DIMENSIONING AND OPTIMIZATION OF TELEPHONE SYSTEM USING COMPUTERIZED TOOLS

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DECELARATION

This is to declare that the work presented in this thesis is the result of my extensive study and investigation carried out by me under the supervision of Dr Chowdhury Mofizur Rahman in the Department of Computer Science and Engineering, Bangladesh University of Engineering and Technology, Dhaka. It is further declared that neither this thesis nor any part thereof has been submitted elsewhere for the award of any degree or diploma.

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Signature of the Author

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Dedicated To

My Parents
And Brother A.K.M. Badrul Alam

ABSTRACT

Recent development in the field of information technology has created high demand for expansion of present telecommunication system with available advanced technology and modern equipment. Computerized optimization and dimensioning of telecommunication system can play a vital role for efficient and cost effective planning of this telecommunication system expansion.

To dimension a telephone network is to design the network structure and to determine the amount of equipment required in each part of the network which will satisfy a specified demand with a prescribed quality of service.

The process of optimizing is choosing the solution which best meets the optimization criteria, which in network dimensioning are usually economic criteria. Complexity of the network is also considered as the criteria of optimization in this research work.

In this research work two important situations of telephone system are considered for study. In the first case a model area is considered. This area is not highly populated and existing telephone system is very small. It is considered that this city will increase in future and very big telephone system have to be developed in future. Future demand may be available from forecast. In this research work the future data are assumed for the study. Optimum number of exchanges to serve the area under study is calculated. Finally optimum location and boundary area of each exchange is obtained. So from this study a good development method is obtained for future telephone system of a city. A computerized software tool is also developed.

In the second part another model area is considered. This area is highly populated urban area. A big existing telephone network is working in the area. Study has been done in this research work for future expansion to satisfy the pending demand. A Computer aided methodology for expansion of telephone system by using dimensioning and optimization has been developed.

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CHAPTER ONE

INTRODUCTION

1. INTRODUCTION

Telecommunication is the basic building block for economic growth. World economy is transformed by telecommunication revolution. All of us are witnessing and enjoying the process of transition from industrial society to information age. The fruits of telecommunication and information technology are completely transforming the work culture, life style, industrial and social activities of the people throughout the world. The availability of telecommunication facility is one of the advantages to develop human resources systematically. So this research work has an important application to social development and economic growth.

Pragmatic methods of planning for telephone system is used in our country. Most of the city Networks and as a whole the telephone system of the country is very small as well as the expansion and investment is very small. So study in this field was not done and the methodical procedure for cost effective optimal solution was not used.

A comprehensive telephone system analysis is extremely complex because many parameters, many conditions and many constraints of telephone system should be considered. Most currently available microcomputer based design tools address only a few aspects of the optimization process [29].

Recent development in the field of information technology has created high demand for expansion of present telecommunication system with available advanced technology and modern equipment. Computerized optimization and dimensioning of telecommunication system can play a vital role for efficient and cost effective planning of this telecommunication system expansion.

1.1. BACKGROUND:

At present there are about four hundred forty six thousand telephone connections in Bangladesh for the whole country. Population of Bangladesh is about 12 Crores. So density of telephone per hundred people is very low. Out of this 4.46 Lac telephones 2.3 Lac are in Dhaka city and the remaining 2.16 Lac lines distributed over the other cities of the country. Very soon a big telephone project of 67 thousand telephone lines for southern Dhaka city is going to be executed which will increase the number of telephone of Dhaka city from 2.3 Lac to 3 Lac. As the demand for telephone is increasing very fast so very soon more big telephone project will have to be taken to meet the demand.

This expansion of telephone system includes mainly the expansion of the local telephone system and medium and long-distance telephone system. Local telephone system is divided into three subtypes according to the size of the area and the amount of urban development. They are (a) Rural telephone system (b) Urban telephone system and (c) Large Metropolitan telephone system.

