be utilized.

(c) The two arcs where assigned capacities are 34 Mbps are located at corners. So, in case of failure of any other arc it would not be possible to divert the traffic in these two links. So, higher transmission capacity, if would assigned in these two links, could not be utilized for reliability purpose like the links FH, HJ, OP and LM.

If cables of 34 Mbps is available at considerably lower cost, it would be cost effective to replace the cables of 140 Mbps by that of 34 Mbps in all cases where optimal capacity is less than or around 34 Mbps. In that case their would be a major change in the cost matrix. As a result the topologies would change. Then it would be an iterative process to adjust capacity of the links, change cost matrix, find out topology and select the best one which fulfils budget constraint and gives minimum delay.

For all the network configurations in figures 5.2-5.6,delay is considerably low for a packetsize of 800 bits. Moreover, the traffic growth factor for estimating the traffic is assumed 2, hence a safety factor of 2 is available here. So, with the increase of computer utilization in any region of the city in the coming years traffic would increase and in that case the links would be able to support the higher traffics.

CHAPTER

SIX

HIERARCHICAL NETWORKS: A POSSIBLE SOLUTION

HIERARCHICAL NETWORKS: A POSSIBLE SOLUTION

So far our study was limited within a single homogeneous network. When number of nodes increases it is desirable to have hierarchical levels in the network. A hierarchical network contains different level of nodes and communication arcs. The objectives of design of a network include lower cost, better capacity utilization, availability of resources, simplicity, better user interface and fast response time. As networks grow in size, the node routing tables grow proportionally. Not only the node memory is consumed by increasing tables, but more CPU time and link capacity are needed to manage different control messages and status reports. At a certain point the network may grow to the point where it is no longer feasible for every node to have an entry for other nodes, so in that case it is necessary to follow hierarchical routing. When hierarchical routing is used, the nodes are divided into regions, with each node knowing all the details about how to route packets to destinations within its own region, but not knowing the internal structure of other regions. When different networks are connected together, each one is regarded as a separate region in order to free the nodes in one network from having to know the topological structure of other nodes. For very large network, a two-level hierarchy may be insufficient; it may be necessary to group the regions into clusters, the clusters into zones, the zones into groups, and so on. Let us consider a network with 20 nodes. Each node will require a routing table with 20 entries. But if the nodes are arranged in five regions, with each region having four nodes, then each node will require 4 local entries and one remote entry for each of other four regions, for a total of 8 entries. Hierarchical routing has reduced the table from 20 to 8 entries. When a single network becomes very large, an interesting issue is the number of required levels for the hierarchy. For example, a network with 720 nodes is assumed. If there is no hierarchy each node needs 720 entries in routing table. If the network is partitioned into 24 regions of 30 nodes each, each node needs 30 local entries plus 23 remote entries for a total of 53 entries. If three level hierarchy is chosen, with eight clusters, each containing nine regions of 10 nodes, each node needs 10 entries for local nodes, 8 entries for routing to other regions within its own cluster, and 7 entries for distant clusters, for a total of 25 entries. Kamoun and Kleinrock (1979) have discovered that the optimal number of levels for an N node network is ln N [1].

For Dhaka city network of three hierarchical levels is being proposed. These are:

Level 1 : Different LANs which contain stand alone PCs or terminals.

Level 2 : Clusters of networks which includes different LANs and other installations having mainframes or minicomputers.

Level 3 : An internetwork which connects the clusters of networks mentioned in level 2.

This chapter is organised as follows- Section 1 includes a discussion on LANs. Section 2 describes the techniques of formation of clusters and the procedure to connect different nodes to different gates. Performance of hierarchical network is analyzed in section 3. A hierarchical network for Dhaka city is proposed in Section 4.

6.1 Local Area Network (LAN)

A LAN is a system that connects computers together within a restricted geographical area to allow sharing of information and hardware and to avail the facility of central or distributed processing as required by different applications.

LANs have three components. These are :

(a) Workstations

(b) Servers

(c) Connection between workstation and Server.

These components are schematically shown in fig 6.1.

Workstation:

A workstation is a simple computer with or without hard disk depending on the requirements. PCs without hard disk are used as workstations only when no local processing is required and the system is dedicated for a specific application. When a PC with hard disk is used as a workstation, certain software is stored in it. These are (i) Application Software, (ii) Network Software and (iii) Systems Software. The system software in a workstation PC is same as that of a single user PC. Application software is word processor, spread sheet or accounting package etc. Network software makes the connection between the applications and the network. A workstation's network software looks for requests that should be handled by the network and sends them to the network, while passing other requests on to the PC system software. A workstation's network software also monitors the network by looking for messages that are destined for that workstation, reading messages and taking necessary actions.

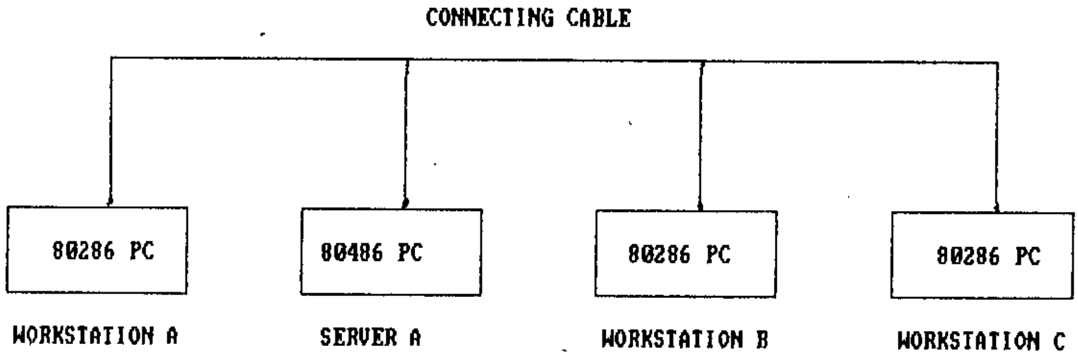


FIGURE 6.1: COMPONENTS OF LAN

Server:

A server is a computer which is normally more powerful and contains more disk space than workstations, and which provides resources to workstations connected to the network. Typical resources include printer, disk drives, plotters as well as application software. Networking system software that runs on a server and controls the sharing of a single server resource is called the server software. Servers can be classified as dedicated and non dedicated server. A dedicated server is used only as a server, while a nondedicated server can also be used simultaneously as a workstation. Servers can also be classified as single purpose server and multipurpose server [4]. A multipurpose server performs all the jobs like printing or providing disk space for workstation users. A single purpose server is dedicated for a specific job. A server dedicated for only printing is called a print server.

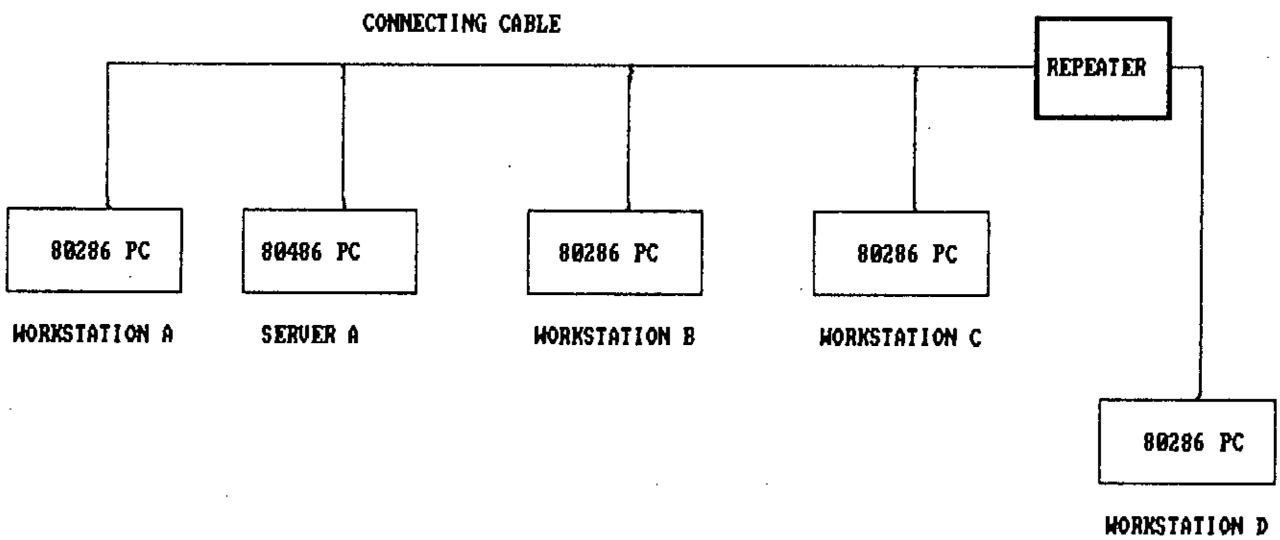
Connections:

The cables and interface hardware used to connect workstations and servers are known as connections. There are three main areas to be considered in choosing a network connection scheme. These are : the topology, the cable type and the network protocol used to transmit data. A printed circuit card, called a network interface card or transceiver is used to hook a PC workstation or a server. The physical layout of connections between workstations and servers is called topology. The most common LAN topologies are bus, ring and star. Normally twisted pair or coaxial cable is used as network cable, although some LANs use optical fibers.

Sometimes it is required to connect one or more workstations at a distance which is greater than the maximum allowable distance from the server. In that case a repeater is required. A repeater in a LAN is shown in Figure 6.2. Repeaters copy individual bits between cable segments. Repeaters are low-level devices that just amplify the electrical signals. In 802.3 LAN, the maximum cable segment length is 500 meters. To allow the network to extend to a larger distance, multiple cable segments can be connected by repeaters. A system may have multiple cable segments and multiple repeaters, but distance between no two transceivers may be more than 2.5 km in 802.3 [1]. As far as software is concerned, a series of cable segments connected by repeaters is not different than a single cable. A repeater receives, amplifies and retransmits signals in both directions.

Internetworking

More than 20,000 SNA networks, 2000 DECNET networks and uncountable number of LANs of different kinds are in daily operation all over the world [1]. To fulfil the requirements of the users it becomes necessary to interconnect two or more networks of similar or dissimilar types. This connection of two or more networks is called internetworking. Bridge is required to communicate between two similar networks and a gateway is used to communicate between two dissimilar networks. Bridges, gateways and essential components for internetworking are shown in Figure 6.3. Normally LANs are connected by bridges. LAN-WAN and WAN-WAN connections are established with gateways.