Thus vast expansion and big investment in telephone system need efficient planning. Telephone system planning and design are ongoing activities key to ensuring a telephone phone system runs smoothly and efficiently.

Today's telephone engineers need flexible, powerful planning and design tools to meet the challenges of large and complex telephone system with diverse parameters. Typically, telephone engineers want to [26]:

- Optimize certain aspect of the telephone system as telephone system reliability and investment cost;

- Study the potential effect of telephone system failures and .

- Dimension the telephone system to meet certain grade of service.

To assist in these tasks, efficient tool for telephone system optimization and dimensioning is needed. The objective of network optimization is to determine from all the possible solutions, the optimum network configuration, given one particular criteria. In general, this criterion is the network cost. The statement of the optimization problem, although it has been implicit in the dimensioning objectives since the inception of telephone communication, was not put in an explicit form until late in the 1950s, and only in the 1960s did the computational power of the computer begin to be exploited [7]. Therefore network optimization is a rather young discipline, within which several different directions were taken, and is still in a development stage. It is nevertheless important to note that the statement and solutions of network optimization problems as presented in this study may differ from approaches and solutions described in other publications and from practices employed by a particular telephone Administration. Therefore, it should be understood that the treatment given here is neither unique nor necessarily optimum under all circumstances.

Network optimization is a part of the network planning activity. This implies that its ultimate aim is to be a basis for the preparation of the network evolution plan: concepts such as quality of service of the network and network flexibility to accommodate change go beyond the strict definition of network optimization, but cannot be disregarded when network dimensioning is seen from the network planning perspective.

1.2 DIMINSIONING AND OPTIMIZATION

To dimension a telephone network is to design the network structure and to determine the amount of equipment required in each part of the network which will satisfy a specified demand with a prescribed quality of service.

There is an almost infinite number of solutions to a dimensioning problem, both from the point of view of the network structure, and from the point of view of deciding the amount of telephone equipment to be put into service in each part of the network. Even if these solutions meet the network dimensioning objectives, that is, to satisfy the demand with a certain quality of service, distinctions exist between them under other criteria such as network cost.

Most of the elements of the telephone network are shared by all the subscribers connected to the network: network dimensioning, therefore, requires consideration of the whole network as single entity. However, the relationship between the solutions adopted for different sections of the network is not so strong as to justify consideration of the network in one single study. Because of this fact, and for practical reasons, network dimensioning separates the study of the local network from that of the long-distance network. Also, within each of these network sections, different parts can be studied separately (although, naturally, relationships within the local and long-distance networks cannot be disregarded).

The problem of optimization is firstly to chose optimization criteria in order to compare different alternatives in a quantitative and objective way. The following optimization criteria are used:

- The compatibility of the alternative plan with the administration's aims;
- The compatibility of the alternative plan with policies and strategies;
- Financial and resource requirements;
- System flexibility.

In the long term, this task essentially consists of the determination of the number of exchanges of the various levels of the hierarchy, their sizes, their locations, their service areas and their technology. The traffic routing structure must also be determined, e.g how to use the transit centres. From the future traffic matrix, the direct circuit groups and those towards the transit centres are dimensioned in order to minimize the system total cost. This work is complex and requires the assistance of computer for efficient result [7].

1.3 TELECOMMUNICATION SYSTEM

When Alexander Graham Bell patented the telephone in 1876 (just a few hours ahead of his rival, Elisha Gray), there was an enormous demand for his new invention. The initial market was for the sale of telephones, which came in pairs. It was up to the customer to string a single wire between them. The electrons returned through the earth. If a telephone owner wanted to talk to n other telephone owners, separate wires had to be strung to all n houses. Within a year, the cities were covered with wires passing over houses and trees in a wild jumble. It became immediately obvious that the model of connecting every telephone to every other telephone was not going to work.