WORKSTATION D IS AT A HIGHER DISTANCE THAN THE MAX. ALLOWABLE DISTANCE BETWEEN A SERVER AND A WORKSTATION

FIG. 6.2 : REPEATER IN A LAN

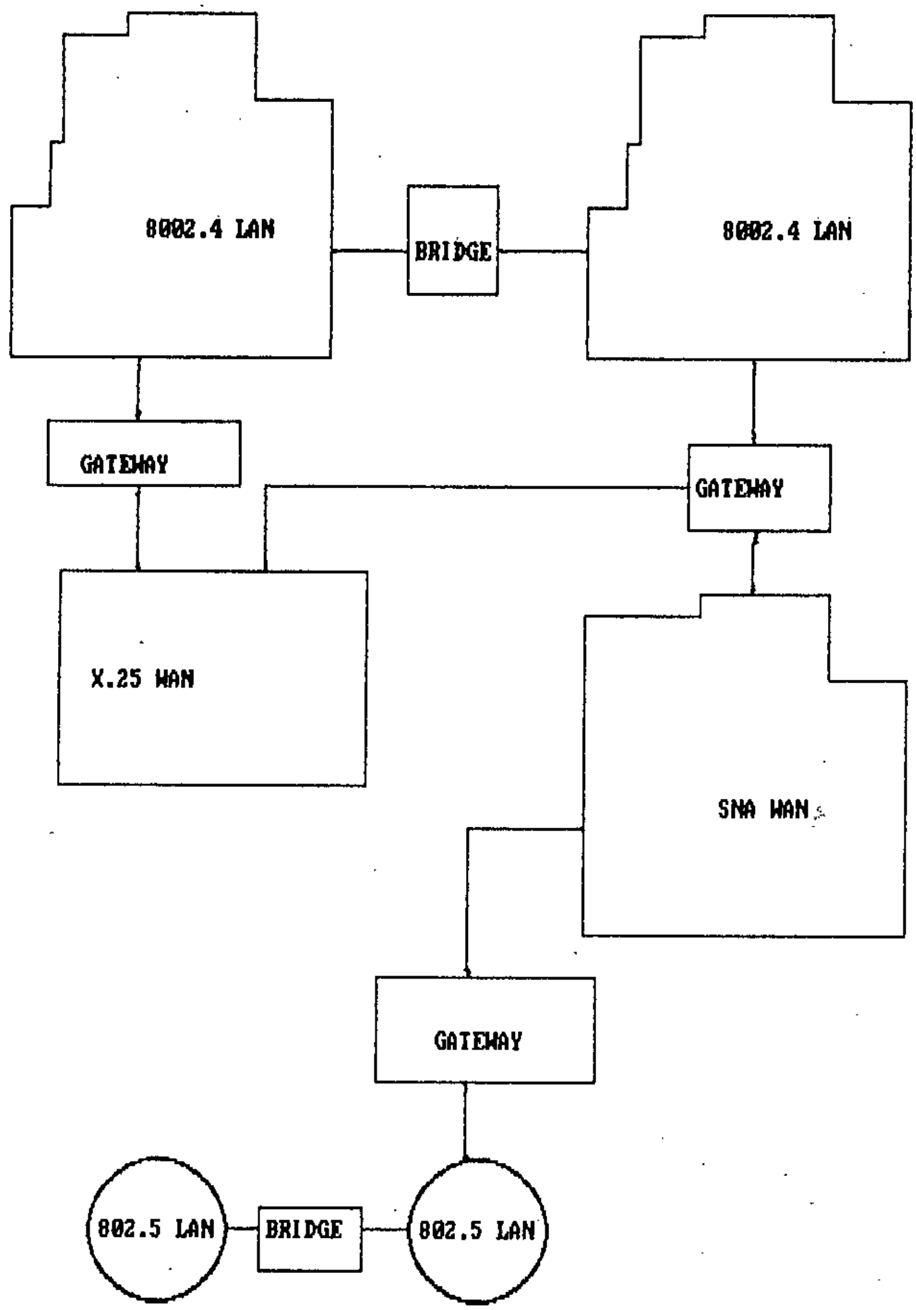


FIG. 6.3 : BRIDGE AND GATEWAY

Bridge:

A bridge connects two identical networks and passes messages between them. Bridges examine each frame and only forward those that need to reach the other segment. Bridges can be programmed to copy frames selectively and make necessary changes while doing so. To design a network with large number of users, the users are grouped into clusters. Clusters are selected in such a way that workstations and servers that most often talk to one another are in the same group. These clusters are then interconnected by bridges. Since the messages local to the cluster stay within that part of the network and do not pass through the bridge, the amount of the total network traffic on the other side of the bridge is reduced. Most bridges connect 802 LANs. The common difficulties encountered by 802 bridges are [1] :

i) Differences in frame formats.

ii) Differences in data speeds.

iii) Differences in frame lengths.

IEEE has designed two types of bridges to interconnect three incompatible LANs. These are [1]:

i) Transparent bridge.

ii) Source Routing bridge.

Normally transparent bridges are used in 802.3 and 802.4 LANs, source routing bridge is used in 802.5 LANs. The transparent bridges are completely invisible to the hosts and are fully compatible with all 802 products. The source bridges are neither transparent nor compatible. When transparent bridges are used, no network management is needed. The bridges configure themselves to the topology automatically. With source routing bridges, the network manager must install the LAN and bridge numbers. The transparent bridge is known as spanning tree bridge, because transparent bridge is only restricted to spanning tree routing, but source routing bridge can use optimal routing.

Gateways:

A gateway connects two dissimilar networks together and lets users on either network to communicate with those on the other network. A gateway can translate addresses between dissimilar networks.This is why gateways are flexible and slow.

Gateways are of two types [1]. These are :

i) Connection oriented gateways.

ii) Connection less gateways.

In connection oriented gateways a sequence of virtual circuits is set up from the source through one or more gateways to the destination. All data packets must traverse the same sequence of gateways between source and destination. The packets arrive at the destination in the same order in which they were sent from the source. Connection less gateways follow datagram model. Datagrams move from network to network using predefined algorithm from source to destination. Packets may not follow the same sequence of gateways. Packets may not arrive at the destination in the same order in which they were sent from the source. However, datagrams at the destination host are reassembled into the original message.

6.2 Formation of clusters

For networks with a large number of nodes (more than a few 100s) it is desirable to have a hierarchical network of more than two levels. Each cluster in a hierarchical network can communicate to another cluster through a gateway. In this thesis a gateway is considered as the entry and exit node for inter-cluster traffic. If point to point wide area network is set up according to any of the topologies mentioned in chapter-5, it is expected that many more users / LANs would like to be connected in such a network. In that case it would be difficult to efficiently support the customers with a single point to point network. A hierarchical structure would be a desirable solution. In this chapter, for the purpose of comparing hierarchical networks with point to point networks described in chapter 5, only 16 nodes in Table 5.1 are considered. Section 4 includes a description on the formation of hierarchical networks with 30 nodes. Dysant and georganas algorithm [3] can be used to find out the number and locations of the gates. Distances between nodes are the input parameters for this algorithm. K is a design parameter which specifies the number of nearest nodes to be considered for each node location. First K = 3 is assumed.

Node Number	List of the nodes and its K nearest neighbours	Frequency
1	1, 2, 5, 4	2
2	2, 1, 5, 7	2
3	3, 4, 7, 6	4
4	4, 3, 7, 5	5
5	5, 7, 9, 4	7
6	6, 8, 10, 3	3
7	7, 4, 5, 3	7
8	8, 6, 10, 12	3
9	9, 5, 14, 7	3
10	10, 12, 8, 11	3
11	11, 12, 13, 15	4
12	12, 11, 13, 15	7
13	13, 12, 11, 15	5
14	14, 9, 5, 7	2
15	15, 16, 13, 12	5
16	16, 15, 13, 12	2

Hence, maximum frequency of occurrence, F is 7 and the ordered list of node locations, s(i), where i is the frequency are:

S(2) = (1,2,14,16)

S(3) = (6,8,9,10)

S(4) = (3,11)

S(5) = (4,13,15)

S(7) = (5,7,12)

So, the constant KM = weighted mean + 1

$$= \frac{\sum_{i=1}^{F} (i.x(i))}{N} + 1$$

Where N is number of nodes

x(i) is number of nodes in list S(i).

So, KM = 5

The initial gateway location list is obtained by the node locations in the list S(F). Further additions are provided by including the nodes from the lists S(P), where KM < p < F. In the above case the gateway list is (5, 7, 12).

If k is assumed 4, maximum frequency of occurrence, F is 8 and the ordered list of node locations are:

S(2) = (1,14)

S(3) = (2,9,10)

S(4) = (3,6)

S(5) = (8,15,16)

S(7) = (5,11,12,13)

S(8) = (4,7)

So, the constant KM = 6

Hence, the gateway list is (4, 7).

If k is assumed 2, maximum frequency of occurrence, F is 6 and the ordered list of node locations are:

S(1) = (14)

S(2) = (1,2,3,6,15,16)

S(3) = (8,9,10,11)

S(4) = (4,7,12)

S(5) = (13)

S(6) = (5)

S(8) = (4,7)

So, the constant KM = 4

Hence, the gateway list is (5, 13).

Connecting nodes to Gateways: For k=3, there are 16 nodes and 3 gateways. The 16 nodes are to be divided in 3 groups so that each group is connected to one particular gateway and the total cost is minimum. The cost of connecting each node to each gateway is shown in Table 6.1. Row i in this table gives the cost of connecting node i to each of the gateways. There are two constraints in the solution of the problem of connecting nodes to gateways. First, a node is connected to only one gateway. Second, each gateway can handle a maximum number of nodes. The limit may be the number of ports, or the processing time required for each interrupt or some other limit like memory, congestion, delay etc. If there is no limit maximum number of nodes may be assumed infinity theoretically.

Node No.	Gateway 1	Gateway 2	Gateway 3
1	2177	2473	4260
2	1870	2288	3953
3	2166	1659	2462
4	1807	1289	2647
5	0	1474	3139
6	2695	1907	1722
7	1474	0	2351
8	2684	1892	1463
9	1511	2277	3720
10	2991	2203	1104
11	3213	2425	722
12	3139	2351	0
13	3224	2436	746
14	2669	3435	4952
15	3372	2584	919
16	3483	2695	1030

TABLE 6.1 : ROW I INDICATES COST IN LACS TAKA TO CONNECT NODE I TO GATES

Hence from Table 6.1 it may be decided that

nodes under gateway 1 (node 5) are 1, 2, 5, 9, 14.

nodes under gateway 2 (node 7) are 3, 4, 7.

nodes under gateway 3 (node 12) are 6,8,10,11,12,13,15,16.

In the same procedure, **for k= 4**

nodes under gateway 1 (node 4) are 1, 3, 4.

nodes under gateway 2 (node 7) are 2, 5-16.

For k = 2

nodes under gateway 1 (node 5) are 1, 2, 3, 4, 5, 7, 9, 14.

nodes under gateway 2 (node 13) are 6, 8, 10, 11, 12, 13, 15, 16.

For k = 4 the nodes are not grouped uniformly, for k=2, there are 2 clusters, and for k=3 there are three clusters. If three clusters are formed with 16 nodes, there would be a better possibility for future expansion to accommodate the users who would be interested to be connected to the network. Hence for subsequent study 16 nodes are grouped into three clusters based on k=3. Later in section 6.4, k has been selected on the basis of cost.

On the basis of the above grouping of nodes different topologies of hierarchical networks are shown in Figures 6.4 - 6.9. These networks are analyzed and discussed in next section.

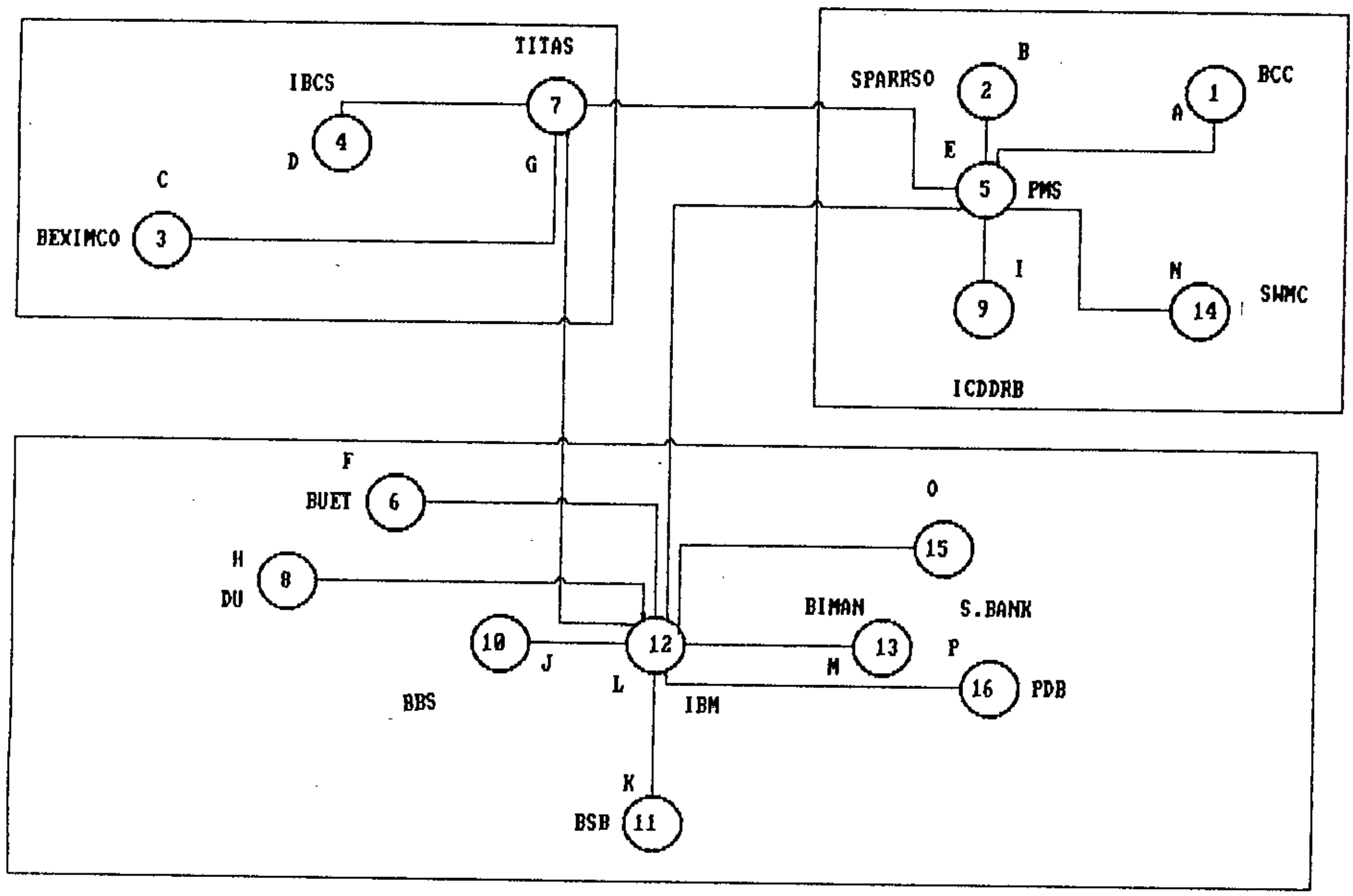


FIGURE 6.4 : HIERARCHICAL CONFIGURATION (RING TOPOLOGY BOR LEVEL 3 AND STAR FOR LEVEL 2)

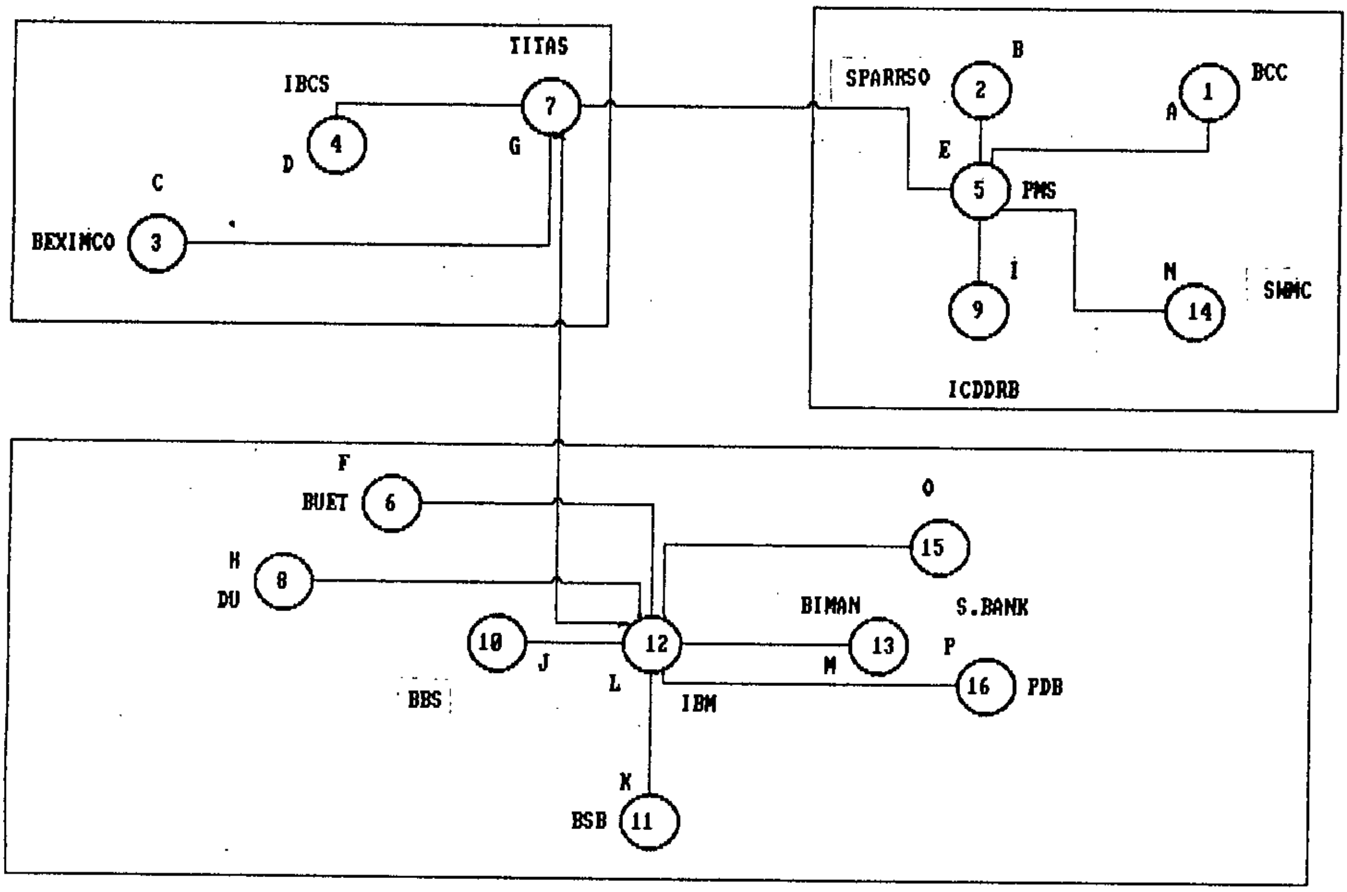


FIGURE 6.5 : HIERARCHICAL CONFIGURATION (MINIMUM SPANNING TREE CONFIGURATION FOR LEVEL 3 AND STAR IN LEVEL 2)

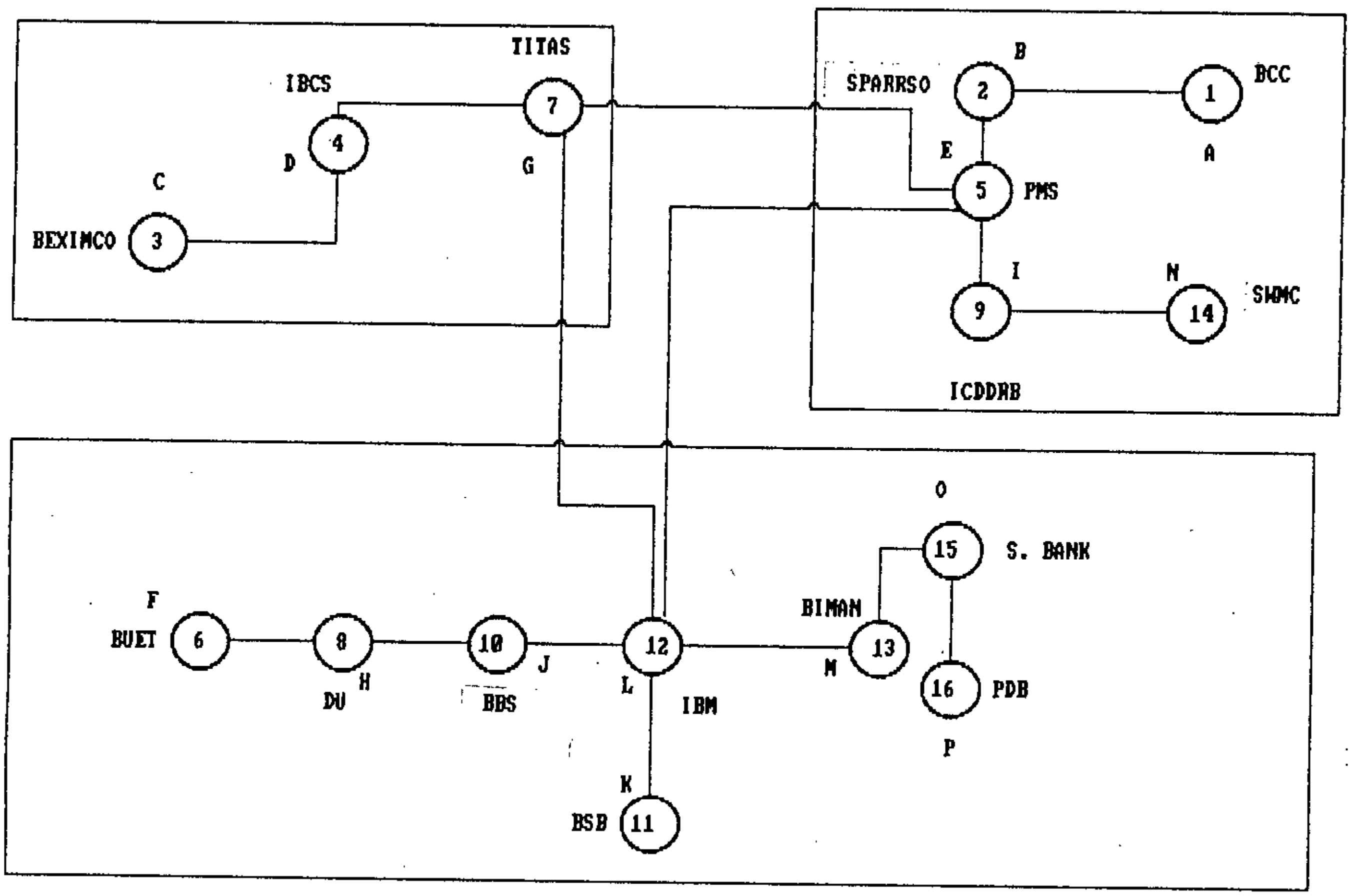


FIGURE 6.6 : HIERARCHICAL CONFIGURATION (RING TOPOLOGY FOR LEVEL 3 AND MIN. SPANNING CONFIGURATION FOR LEVEL 2)

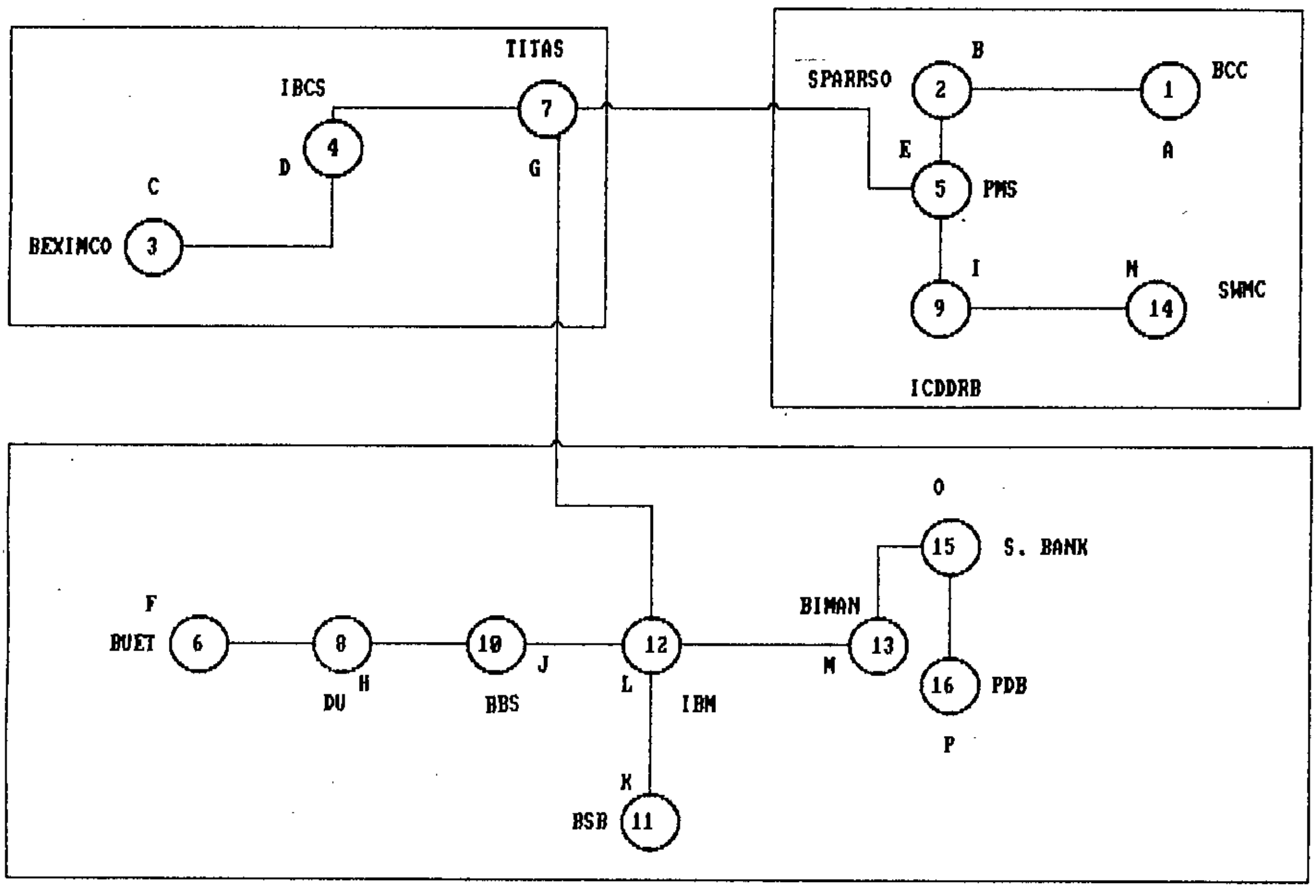


FIGURE 6.7 : HIERARCHICAL NETWORK (MIN. SPANNING TREE CONFIGURATION FOR BOTH LEVEL 2 AND 3)