To his credit, Bell saw this and formed the Bell Telephone Company, which opened its first switching office (in New Haven, Connecticut) in 1878. The company ran a wire to each customer's house or office. To make a call, the customer would crank the phone to make a ringing sound in the telephone company office to attract the attention of an operator, who would then manually connect the caller to the callee using a jumper cable.

Pretty soon, Bell System switching offices where springing up everywhere and people wanted to make long-distance calls between cities, so the Bell system began to connect the switching offices. The original problem soon returned: to connect every switching office to every other switching office by means of a wire between them quickly became unmanageable, so second-level switching offices were invented. After a while, multiple second-level offices were needed. Eventually, the hierarchy grew to five levels.

By 1990, the three major parts of the telephone system were in place: the switching offices, the wires between the customers and the switching offices (by now balanced twisted pairs instead of open wires with an earth return), and the long-distance connections between the switching offices. While there have been improvements in all three areas since then, basic Bell System model has remained essentially intact for over 100 years.

At present, the telephone is organized as a highly redundant, multilevel hierarchy. The following description is highly simplified but gives the essential flavor nevertheless. Each telephone has two copper wires coming out of it that go directly to the telephone company's nearest end office (also called a local central office). The distance is typically 1 to 10 km being smaller in cities than in rural areas.

The two-wire connections between each subscriber's telephone and the end office are known in the trade as the local loop).

If a subscriber attached to a given end office calls another subscriber attached to the same end office, the switching mechanism within the office sets up a direct electrical connection between the two local loops. This connection remains intact for the duration of the call.

If the called telephone is attached to another end office, a different procedure has to be used. Each end office has a number of out going lines to one or more nearby switching centers, called toll offices (or if they are within the same local area tandem offices). These lines are called toll connecting trunks. If both the caller's and callee's end offices happen to have a tool connecting trunk to the same toll office (a likely occurrence if they are relatively close by), the connection is established within the toll office.

If the caller and callee do not have a toll office in common, the path will have to be established somewhere higher up in the hierarchy. There are primary, sectional, and regional offices that form a network by which the toll offices are connected. The toll primary, sectional, and regional exchanges communicate with each other via high bandwidth intertoll trunks (also called interoffice trunk).

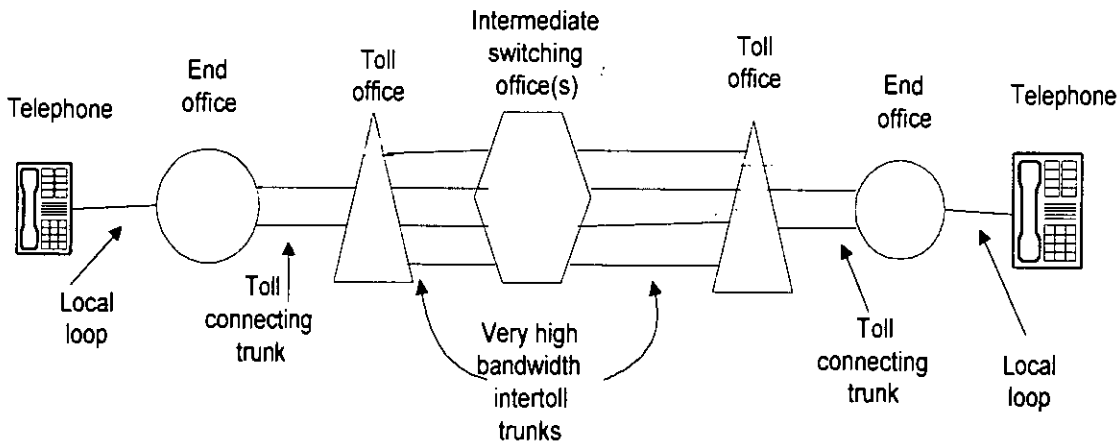


Fig.1.1 Typical circuit route for a medium-distance call.