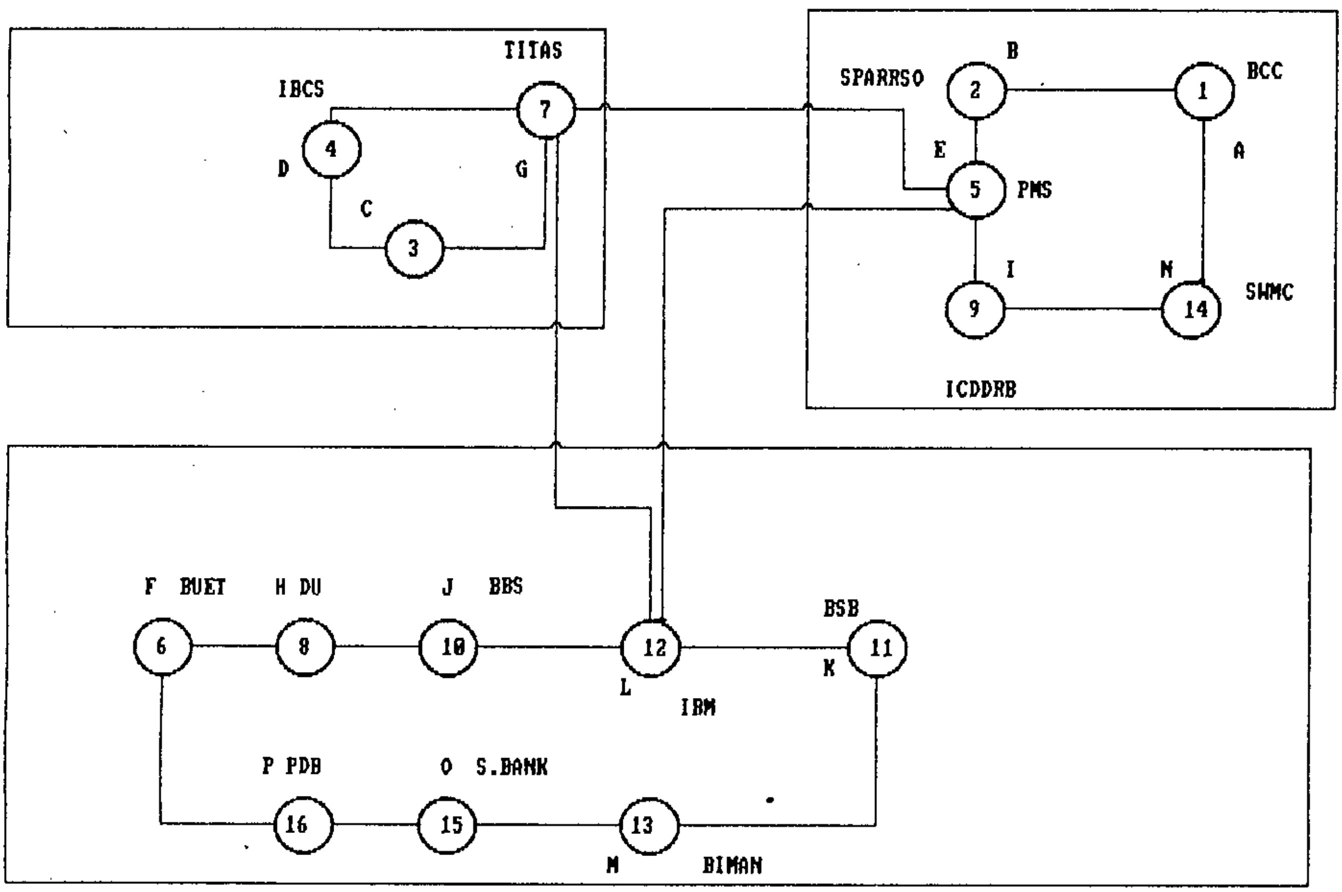


FIGURE 6.8 : HIERARCHICAL CONFIGURATION (RING TOPOLOGY FOR BOTH LEVEL 3 AND 2)

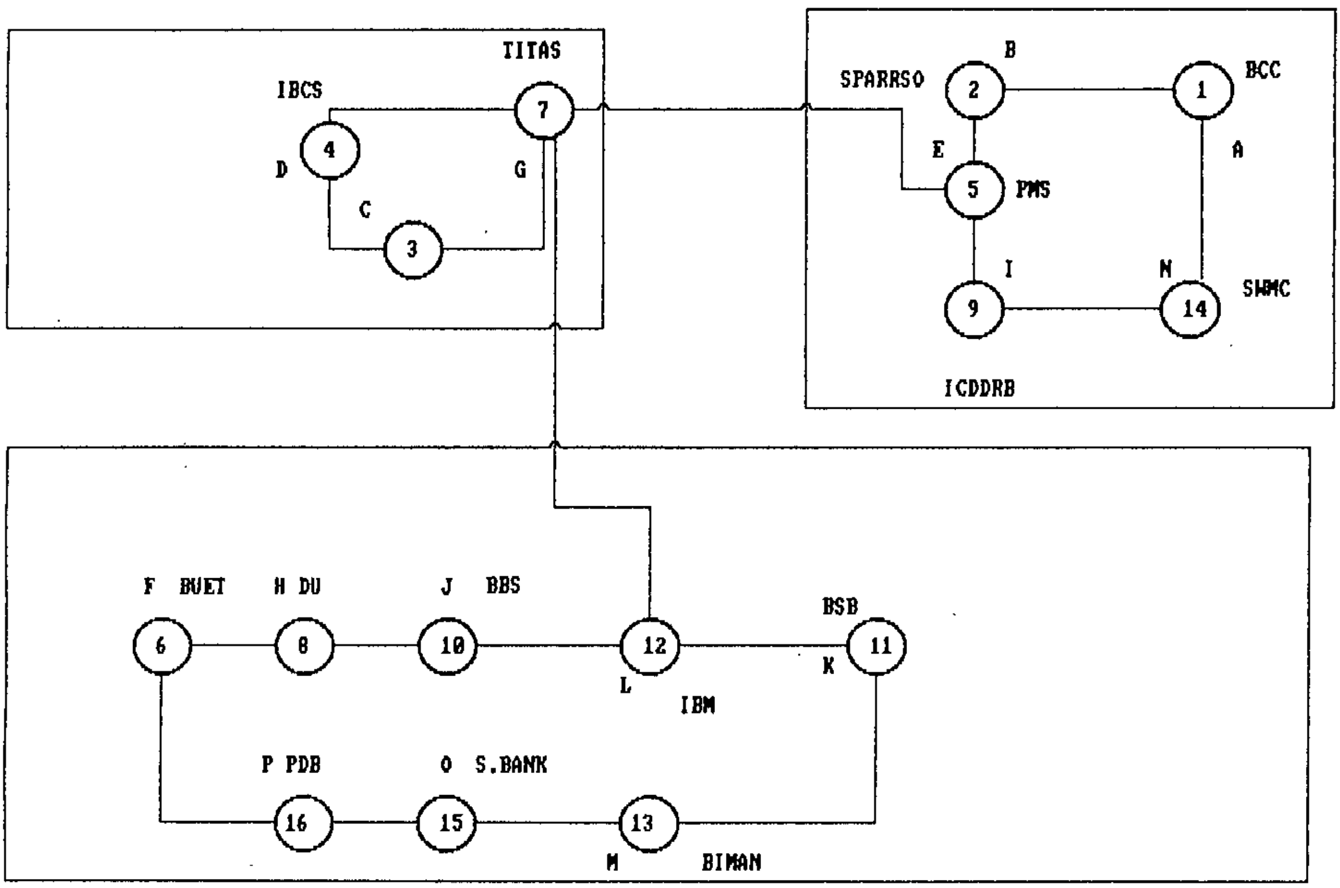


FIGURE 6.9 : HIERARCHICAL CONFIGURATION (RING TOPOLOGY FOR LEVEL 2 AND M. S. T. FOR LEVEL 3]

6.3 Performance analysis and Discussions on hierarchical networks

The nodes in figure 6.4 around different gateways form star topology for level 2 in each cluster. Level 3 of this network is a ring. Here if any link of level 2 fails then only the node connected to that particular link would be out of order. If any link of level 3 fails, then communication would remain available through alternate paths. Different arcs of figure 6.4 are AE, BE, NE, IE, CG, DG, PL, ML, OL, KL, JL, HL, FL, EG, EL, GL. Total traffic in these arcs are 2558, 19455, 7416, 26880, 4729, 10813, 20751, 50453, 34798, 29720, 26792, 6087, 34074, 7451, 26039, 10148 packets/sec respectively. The total cost of this network is 258.45 lacs. Following Dijkstra algorithm shortest distance and path is calculated on the basis of the distance matrix shown in Table 6.2 and the evaluated distance and route matrix is shown in Table 6.3. The mean delay is 14.57 microsec. A scale factor of 3.468 is available assuming scale factor = 1 for a packetsize of 800 bits/packet. The average traffic per link is 19885 packets/sec, whereas in a nonclustered but minimum spanning topology this value is 31890 packets/sec. So, in a clustered network line delay and mean delay is less.

If minimum spanning tree (M. S. T.) is followed in level 3 of Figure 6.4, then total cost would decrease from 258.45 lacs to 227.06 lacs. In that case the traffic in link EL (26039 packets/sec) would be diverted through EG and GL. Hence total traffic in EG would increase from 7451 packets/sec to 33490 packets/sec and that in GL would be 36187 packets/sec. Mean delay increases from 14.57 microsec to 16.013 microsec. Scale factor is 3.468. This topology is shown in Figure 6.5.

Node No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	HIGH	HIGH	HIGH	4100	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
2	HIGH	0	HIGH	HIGH	3267	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
3	HIGH	HIGH	0	HIGH	HIGH	HIGH	2700	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
4	HIGH	HIGH	HIGH	0	HIGH	HIGH	1700	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
5	4100	3267	HIGH	HIGH	0	HIGH	2200	HIGH	2300	HIGH	HIGH	6700	HIGH	5433	HIGH	HIGH
6	HIGH	HIGH	HIGH	HIGH	HIGH	0	HIGH	HIGH	HIGH	HIGH	HIGH	2867	HIGH	HIGH	HIGH	HIGH
7	HIGH	HIGH	2700	1700	2200	HIGH	0	HIGH	HIGH	HIGH	HIGH	4567	HIGH	HIGH	HIGH	HIGH
8	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	0	HIGH	HIGH	HIGH	2167	HIGH	HIGH	HIGH	HIGH
9	HIGH	HIGH	HIGH	HIGH	2300	HIGH	HIGH	HIGH	0	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
10	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	0	HIGH	1200	HIGH	HIGH	HIGH	HIGH
11	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	0	167	HIGH	HIGH	HIGH	HIGH
12	HIGH	HIGH	HIGH	HIGH	6700	2867	4567	2167	HIGH	1200	167	0	233	HIGH	700	1000
13	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	233	0	HIGH	HIGH	HIGH
14	HIGH	HIGH	HIGH	HIGH	5433	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	0	HIGH	HIGH
15	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	700	HIGH	HIGH	0	HIGH
16	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	1000	HIGH	HIGH	HIGH	0

THE VALUES ARE IN METER

TABLE- 6.2 : DISTANCE MATRIX (FOR FIG. 6.4)

Node No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	7367 AEB	9000 AEGC	8000 AEGD	4100 AE	13667 AELF	6300 AEG	12967 AELH	6400 AEI	12000 AELJ	10967 AELK	10800 AEL	11033 AELM	9533 AEN	11500 AELO	11800 AELP
2	7367 BEA	0	8167 BEGC	7167 BEGD	3267 BE	12834 BELF	5467 BEG	12134 BELH	5567 BEI	11167 BELJ	10134 BELK	9967 BEL	10200 BELM	8700 BEN	10667 BELO	10967 BELP
3	9000 CGEA	8167 CGEB	0	4400 CGD	4900 CGE	10134 CGLF	2700 CG	9434 CGLH	7200 CGEI	8467 CGLJ	7434 CGLK	7267 CGL	7500 CGLM	10333 CGEN	7967 CGLO	8267 CGLP
4	8000 DGEA	7167 DGEB	4400 DGC	0	3900 DGE	9134 DGLF	1700 DG	8434 DGLH	6200 DGEI	7467 DGLJ	6434 DGLK	6267 DGL	6500 DGLM	9333 DGEN	6967 DGLO	7267 DGLP
5	4100 EA	3267 EB	4900 EGC	3900 EGD	0	9567 ELF	2200 EG	8867 ELH	2300 EI	7900 ELJ	6867 ELK	6700 EL	6933 ELM	5433 EN	7400 ELO	7700 ELP
6	13667 FLEA	12834 FLEB	10134 FLGC	9134 FLGD	9567 FLE	0	7434 FLG	5034 FLH	11867 FLEI	4067 FLJ	3034 FLK	2867 FL	3100 FLM	15000 FLEN	3567 FLO	3867 FLP
7	6300 GEA	5467 GEB	2700 GC	1700 GD	2200 GE	7434 GLF	0	6734 GLH	4500 GEI	5767 GLJ	4734 GLK	4567 GL	4800 GLM	7633 GLEN	5267 GLO	5567 GLP
8	12967 HLEA	12134 HLEB	9434 HLGC	8434 HLGD	8867 HLE	5034 HLF	6734 HLG	0	11167 HLEI	3367 HLJ	2334 HLK	2167 HL	2400 HLM	14300 HLEN	2867 HLO	3167 HLP
9	6400 IEA	5567 IEB	7200 IEGC	6200 IEGD	2300 IE	11867 IELF	4500 IEG	11167 IELH	0	10200 IELJ	9167 IELK	9000 IEL	9233 IELM	7733 IEN	9700 IELO	10000 IELP
10	12000 JLEA	11167 JLEB	8467 JLGC	7467 JLGD	7900 JLE	4067 JLF	5767 JLG	3367 JLH	10200 JLEI	0	1367 JLK	1200 JL	1433 JLM	13333 JLEN	1900 JLO	2200 JLP
11	10967 KLEA	10134 KLEB	7434 KLGC	6434 KLGD	6867 KLE	3034 KLF	4734 KLG	2334 KLH	9167 KLEI	1367 KLJ	0	167 KL	400 KLM	12300 KLEN	867 KLO	1167 KLP
12	10800 LEA	9967 LEB	7267 LGC	6267 LGD	6700 LE	2867 LF	4567 LG	2167 LH	9000 LEI	1200 LJ	167 LK	0	233 LM	12133 LEN	700 LO	1000 LP
13	11033 MLEA	10200 MLEB	7500 MLGC	6500 MLGD	6933 MLE	3100 MLF	4800 MLG	2400 MLH	9233 MLEI	1433 MLJ	400 MLK	233 ML	0	12366 MLEN	933 MLO	1233 MLP
14	9533 NEA	8700 NEB	10333 NEGC	9333 NEGD	5433 NE	15000 NELF	7633 NEG	14300 NELH	7733 NEI	13333 NELJ	12300 NELK	12133 NEL	12366 NELM	0	12833 NELO	13133 NELP
15	11500 OLEA	10667 OLEB	7967 OLGC	6967 OLGD	7400 OLE	3567 OLF	5267 OLG	2867 OLH	9700 OLEI	1900 OLJ	867 OLK	700 OL	933 OLM	12833 OLEN	0	1700 OLP
16	11800 PLEA	10967 PLEB	8267 PLGC	7267 PLGD	7700 PLE	3867 PLF	5567 PLG	3167 PLH	10000 PLEI	2200 PLJ	1167 PLK	1000 PL	1233 PLM	13133 PLEN	1700 PLO	0

TABLE 6.3: SHORTEST DISTANCE AND CONCERNED PATH (FOR FIG. 6.4)

If minimum spanning tree configuration is followed in level 2 and ring topology is followed in level 3 then the network is as shown in Figure 6.6. Here the arcs are AB, BE, NI, IE, CD, DG, FH, HJ, JL, KL, PO, OM, LM, EG, GL, EL. Traffics in these links are 2558, 20281, 7416, 28150, 4729, 13950, 34074, 34879, 46625, 29720, 20751, 39525, 58174, 7451, 10148, 26039 packets/sec respectively. Average traffic per link is 24029 packets/sec. Mean delay is 18.36 microsec, total cost is 226.72 lacs and scale factor is 3.008.

If both level 2 and level 3 is configured on minimum spanning tree then total cost is 195.53 lacs. In that case mean delay is 19.8 micro sec. The scale factor is 3.008. This network is shown in Figure 6.7. In Figure 6.8 and 6.9 ring configuration is considered in level 2. Concerned network parameters for different hierarchical and point to point topologies (Fig. 6.4-6.9, 5.2, 5.8-5.10) are shown in table 6.4.

From the results in Table 6.4 it is observed that for Star network, delay is less for both in point to point and hierarchical network. Delay in all hierarchical structures is reasonably less than point to point networks, except the point to point star network (Fig. 5.10) where involved cost is maximum.

For any change in the topology, both cost and mean delay is changed, but scale factor may or may not change. Because, scale factor depends on the traffic on the arc which saturates first. Though cost in topology of Figure 6.8 is greater than that in Figure 6.5, scale factor is less in Figure 6.8. Any failure of any arc in level 2 in case of star configuration will cause less users isolated from the network, than in case of any other configuration. For example, if the arc LJ in Figure 6.4 or 6.5 fails, only users in node 10 would be

SL. NO.	FIG. NO.	TOPOLOGY	MEAN DELAY IN MICRO SEC	SCALE FACTOR	COST IN LACS TAKA
1	6.4	STAR IN LEVEL2, RING IN LEVEL 3	14.57	3.468	258
2	6.5	STAR IN LEVEL 2, M.S.T. IN LEVEL 3	16.01	3.468	227
3	6.6	M.S.T. IN LEVEL 2, RING IN LEVEL 3	18.36	3.008	226
4	6.7	M.S.T. IN BOTH LEVEL 2 AND 3	19.8	3.008	195.53
5	6.8	RING IN BOTH LEVEL 2 AND 3	17.89	3.264	305.6
6	6.9	RING IN LEVEL 2, M.S.T. IN LEVEL 3	19.33	3.264	274.21
7	5.2	M.S.T. (POINT TO POINT)	23.38	3.008	189.52
8	5.8	RING CONFIGURATION (POINT TO POINT)	25.70	2.648	253.35
9	5.9	BUS CONFIGURATION (POINT TO POINT)	26.44	3.008	209.87
10	5.10	STAR CONFIGURATION (POINT TO POINT)	13.58	3.468	333.88

TABLE 6. 4 : IMPORTANT CHARACTERISTICS OF DIFFERENT TOPOLOGIES.

isolated from the network. But if arc LJ in Figure 6.6 or 6.7 fails then users in a number of nodes would be isolated from the network.

In Figure 5.10, the routing table in the star controller (node-7) in non-clustered configuration would contain 15 entries, but in clustered network in Figure 6.5 the routing table with largest number of entries in node 12 will be 8. As traffic from all surrounding nodes arrive at star controller, probability of congestion with same number of nodes in clustered network is less than that in non-clustered network.
If any gate fails, then the concerned cluster would be isolated from other clusters, but the nodes within the cluster would communicate among themselves. For reliability purpose, if interruption is not tolerable, more than one gateway in a cluster may be suggested. From Table 6.4 it seems that star network is better than other hierarchical networks in consideration of mean delay or scale factor and failure in individual arc, but in consideration of failure in gate any other hierarchical network is a better solution than the star. If gateway 3 (node 12) in Figure 6.4 fails then all the nodes associated with this gateway would get no service from the network.

6.4 Proposed Network for Dhaka City

Recent trend of applications and uses of computers indicate that the nodes considered in the hierarchical network in sec 6.2 would be insufficient to meet the requirements of the users. Number of organizations and private enterprises interested to avail network facilities would increase and in that case it would be required to form several clusters in different regions of the city. Concepts and methodology of forming point to point networks mentioned in chapter-5 would be applicable to build different clusters. The following 30 nodes are considered for a proposed hierarchical network in Dhaka city. The nodes are numbered in increasing order of their X co-ordinates. Number of users (Terminals and PCs) and the co-ordinates of the nodes are also mentioned. Organizations with asterisk (*) sign were previously considered in chapter 5.

Sl No	Name of the node	Co-ordinates	No. of users
1.	Bangladesh Computer Council *	(-3009, 5833)	10
2.	UNDP	(-2009, 2833)	72
3.	SPARRSO *	(-1475, 6666)	104
4.	BEXIMCO *	(-1375, 1466)	14
5.	IBCS-PRIMAX *	(-942 , 2200)	35
6.	Prime Minister's secretariat *	(-175 , 5030)	13
7.	British Council	(-75 , 433)	26
8.	BUET *	(0 , 0)	110
9.	Titas Gas *	(125 , 3000)	14
10.	Hotel Sonargaon	(325 , 2800)	46
11.	Hotel Sheraton	(725 , 1700)	10
12.	Dhaka University *	(725 , 70)	10
13.	Bangladesh Oxygen limited	(1025 , 6833)	34
14.	ICDDR'B *	(1190 , 6330)	146
15.	Directorate of Narcotics	(1591 , 866)	14

Sl No	Name of the node	Co-ordinates	No. of users
16.	BRAC	(1591 , 6666)	32
17.	Bureau of Statistics *	(1855 , 100)	60
18.	National Board of Revenue	(1991 , 1033)	40
19.	House Building Finance Corp.	(2191 , 366)	12
20.	Bangladesh Shilpa Bank *	(2558 , 30)	30
21.	IBM world trade corporation *	(2625 , 166)	12
22.	Biman Bangladesh Airlines *	(2795 , 30)	62
23.	Arab Bangladesh Bank Ltd.	(3158 , -134)	20
24.	SWMC *	(3191 , 7566)	40
25.	Sonali Bank *	(3200 , -200)	46
26.	PDB *	(3225 , -506)	29
27.	British High Commission	(3225 , 8833)	13
28.	Bank Indosuez	(3391 , -67)	22
29.	Bangladesh Bank	(3425 , -234)	20
30.	American Embassy	(3491 , 8633)	50

The linear distances and the distances along the road among the nodes are shown in Table 6.5 and 6.6 respectively.