The number of different kinds of switching centers and their topology (e.g. may two sectional offices have a direct connection or must they go through a regional office?) varies from country to country depending on its telephone density. Figure-1.1 shows how a medium-distance connection might be routed.

A variety of transmission media are used for telecommunication. Local loops consists of twisted pairs nowadays, although in the early days of telephony, uninsulated wires spaced 25 cm apart on telephone poles were common. Between switching offices, coaxial cables, microwaves, and especially fiber optics are widely used.

In the past, signaling throughout the telephone system was analog, with the actual voice signal being transmitted as an electrical voltage from source to destination. With the advent of digital electronics and computers, digital signaling has become possible. In this system, only two voltages are allowed, for example –5 volts and + 5 volts.

This scheme has a number of advantages over analog signaling. First is that although the attenuation and distortion are more severe when sending two-level signals than when using modems, it is easy to calculate how far a signal can propagate and still be recognizable. A digital regenerator can be inserted into the line there, to restore the signal to its original value, since there are only two possibilities. A digital signal can pass through an arbitrary number of regenerators with no loss in signal and thus travel long distances with no information loss. In contrast, analog signals always suffer some information loss. When amplified, and this loss is cumulative. The net result is that digital transmission can be made to have a low error rate.

A second advantage of digital transmission is that voice, data, music, and images (e.g television, fax, and video) can be interspersed to make more efficient use of the circuits and equipment. Another advantage is that much higher data rates are possible using existing lines.

A third advantage is that digital transmission is much cheaper than analog transmission, since it is not necessary to accurately reproduce an analog waveform after it has passed through potentially hundreds of amplifiers on a transcontinental call. Being able to correctly distinguish a 0 from a 1 is enough.

Finally, maintenance of a digital system is easier than maintenance of an analog one. A transmitted bit is either received correctly or not, making it simpler to track down problems.

Consequently, all the long-distance trunks within the telephone system are rapidly being converted to digital. The old system used analog transmission over copper wires; the new one uses digital transmission over optical fibers [36].

1.4 LITERATURE SURVEY

The planning of national telecommunication networks requires a advanced and latest methodology and a set of tools supporting modern network models, to evaluate and optimize real networks. The effective planning of national telecommunication networks depends on the right tools.

The planning of national telecommunication networks must include the analysis of both network models: today's hierarchical network structures and the non-hierarchical structures to be developed at the nodal level.

Network security aspects are of major importance when planning national networks, as a network breakdown produces huge losses. In the planning process more-reliable structure are being considered for security in the physical and functional planes. When looking for a secure structure the relationship between the obtained security and its cost is of major importance for considering the optimization and dimensioning of the telecommunication system.

Due to technological limitations the first alternate routing scheme developed on national networks was hierarchical routing. Different levels are used to concentrate traffic from one region to another, so small traffic parcels are combined on efficient final trunk groups. Hierarchical routing allows switching system to determine the path for a call very simply and quickly, using only the call's destination, and it is guaranteed that the call will loop back to the switching system previously traversed. Hierarchical routing is still in use world-wide.

The advent of stored program controlled (SPC) switches and the advances in signaling technology have allowed the development of non-hierarchical routing schemes. All nodes are uniform in the sense that all of them generate and transfer traffic. Although a call can theoretically use any path connecting its origination and destination, two-link paths are preferred. A two-link path may have at most two links from origin to destination.

The formation of the non-hierarchical upper planes creates a unique opportunity and environment for different call routing systems to be used.

Under engineering traffic conditions the use of non-hierarchical routing improves network flexibility and performance by making use of all available resources in the network. The overall loss may be decreased by 10% to 20% as compared to a fixed hierarchical routing scheme. The reduction can be even greater if non-coincidence of busy hours is considered. In cases of failure, focused overload or traffic shifts, non-hierarchical routing improves the fairness of the network by making the grade-of-service distribution of the origin-destination pairs more uniform. In the case of global overload, the best solution is to apply direct routing and prohibit the alternative routes by means of the trunk reservation parameter. In this case, hierarchical routing performs as direct routing.

ESCORIAL-N and ESCORIAL-H are tools to dimension, optimize and analyze national networks with non-hierarchical structures. The network is divided into the access and the nodal levels. The tool offers the option to dimension and optimize the network with different trunk reservation parameters, different routing schemes and different levels of security (physical or functional). Another option is to analyze the network of different trunk group dimensions, and obtain the grade of service for each origin destination pair. The optimization process is developed in two steps: First, the access level is optimized considering the nodal level as a full mesh without alternate routing. Second, the nodal level is dimensioned to satisfy the requested grade of service. The optimization criterion is to minimize the amount of network resources. Access level optimization algorithm and nodal level optimization algorithm are developed [30].

ESCORIAL-H and ESCORIAL-N have been applied in the long-term planning of the Spanish National Network. The main results of this study have been presented in [22]. The main objectives were, on the one hand, the study of Spanish National Network evolution from hierarchical to non-hierarchical network structures, and on the other hand, the new network structure dimensioning and optimization.

Telecom Long Distance Networks in Developing Countries, actually are based in Core Switching Networks with hierarchical structures and point to point transmission. Technology evolution, with the new digital multifunctional switches able to manage the traffic with non-hierarchical schemes and the introduction of the SDH transmission, modify the network architecture and present evolution challenges to the Operators.

The planning tools chain operates as part of an integrated planning process, that is an iterative process due to the fact that the network structures changes along the planning period and impacts in the network solution and costs (Switching and Transmission). The Transmission Networks solution produced by Alcala can modify the transmission cost and configuration assumed in the Escorial network model. A second iteration of the Switching Network Design (Escorial) and Transmission Network Design (Alcala) refines the optimal Global Network Design and Evolution. Furthermore, along the network evolution, the network traffic can be modified due to changes in service evolution hypothesis, quick actualization of traffic with management systems (Alma) and the application of the Telecom Planning System [24] with the tool Chain (Premat, Escorial, Alcala), integrated in Cibeles planning platform [31], allows the Network Operator to Define and Optimize the Network Evolution.

Starting with network service data and traffic measurement, the traffic matrix between existing offices can be calculated, and it is also possible to determine the total present traffic originated and terminated at each area (exchange service area).

Using the Traffic Measurement facilities (implemented in the switch nodes or in the network management system) the actual traffic matrix can be calculated.

Alcatel ALMA traffic [2] system using the TDAS (Traffic Data Analysis System) produces the network traffic matrix.

Two networks models have traditionally been distinguished: functional and physical. The first one deals with the routing of the traffic, the second with the routing of the facilities. The Physical Network Model, considers the costs of the transmission network (cables infrastructure, and transmission systems), represents the geographical layout of the topological network, selects the minimum cost paths for node to node interconnection. The Switching Network Model considers the logical network structure (traffic alternative routing schemes and traffic models) for network dimensioning in accordance to the network grade of service objective and the combined switching and transmission costs for network economic optimization [23]. There is a planning methodology developed at Alcatel [14], [19], which supports Alcala planning process. The planning process has been structured in four steps: topological design of the physical network, network configuration, optimized circuit routing and equipment dimensioning, and demand availability analysis.

Alcatel has developed a set of planning tools called ALCALA [17] which supports an operator in designing and optimizing a network for all the network segments. The basic ring planning problem is to identify which sets of the remaining nodes should be placed on the same ring – ALCALA provides a mechanism to identify candidate rings on the basis of maximizing traffic affinity and minimizing ring size. A ring distance matrix [D"] is constructed from the sub-network distance matrix [D] where each entry D''_{ij} is equal to the sum of the lengths of the least-cost node and link disjoint alternative [27]. The dispersion of ring distance and traffic values is then calculated. That is, weight values $\mathbf{W}_{dist}$ and $\mathbf{W}_{traff}$ are defined for the future distance affinity coefficients and traffic affinity coefficients matrix.