Node No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	3162	1746	4663	4180	2946	6146	6563	4225	4507	5438	6867	4156	4228	6770
2	3162	0	3870	1507	1241	2862	3082	3473	2141	2334	2776	3887	5020	4739	4102
3	1746	3870	0	5201	4498	2090	6388	6827	4000	4264	5354	6953	2506	2686	6561
4	4663	1507	5201	0	852	3761	1660	2010	2145	2161	1914	2522	5879	5499	3026
5	4180	1241	4498	852	0	2932	1968	2393	1334	1402	1550	2705	5033	4648	2863
6	2946	2862	2090	3761	2932	0	4598	5033	2052	2285	3403	5041	2166	1885	4523
7	6146	3082	6388	1660	1968	4598	0	439	2575	2401	1402	879	6494	6031	1721
8	6563	3473	6827	2010	2393	5033	439	0	3003	2819	1779	728	6909	6441	1811
9	4225	2141	4000	2145	1334	2052	2575	3003	0	283	1360	2991	3937	3496	2589
10	4507	2334	4264	2161	1402	2285	2401	2819	283	0	1118	2759	4093	3634	2312
11	5438	2776	5354	1914	1550	3403	1402	1779	1360	1118	0	1642	5157	4678	1353
12	6867	3887	6953	2522	2705	5041	879	728	2991	2759	1642	0	6770	6277	1176
13	4156	5020	2506	5879	5033	2166	6494	6909	3937	4093	5157	6770	0	529	5994
14	4228	4739	2686	5499	4648	1885	6031	6441	3496	3634	4678	6277	529	0	5479
15	6770	4102	6561	3026	2863	4523	1721	1811	2589	2312	1353	1176	5994	5479	0
16	4675	5259	3066	5986	5134	2407	6452	6853	3948	4068	5079	6653	590	523	5800
17	7518	4733	7362	3507	3498	5332	1959	1858	3377	3103	2081	1130	6784	6265	810
18	6931	4386	6614	3394	3157	4546	2151	2243	2711	2429	1611	1591	5880	5357	433
19	7545	4871	7289	3732	3630	5230	2267	2221	3348	3067	2134	1496	6571	6047	781
20	8042	5359	7765	4187	4118	5698	2664	2558	3839	3558	2631	1833	6974	6447	1278
21	7991	5347	7685	4206	4106	5612	2713	2630	3779	3497	2601	1902	6856	6329	1249
22	8207	5562	7891	4410	4321	5816	2898	2795	3994	3711	2818	2070	7029	6501	1466
23	8581	5958	8228	4807	4718	6146	3282	3161	4361	4079	3209	2442	7286	6757	1859
24	6438	7031	4752	7620	6773	4214	7845	8211	5500	5561	6443	7891	2287	2352	6888
25	8657	6028	8306	4869	4787	6224	3336	3206	4438	4155	3281	2490	7362	6832	1930
26	8886	6205	8570	5003	4965	6492	3429	3264	4675	4393	3483	2564	7656	7127	2130
27	6918	7962	5176	8685	7833	5101	9025	9403	6606	6694	7627	9113	2973	3226	8133
28	8705	6129	8307	5006	4890	6221	3502	3392	4480	4198	3367	2670	7294	6765	2027
29	8843	6240	8463	5092	5000	6377	3563	3433	4620	4338	3486	2717	7463	6934	2139
30	7077	7993	5341	8663	7812	5140	8942	9312	6562	6637	7541	8999	3053	3256	7996

TABLE 6.5 (PART 1 OF 2) : LINEAR DISTANCES AMONG THE NODES IN METER

Node No.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	4675	7518	6931	7545	8042	7991	8207	8581	6438	8657	8886	6918	8705	8843	7077
2	5259	4733	4386	4871	5359	5347	5562	5985	7031	6028	6205	7962	6129	6240	7993
3	3066	7362	6614	7289	7765	7685	7891	8228	4752	8306	8570	5176	8307	8463	5341
4	5986	3507	3394	3732	4187	4206	4410	4807	7620	4869	5003	8685	5006	5092	8663
5	5134	3498	3157	3630	4118	4106	4321	4718	6773	4787	4965	7833	4890	5000	7812
6	2407	5332	4546	5230	5698	5612	5816	6146	4214	6224	6492	5101	6221	6377	5140
7	6452	1959	2151	2267	2664	2713	2898	3282	7845	3336	3429	9025	3502	3563	8942
8	6853	1858	2243	2221	2558	2630	2795	3161	8211	3206	3264	9403	3392	3433	9312
9	3948	3377	2711	3348	3839	3779	3994	4361	5500	4438	4675	6606	4480	4620	6562
10	4068	3103	2429	3067	3558	3497	3711	4079	5561	4155	4393	6694	4198	4338	6637
11	5079	2081	1611	2134	2631	2601	2818	3209	6443	3281	3483	7627	3367	3486	7541
12	6653	1130	1591	1496	1833	1902	2070	2442	7891	2490	2564	9113	2670	2717	8999
13	590	6784	5880	6571	6974	6856	7029	7286	2287	7362	7656	2973	7294	7463	3053
14	523	6265	5357	6047	6447	6329	6501	6757	2352	6832	7127	3226	6765	6934	3256
15	5800	810	433	781	1278	1249	1466	1859	6888	1930	2130	8133	2027	2139	7996
16	0	6571	5647	6329	6706	6582	6744	6978	1836	7052	7350	2714	6969	7140	2735
17	6571	0	943	429	706	773	943	1324	7585	1378	1496	8840	1545	1605	8688
18	5647	943	0	696	1152	1074	1285	1650	6642	1727	1968	7897	1780	1914	7747
19	6329	429	696	0	498	478	691	1089	7269	1157	1349	8530	1276	1372	8369
20	6706	706	1152	498	0	152	237	622	7563	682	852	8828	839	906	8653
21	6582	773	1074	478	152	0	218	612	7422	682	896	8688	801	894	8511
22	6744	943	1285	691	237	218	0	398	7546	466	682	8813	604	683	8631
23	6978	1324	1650	1089	622	612	398	0	7700	78	372	8967	242	285	8773
24	1836	7585	6642	7269	7563	7422	7546	7700	0	7766	8066	1267	7636	7804	1108
25	7052	1378	1727	1157	682	682	466	78	7766	0	301	9033	233	228	8838
26	7350	1496	1968	1349	852	896	682	372	8066	301	0	9333	464	333	9137
27	2714	8840	7897	8530	8828	8688	8813	8967	1267	9033	9333	0	8902	9069	333
28	6969	1545	1780	1276	839	801	604	242	7636	233	464	8902	0	170	8701
29	7140	1605	1914	1372	906	894	683	285	7804	228	333	9069	170	0	8867
30	2735	8688	7747	8369	8653	8511	8631	8773	1108	8838	9137	333	8701	8867	0

TABLE 6.5 (PART 2 OF 2) : LINEAR DISTANCES AMONG NODES IN METER

Node No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	4067	2400	5033	4267	4100	6667	7300	4900	5567	6533	7867	6533	6267	8233
2	4067	0	5467	1767	1433	4500	3467	4400	2833	2867	3833	4967	6933	6667	5633
3	2400	5467	0	6267	5300	3267	7267	7700	4400	4733	5700	7667	5700	5433	7400
4	5033	1767	6267	0	1233	4067	2300	3000	2700	2733	2333	3567	6500	6233	3467
5	4267	1433	5300	1233	0	3100	2800	3500	1700	1733	2700	4067	5533	5267	3967
6	4100	4500	3267	4067	3100	0	5067	5500	2200	2533	3500	5467	2567	2300	5200
7	6667	3467	7267	2300	2800	5067	0	500	3000	2733	1767	1133	7500	7233	2900
8	7300	4400	7700	3000	3500	5500	500	0	3367	3167	2200	833	8200	8133	2233
9	4900	2833	4400	2700	1700	2200	3000	3367	0	400	1367	3333	4633	4367	3067
10	5567	2867	4733	2733	1733	2533	2733	3167	400	0	1167	3133	4967	4700	2867
11	6533	3833	5700	2333	2700	3500	1767	2200	1367	1167	0	2167	5933	5667	1900
12	7867	4967	7667	3567	4067	5467	1133	833	3333	3133	2167	0	7900	7633	1533
13	6533	6933	5700	6500	5533	2567	7500	8200	4633	4967	5933	7900	0	933	7100
14	6267	6667	5433	6233	5267	2300	7233	8133	4367	4700	5667	7633	933	0	6533
15	8233	5633	7400	3467	3967	5200	2900	2233	3067	2867	1900	1533	7100	6533	0
16	7167	7567	6333	7133	6167	3200	8133	8567	5267	5600	6567	8533	833	1567	7733
17	9333	6200	8500	4733	5233	6300	2300	2000	4167	3967	3000	1300	8433	7867	1333
18	8333	5733	7500	4000	4500	5300	3433	2733	3167	2967	2000	2033	7000	6433	567
19	9133	5733	8300	4267	4767	6133	2567	2267	3967	3767	2800	1567	8233	7667	1167
20	9933	6533	9100	5067	5567	6900	3367	3067	4767	4567	3600	2367	9033	8467	1967
21	9733	6400	8900	4867	5367	6700	3233	2867	4567	4433	3467	2167	8900	8267	1833
22	9967	6567	9133	5100	5600	6933	3400	3033	4800	4600	3633	2400	9067	8500	2000
23	10333	6933	9500	5467	5967	7300	3767	3467	5167	4967	4000	2767	9433	8867	2367
24	9400	9800	8567	9367	8400	5433	10367	10800	7500	7833	8800	10767	3067	3800	9967
25	10367	6967	9533	5500	6000	7333	3800	3500	5200	5000	4033	2800	9467	8900	2400
26	10667	7267	9833	5800	6300	7633	4100	3800	5500	5300	4333	3100	9767	9200	2700
27	10500	10900	9667	10467	9500	6533	11467	12167	8600	8933	9900	11867	4500	4900	11067
28	10533	7133	9700	5667	6167	7500	3967	3667	5367	5167	4200	2967	9633	9067	2567
29	10600	7200	9767	5733	6233	7567	4033	3733	5433	5233	4267	3033	9700	9133	2633
30	10433	10833	9600	10400	9433	6467	11400	12100	8533	8867	9833	11800	4433	4833	11000

TABLE 6.6 (PART 1 OF 2) : DISTANCES AMONG THE NODES IN METER (ALONG THE ROAD)

Node No.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	7167	9333	8333	9133	9933	9733	9967	10333	9400	10367	10667	10500	10533	10600	10433
2	7567	6200	5733	5733	6533	6400	6567	6933	9800	6967	7267	10900	7133	7200	10833
3	6333	8500	7500	8300	9100	8900	9133	9500	8567	9533	9833	9667	9700	9767	9600
4	7133	4733	4000	4267	5067	4867	5100	5467	9367	5500	5800	10467	5667	5733	10400
5	6167	5233	4500	4767	5567	5367	5600	5967	8400	6000	6300	9500	6167	6233	9433
6	3200	6300	5300	6133	6900	6700	6933	7300	5433	7333	7633	6533	7500	7567	6467
7	8133	2300	3433	2567	3367	3233	3400	3767	10367	3800	4100	11467	3967	4033	11400
8	8567	2000	2733	2267	3067	2867	3033	3467	10800	3500	3800	12167	3667	3733	12100
9	5267	4167	3167	3967	4767	4567	4800	5167	7500	5200	5500	8600	5367	5433	8533
10	5600	3967	2967	3767	4567	4433	4600	4967	7833	5000	5300	8933	5167	5233	8867
11	6567	3000	2000	2800	3600	3467	3633	4000	8800	4033	4333	9900	4200	4267	9833
12	8533	1300	2033	1567	2367	2167	2400	2767	10767	2800	3100	11867	2967	3033	11800
13	833	8433	7000	8233	9033	8900	9067	9433	3067	9467	9767	4500	9633	9700	4433
14	1567	7867	6433	7667	8467	8267	8500	8867	3800	8900	9200	4900	9067	9133	4833
15	7733	1333	567	1167	1967	1833	2000	2367	9967	2400	2700	11067	2567	2633	11000
16	0	9067	7633	8867	9667	9533	9700	10067	2300	10100	10400	3933	10267	10333	3867
17	9067	0	1833	667	1400	1200	1500	1867	11300	1900	2200	12733	2067	2133	12667
18	7633	1833	0	1000	1800	1667	1833	2200	9867	2233	2533	10967	2400	2467	10900
19	8867	667	1000	0	867	733	900	1267	11100	1300	1600	12233	1467	1533	12167
20	9667	1400	1800	867	0	167	300	733	11833	767	1067	13000	967	1033	12933
21	9533	1200	1667	733	167	0	233	667	11633	700	1000	12867	867	933	12800
22	9700	1500	1833	900	300	233	0	433	11867	500	800	13033	633	700	12967
23	10067	1867	2200	1267	733	667	433	0	12300	167	467	13400	333	400	13333
24	2300	11300	9867	11100	11833	11633	11867	12300	0	12267	12567	1567	12433	12500	1500
25	10100	1900	2233	1300	767	700	500	167	12267	0	333	13433	233	300	13367
26	10400	2200	2633	1600	1067	1000	800	467	12567	333	0	13733	467	433	13667
27	3933	12733	10967	12233	13000	12867	13033	13400	1567	13433	13733	0	13600	13667	533
28	10267	2067	2400	1467	967	867	633	333	12433	233	467	13600	0	200	13533
29	10333	2133	2467	1533	1033	933	700	400	12500	300	433	13667	200	0	13600
30	3867	12667	10900	12167	12933	12800	12967	13333	1500	13367	13667	533	13533	13600	0

TABLE 6.6 (PART 2 OF 2) : DISTANCES AMONG NODES IN METER (ALONG THE ROAD)

On the basis of Table 6.6 and the cost information for optical communication mentioned in chapter-5 a cost matrix is found. Dysant and georganas' algorithm can be used to find out the number and locations of the gates.

Node Number	List of the nodes and its K (3) nearest neighbours	Frequency
1	1, 2, 3, 6	2
2	2, 4, 5, 9	4
3	1, 3, 6, 9	2
4	2, 4, 5, 7	3
5	2, 4, 5, 9	5
6	6, 9, 10, 14	5
7	7, 8, 11, 12	5
8	7, 8, 12, 17	3
9	5, 9, 10, 11	7
10	5, 9, 10, 11	4
11	7, 9, 10, 11	4
12	7, 8, 12, 17	4
13	6, 13, 14, 16	3
14	6, 13, 14, 16	4
15	15, 17, 18, 19	2
16	13, 14, 16, 24	6
17	12, 17, 19, 21	5
18	15, 18, 19, 21	2

Node Number	List of the nodes and its K (3) nearest neighbours	Frequency
19	17, 19, 20, 21	4
20	20, 21, 22, 23	4
21	20, 21, 22, 23	6
22	20, 21, 22, 23	3
23	23, 25, 28, 29	8
24	16, 24, 27, 30	4
25	23, 25, 28, 29	5
26	23, 25, 26, 29	1
27	16, 24, 27, 30	3
28	23, 25, 28, 29	4
29	23, 25, 28, 29	5
30	16, 24, 27, 30	3

Hence, maximum frequency of occurrence, F is 8 and the ordered list of node locations, s(i), where i is the frequency are:

S(1) = (26)

S(2) = (1,3,15,18)

S(3) = (4,8,13,22,27,30)

S(4) = (2,10,11,12,14,19,20,24,28)

S(5) = (5,6,7,17,25,29)

S(6) = (16,21)

S(7) = (9)

S(8) = (23)

So, the constant KM = weighted mean + 1 = 5

The initial gateway location list is obtained by the node locations in the list S(F). Further additions are provided by including the nodes from the lists S(P), where KM < p < F. In the above case the gateway list is (9, 16, 21, 23). If k is assumed 4, the gateway list is (6, 23, 25)
If k is assumed 2, the gateway list is (21, 25)

Connecting nodes to Gateways: For k=3, there are 30 nodes and 4 gateways. The 30 nodes are to be divided in 4 groups so that each group is connected to one particular gateway and the total cost is minimum. The cost of connecting each node to each gateway is shown in Table 6.7. Row i in this table gives the cost of connecting node i to each of the gateways. There are two constraints in the solution of the problem of connecting nodes to gateways. First, each node is connected to only one gateway. Second, each gateway can handle a maximum number of nodes. The limit may be the number of ports, or the processing time required for each interrupt or some other limit. If there is no limit maximum number of nodes may be assumed infinity theoretically. Hence from Table 6.7 it may be decided that

nodes under gateway 1 (node 9) are 1, 2, 3, 4, 5, 6, 7, 9, 10, 11.
nodes under gateway 2 (node 16) are 13, 14, 16, 24, 27, 30.
nodes under gateway 3 (node 21) are 8, 12, 15,17, 18, 19, 20, 21, 22
nodes under gateway 4 (node 23) are 23, 25,26, 28, 29

Node No.	Gateway (Node) 1(9).	2(16)	3(21)	4(23)
1	2473000	3311790	4261210	4483210
2	1708210	3459790	3028000	3225000
3	2288000	3003210	3953000	4175000
4	1659000	3299210	2460790	2682790
5	1289000	2941790	2645790	2867790
6	1474000	1844000	3139000	3361000
7	1770000	3669210	1856210	2053790
8	1905790	3829790	1720790	1942790
9	0	2608790	2349790	2571790
10	808000	2732000	2300210	2479790
11	1165790	3089790	1942790	2140000
12	1893210	3817210	1461790	1683790
13	2374210	968210	3953000	4150000
14	2275790	1239790	3718790	3940789
15	1794790	3521210	1338210	1535790
16	2608790	0	4187210	4384790
17	2201790	4014790	1104000	1350790
18	1831790	3484210	1276790	1474000
19	2127790	3940789	931210	1128790
20	2423790	4236790	721790	931210
21	2349790	4187210	0	906790
22	2436000	4249000	746210	820210
23	2571790	4384790	906790	0
24	3435000	1511000	4964210	5211000
25	2584000	4397000	919000	721790
26	2685000	4508000	1030000	832790
27	3842000	2115210	5420790	5660210
28	2645790	4458790	980790	783210
29	2670210	4483210	1005210	919000
30	3817210	2090790	5396000	5593210

TABLE 6.7 : ROW I INDICATES COST IN TAKA TO CONNECT NODE I TO GATES

Similarly, **for K = 4**

nodes under gateway 1 (node 6) are 1, 2, 3, 4, 5, 6, 9, 10, 11, 13, 14, 16, 27, 30.

nodes under gateway 2 (node 23) are 7, 8, 12, 15, 17,18, 19, 20, 21, 22, 23.

nodes under gateway 3 (node 25) are 24, 25, 26, 28, 29.

For K=2,

nodes under gateway 1 (node 21) are 1, 2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 24, , 27, 30.

nodes under gateway 2 (node 25) are 23, 25,26, 28, 29.

The gateways are more properly distributed and the nodes are more uniformly grouped in the case for K=3. In this case total cost for star connection in level 2 and minimum cost spanning tree connection in level 3 is taka 409.83 lacs. This cost is taka 518.74 lacs for k=4, and 688 lacs for K=2. So, the clusters obtained for K=3 is accepted.

On the basis of this grouping, for higher scale factor and lower mean delay a probable topology for Dhaka city is shown in Figure 6.10. Total cost for this configuration is Tk. 453.68 lacs, mean delay is 18.92 microsec, average number of hops is 2.33 and scale factor is 2.101. But according to the discussion in section 6.3, a star configuration is not a practical solution. So, a minimum spanning tree in level 2, and a ring in level 3 is proposed for Dhaka city. Total cost for this configuration is Tk. 390.15 lacs, mean delay is 32.92 microsec, average number of hops is 3.40 and scale factor is 1.501. The network is shown in Figure 6.11. As scale factor and mean delay

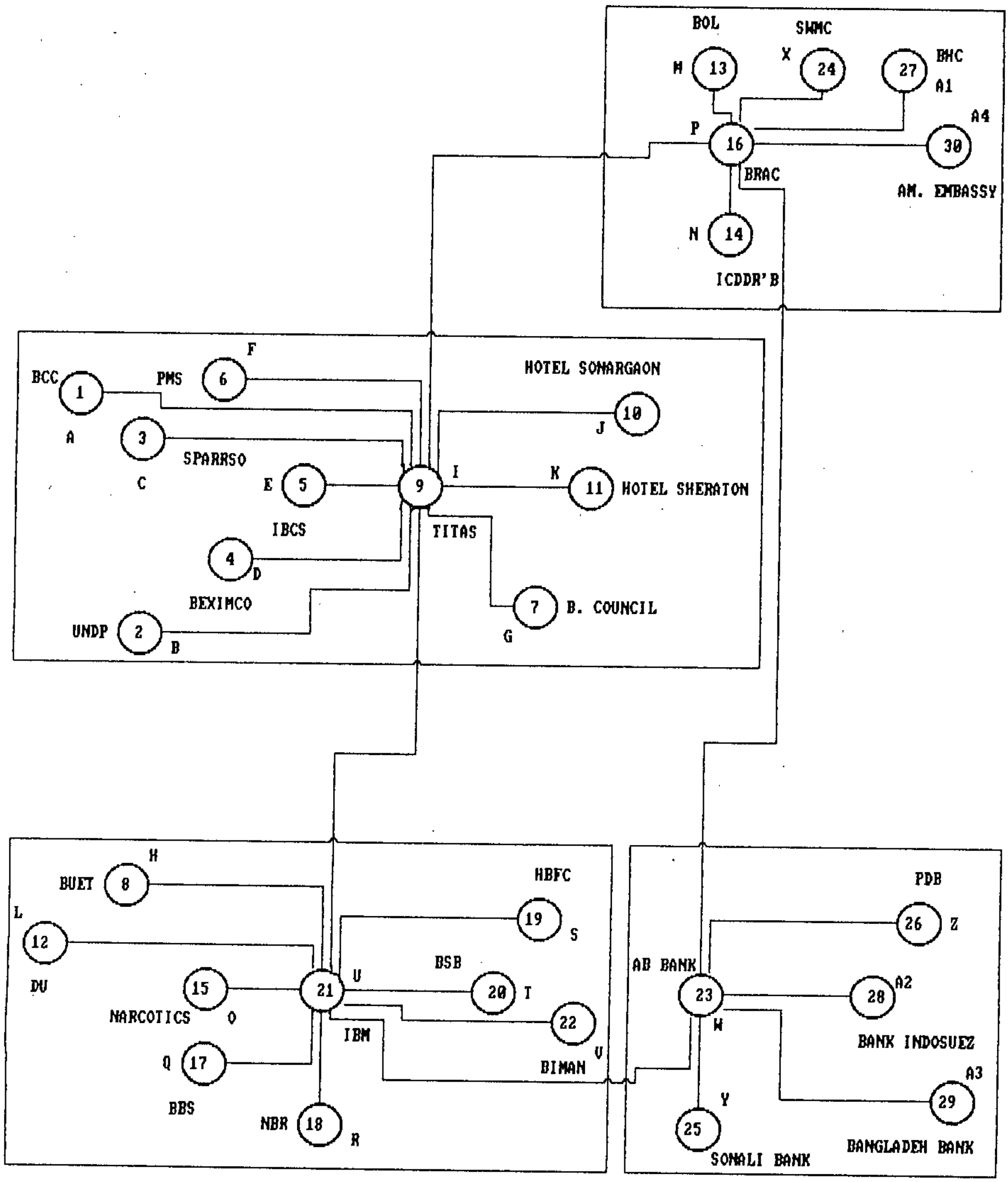


FIGURE 6.10 : HIERARCHICAL NETWORK TOPOLOGY WITH 30 NODES FOR DHAKA CITY

(STAR CONFIGURATION FOR LEVEL 2 AND RING CONFIGURATION FOR LEVEL 3)