The design problem of high capacity transmission network is addressed in two parts. The first one is concerned with the comprehensive modeling applied to obtain an optimum use of new SDH transmission functionalities. The second analyzes the logical structure and the equipment configuration to implement in an SDH network as a function of protection cost and technological limits [18].

The optimization of the ATM layer focuses at three main areas [32]:

- Network Routing Optimization. Select the route for a connection maximizing the carried traffic.
- Switching Equipment Optimization. It groups circuits maximizing the occupancy of the switching node ports.
- Bandwidth resources Optimization by means of statistical multiplexing, Optimum services grouping over the same line.

ALBATROS is network design tool that covers the broadband switching design activity of the planning process. The dimensioning algorithm is based on the CAC algorithm characterized by the effective bandwidth and an acceptance logical function, published on [5]. ALBATROS Tool is supported by the network analysis development platform CIBELES [31][25], which permits the interrelation of computer tools to perform network planning studies and development of new ones.

1.5 TELEPHONE TRAFFIC

The telephone traffic is generated by a number of subscribers. When a subscriber marks his intention to make a telephone call by lifting his receiver the local telephone exchange receives an electric impulse which starts a number of actions to make it possible to receive numerical information from the caller so that the telephone exchange later on can connect the calling subscriber to desired subscriber. When the exchange is ready to receive the desired number a dialing tone is sent to the caller. The caller can then dial the desired number and the telephone exchange connects the caller to the desired number.

The setting-up procedure involves generally that the call is switched over a number of selectors. These selectors may be all situated in the calling subscribers own local exchange. However, when the telephone network is large enough, the switching may pass over several switching stages in different exchanges. Consequently one switching unit, handling the call, will request another switching unit, which may be geographically near or far to continue the switching procedure. When doing so, information concerning the desired destination must also be transferred. Finally when the last switching stage is passed the ringing of the called subscriber indicates that some one wants to speak with him.

The setting – up procedure for a telephone call involves consequently a series of requests for the call to be processed, The total number of such requests to a switching unit – or subscriber – per time unit is the call intensity.

Consequently the first switching unit in the selection chain receives calls from subscribers, following switching units receives calls from the previous ones, and finally, the called subscribers receive calles from the last link in the switching chain. Moreover, registers, markers, signalling senders and receivers, and other common equipment taking part in the setting-up procedures will also receive calls. One can therefore define the call intensity and subsequently telephone traffic for each distinct part of the switching chain from calling to called subscriber [10].

The development of telephone traffic theory started at the beginning of this century. The pioneering achievement in this field was that of the Dane. A Erlang, whose works were published between 1909 and 1928 . Among those who built upon Erlang's ideas should also be mentioned the swede, conny palm, whose papers during the period 1935-1946 (1957) constitute to give traffic theory its present stringency. Many other persons of various nationalities have also contributed to the development of the present theory.

The traffic theory that can be applied to practical cases is based on the assumption of statistical equilibrium, which implies that it can only deal with cases subject to stationary conditions.

For non – stationary conditions no practical methods of calculation have yet been devised. The theoretical background for dealing with such cases was, however, presented in palm's doctoral thesis of 1943, in which he made a study of variations in the call intensity. But it is already now quite possible to deal with non- stationary traffic cases with the aid of computer simulations. The theories considered here, however, will be confined to stationary conditions.

Existing theories use different combinations of assumptions, and the derivations from 1909 to date build upon different levels of knowledge and use partly different terminology. A direct review of the derivations for different cases originally presented would therefore not provide a clear survey of the ability of the theory to describe different cases occurring in practice. It has therefore been preferred to present the traffic theory in a more general form, from which various special cases can then be derived [10].

1.6 STATEMENT OF THE PROBLEM

In this research work different aspect of the expansion plan of telephone system will be thoroughly studied and eventually an algorithm will be developed for efficient optimization and dimensioning of the telephone system expansion. And then a software will be developed for computerized tool which will give an optimal solution of optimization and dimensioning of telephone system. Computerized tool will be very efficient for optimal solution having illustrative execution of the software considering different criteria and conditions of a telephone system. Manual approach of having an optimal solution considering different criteria and conditions is very difficult.

The construction of an advanced Information and Telecommunication society is essential for development of the economy and growth of a country. Development of national Information infrastructure therefore deserves the highest priority.

Like other countries of the world Bangladesh is also developing and modernizing its telephone system. Present system is not adequate according to the need of the development of socio-economic activities of the country. Very vital step towards the development of this undeveloped country is the expansion of its telephone system methodically which needs the efficient optimization and dimensioning its expansion considering its existing infrastructure.

The objective of this research work is to develop a planning method of telephone system using optimization and dimensioning. Finally computerize the method and develop a software tool for planning method of telephone system. The whole problem is divided in the following steps.

a.) Telephone demand per unit area is collected for the total area which is considered for network development. Initially the minimum number of exchanges to serve the area under study is guessed. For this minimum number of exchanges optimum location of each exchange and optimum service areas of each exchange are calculated out. On the basis of the above calculation and data obtained size of the exchanges are found out and distance matrix is developed.

b.) Based on the capacity of exchanges, consideration of the traffic generation from different class of subscribers and from the traffic affinity between exchange to exchange traffic matrix can be obtained.

c.) Different possible network configurations are studied to connect all these exchanges by junction network. Different types of switching system, transmission systems and media for communication is studied thoroughly to choose the best configuration.

d.) From the distance matrix, and consideration of different technology and equipment a cost matrix is developed. On the basis of this cost matrix increamental cost rated matrix is obtained.

e.) Teletraffic engineering theories are studied thoroughly to find out the required formula for solving the problems of dimensioning the network. First of all direct circuit matrix is calculated out. Finally cost is calculated for the network.

f) To find out the overflow traffic Moe's formula is used [7]. On the basic of the result of Moe's formula high usage route can be obtained Wilkinson's formula for alternating traffic is used to find out the overflow route and tandem size [10].

g) Finally cost of the network is calculated for the following alternatives.

(1) Only direct route junctions are considered without considering alternate route and tandem.

(2) All traffic through tandem is considered without taking direct rout junction.

(3) Direct route junctions and alternating route through tandem are considered simultaneously.

(4) Direct route junctions is considered for high traffic route and tandem routes are considered for low traffic routes.

Cheapest of the above alternatives is considered. Then number of exchange is increased and again cheapest alternative is considered and finally optimum number of exchange is found out. For this optimum number of exchange cheapest alternative is considered for optimum dimensioning of the network.

The expected result of this research work is to have an efficient procedure for telephone system planning, expansion and development. The algorithm to be developed in this research work will be useful in optimization and dimensioning of telephone system in Bangladesh and the software to be developed will act as a computerized tool which will be reliable, quick and efficient.

Optimization and dimensioning a telephone system is a very complex job. A computerized tool will be very helpful and useful to consider different criteria and conditions in order to have a more accurate result.

1.7 DESCRIPTION OF THE IMPORTANT FORMULA USED

If the whole area under study is divided into small grid of small area then the optimum location (x^*, y^*) of an exchange within a defined area is given by the condition:

$$\min C = \min \Sigma (n_i / x_i - x^* / + n_i / y_i - y^* /) \qquad 1.1$$

Where

i denotes any square of the grid.

Σ includes the entire area under study

n_i is the number of subscribers in the square (x_i,y_i)

/ $x_i - x^*$/ and /$y_i - y^*$/ are the distances from the square (x_i,y_i) to square (x^*, y^*) along the x and y axes respectively.