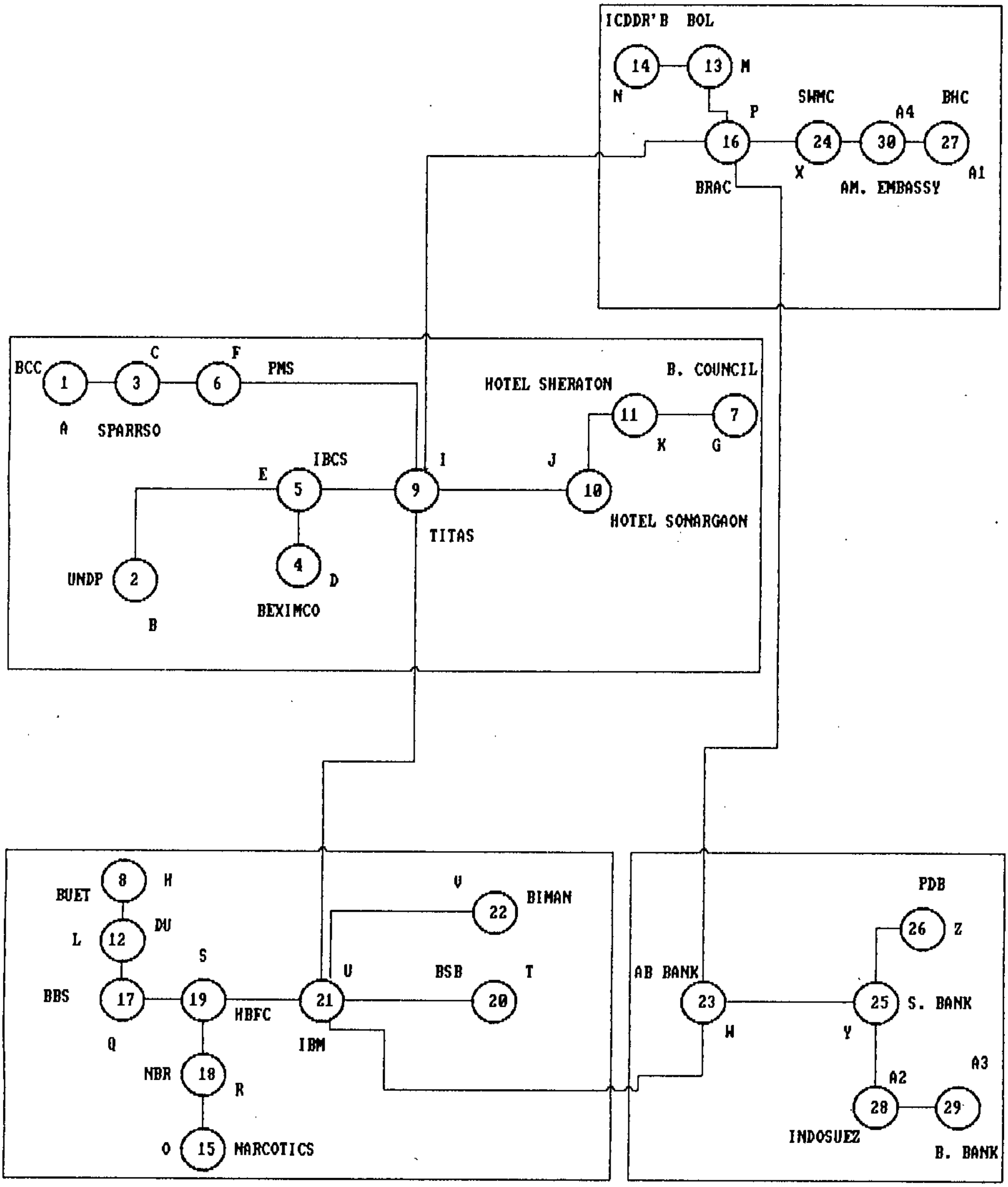


FIGURE 6.11 : PROPOSED NETWORK TOPOLOGY WITH 30 NODES FOR DHAKA CITY

(M. S. T. FOR LEVEL 2 AND RING CONFIGURATION FOR LEVEL 3) in a star network is better, the proposed network is compared with the topology in Figure 6.10. Total traffic and delay in individual links of Figure 6.10 and 6.11 are as follows:

A. Traffic and delay for figure 6.10

SL. NO.	**Link**	**Total traffic in packets/sec (800 bits/packet)**	**Delay in microsec**
1	AI	3769	5.84
2	BI	30545	6.92
3	CI	32110	7.00
4	DI	7990	5.99
5	EI	20108	6.46
6	FI	7225	5.96
7	GI	24118	6.63
8	HU	65671	9.15
9	JI	28725	6.84
10	KI	6808	5.95
11	LU	9000	6.02
12	MP	22718	6.57
13	NP	59752	8.68
14	OU	11417	6.11
15	QU	42556	7.55
16	RU	27676	6.79
17	SU	12417	6.15
18	TU	39086	7.36

Traffic and delay for figure 6.10 (Continued)

SL. NO.	Link	Total traffic in packets/sec (800 bits/packet)	Delay in microsec
19	VU	74616	9.96
20	XP	15012	6.25
21	YW	67374	9.29
22	ZW	32485	7.02
23	A1P	6193	5.92
24	A2W	32474	7.02
25	A3W	27303	6.77
26	A4P	17151	6.34
27	PI	58355	8.57
28	IU	64911	9.08
29	UW	83290	10.90
30	WP	8418	6.00

B. Traffic and delay for figure 6.11

SL. NO.	Link	Total traffic in packets/sec (800 bits/packet)	Delay in microsec
1	AC	3769	5.84
2	BE	30545	6.92
3	CF	34147	7.1
4	DE	7990	5.99
5	EI	47741	7.86
6	FI	39592	7.39
7	GK	24118	6.63
8	HL	65671	9.15
9	IJ	55737	8.38
10	JK	30338	6.91
11	LQ	69029	9.44
12	MN	59752	8.68
13	OR	11417	6.11
14	PM	61190	8.79
15	QS	96539	12.75
16	RS	35143	7.15
17	SU	116553	17.11
18	TU	39086	7.36
19	UV	74616	9.96
20	WY	94329	12.40
21	XP	26820	6.75

Traffic and delay for figure 6.11 (Continued)

SL. NO.	Link	Total traffic in packets/sec (800 bits/packet)	Delay in microsec
22	YA2	50952	8.06
23	ZY	32485	7.02
24	A1A4	6193	5.92
25	A2A3	27303	6.77
26	A4X	18446	6.39
27	PI	58355	8.57
28	IU	64911	9.08
29	UW	83290	10.90
30	WP	8418	6.00

Minimum traffic in both topology is 3769 packets/sec in arc AC and AI respectively. Delay for this traffic is 5.84 microsec. Maximum traffic in the topology of Figure 6.11 is 116553 packets/sec in arc SU and maximum delay is 17.11 microsec. In case of Figure 6.10 these values are 83290 packets/sec in arc UW and 10.90 microsec respectively.

CHAPTER

SEVEN

CONCLUSIONS AND SCOPE OF FUTURE RESEARCH

CONCLUSIONS AND SCOPE OF FUTURE RESEARCH

7.1 Conclusions

Numerous networks are currently operating around the world. In many countries the government or private companies have begun to offer networking services to any organization that wishes to subscribe [1]. The subnet is owned by the network operator, providing communication service for the customers' hosts and terminals. Such a system is called a public network. It is often a part of the public telephone system. BTTB is investigating and planning to install such a public data network in the country. The topological study in this thesis will be very useful in establishing such a public data network in Dhaka city. The X.25 protocol is used in public data networks. To establish a public data network, coordination between BTTB, Ministry of Science and Technology, computer experts in universities and in different computer installations is required so that all possible aspects are considered.

Designing a computer network has many properties in common with designing a telephone network, electric power grid, natural gas pipeline, railroad network and many other networks. The basic principle upon which all these networks are based is that the customers are not spread around uniformly. As number of nodes increases significantly, hierarchical strategy would be the approach for design of the computer network in Dhaka city. Each large computer installation is considered as a node. Each small or single user customer site would have a leased or dial-up connection to the nearest node. Nodes are divided into four groups or clusters. In the proposed network [Figure 6.11], the nodes within the cluster are connected to the concerned gateway in minimum spanning tree configuration. These nodes may also be connected on the basis of any other standard network structure like ring, bus or tree to form clusters. Provisions for alternate paths in these clusters are in practice for higher reliability and scale factor; and to avoid congestion and minimize delay. Again these clusters are interconnected by gateways in a ring topology (Fig. 6.11). There are four links to connect the gateways. If any one of these four links fails, communication would be possible in alternate path. If any gate fails, then the cluster associated with the concerned gateway would be isolated. Provision for more than one gateway in a cluster solves this problem. Another four gateways in four clusters may be chosen to form another ring in level 3. Otherwise, there may be one alternate gateway in each Cluster. In that case a Switching arrangement should be done in such a way that, the alternate gateway takes control of the main gateway when the main gateway is out of order.

The scale factor in the proposed network is 1.501. The arc SU saturates first. Total traffic in SU is 116553 packets/sec. But total traffic in almost all links is below 50000 packets/sec. In future if traffic grows more than double, it would be possible to accommodate the traffic by providing extra paths as followed in section 5.7 or by increasing the link capacity of the arc which is most saturated. It is noted that scale factor in Figure 5.2 is 3.008, but that in Figure 5.7 is 4.257. So, it is not required to invest for the future growth of traffic, there is option to invest in future as required to fulfil the increasing demand.

Capacities of all the links in Figure 6.11 is assumed 140 Mbits/sec, but the use of same capacity in all links is not the best solution. Optical fiber of the next higher available capacity (565 Mbits/sec) may be used in arcs which are highly loaded. Assignment of proper capacity is discussed in section 5.6.

From Table 6.4, it is observed that mean delay is minimum in a nonclusterd star network. But if the star controller fails, the whole network would be out of order. Moreover, cost in this case is maximum. So, such a topology is not a practical solution. Other than this one, mean delay is less in all clustered networks than any non-clustered network. The characteristics of the network for 16 nodes in Table 6.4 is also valid for 30 nodes. This can be decided from Figures 6.4, 6.6, 6.10, 6.11 and on the basis of the following observations.

1. Cost and scale factor in Figure 6.4 is higher than that in 6.6. Similarly cost and scale factor in Figure 6.10 is higher than that in Figure 6.11.
2. Mean delay in Figure 6.6 is higher than that in Figure 6.4. Mean delay in Figure 6.11 is higher than that in Figure 6.10 also.

Outside Dhaka, in Chittagong there are one mainframe, a number of minicomputers and a lot of microcomputers. In near future it would be required to provide data communication facility between Dhaka and Chittagong. At least one cluster would be required to provide communication facility among the users in Chittagong.

7.2 Scope of future research

Shortest path from a source to a destination is calculated on the basis of a predefined topology and traffic status, i.e., the routing technique followed here is static. It is an important area for further research to consider the dynamic changes in the traffic and topology of the network.

The shortest path problem is a major issue for topological design of computer networks. This problem has been studied extensively in the past [20]. Dijkstra's algorithm [18] and the Bellman-Ford algorithm [21] are two classical algorithms for solving shortest path problems. Most of the other algorithms in the literature are variations of either the Dijkstra or Bellman-Ford algorithm [22]. The Dijkstra-type algorithms tend to be inherently serial and are not, therefore, easily implementable as distributed algorithms in large data networks. The Bellman-Ford-type algorithms, on the other hand, can be implemented in a distributed data network. The fact with all of the classical shortest path algorithms is that the assumed network topology is normal, not clustered. In reference [20] 'a fast distributed shortest path algorithm for a class of hierarchically clustered data networks' has been described. This new algorithm operates as follows:

First, shortest path subproblems are solved in parallel at each cluster from the nodes within each cluster to each of their associated gates, then the solutions from all the clusters are merged together to obtain the complete solution for the entire network.

This algorithm can be applied for finding the shortest path and to measure the required time. The saving in computation time using this algorithm in comparison to existing algorithms is an issue for further research.

For the implementation of the proposed hierarchical clustered network hundreds of lacs of taka will be required. It would take time for us to provide the network facilities to the users for the shortage of budget and lack of coordination among the organizations of the proposed computer installations. But to establish a high speed data communication link between BUET and Dhaka University, involvement of money is not considerably high. It is possible to arrange necessary budgets jointly by the universities. Design and implementation of a high speed data communication link between BUET and Dhaka university is an interesting research topic. The constant of proportionality for the calculation of traffic between nodes mentioned in chapter 4 is based on assumption. But if a sample link between these two nodes is implemented then it would be helpful to consider this constant of proportionality on the basis of the data transfer experience between the two nodes.

In this thesis main consideration for selecting the topology was delay and cost. But multihop networks must pass messages between source and destination nodes via intermediate links and nodes. Assuming propagation delay is ignored, the mean amount of time the average message stays in a multihop network is directly proportional to the mean distance, in hops, between nodes. Thus, the aggregate link capacity of the network is also proportional to the mean internodal distance [23]. Mean internodal distance is, therefore, an important network characteristic. Careful selection of network topology to minimize the mean internodal distance, as well as the necessary aggregate link capacity may be important in only the most sensitive applications [23]. In such sensitive applications, an almost randomly chosen network may be the optimal choice[23]. Through simulated annealing algorithm [24] low mean internodal distance can be achieved. The simulated annealing is a process whereby candidate networks are modified incrementally. At each step, the modification is either adopted or not adopted depending upon whether the change has lowered or incremented the mean internodal distance. This simulated annealing algorithm may be implemented for the topological design of computer network in and around Dhaka city and this task can be undertaken as a future research work. This concept of topological design need no cost information regarding communication line equipment.

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