The optimum location (x^*, y^*) satisfies the condition that the difference between the total number of subscribers to the left and to the right of x^* is minimum, and similarly above y^*. This condition provides an easy method for finding the optimum location.

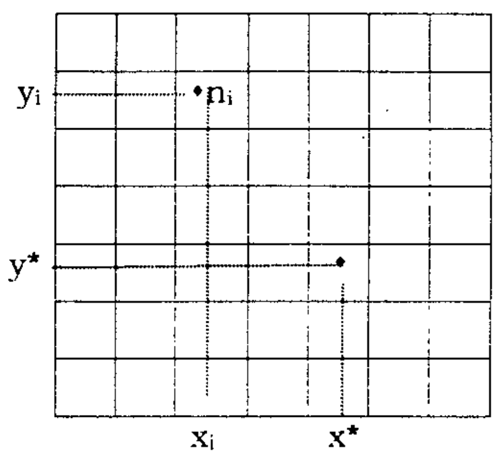


Figure 1.2 Optimum location.

The cost of connecting a subscriber to an exchange can be represented [13]

$$D_E \cdot C_s(D_E) + C_f \qquad 1.2$$

Where

D_E is distance subscriber – exchange,

C_s is distance – dependent transmission media cost,

C_f is distance - independent transmission media cost,

The cost of a circuit exchange to exchange can be represented as

$$D_{EF} \cdot C_c(D_E) + C_d \qquad 1.3$$

where

D_{EF} is distance from exchange E to exchange F,

C_c is distance - dependent transmission media cost,

C_d is distance - independent transmission media cost,

When using different transmission system, the choice is made on the number of circuits between E and F. In this case a separate optimization is carried out.

Additional parameter of a transmission system is the capacity, i.e. the maximum number of circuits which could be carried over.

Exchange cost consists of two components:

- cost of exchange equipment
- cost of building

Both components are assumed to be a function of the subscribers, incoming and outgoing circuits.

For a given exchange E, we denote the exchange equipment cost with Ca(E) and the building cost with Cb(E).

Thus, the total network cost function, C, could be expressed as [13]

$$C = \sum_{E=1}^{NEX} \sum_{(i,j)\in E} sub\,(i,j).\,[C_s\,(D_E).\,D_E + C_f] + \sum_{E=1}^{NEX} [C_a\,(E) + C_b\,(E)] +$$

$$+ \sum_{E=1}^{NEX} \sum_{F=1}^{NEX} N_{EF}.[C_c\,(D_{EF}).\,D_{EF} + C_d] \qquad 1.4$$

where

NEX is the exchanges,

N_{EF} is the number of circuits from exchange E to exchange F.

The most commonly used relationship for grade of service with full availability trunking is that due to A.K. Erlang. This is given by the following expression [8].

$$E\,(n,A) = \frac{\frac{A^n}{N!}}{1 + A + \frac{A^2}{2!} + \ldots + \frac{A^n}{N!}} \qquad 1.5$$

$$= \frac{\frac{A^n}{N!}}{\sum_{i=0}^{n} \frac{A^i}{i!}}$$

Where

E = degree of congestion

N = number of circuits

A = traffic offered

Erlang's first formula – conditions

In order to be able to use Erlang's first formula the following four conditions must be fulfilled.

1. Loss system, i.e. a call which failed because of congestion is disconnected and there is no attempt to call again.
   Note: This is not completely realistic-the subscriber often immediately makes a new attempt to call.
2. Full accessibility, i.e. any free inlet can reach any free outlet.
3. Pure chance (random) traffic i.e. the time between two calls will be random. This type of random course of events may be described by a negative exponential function.
4. A large number of call sources, i.e. regardless of whether few or many calls are in progress, the traffic interest is approximately constant (same average value). In the mathematical model this is equivalent to an infinite number of call sources.

Now we consider the case of Junction circuits as tandem circuits and as well as direct routes. The class of circuits to be used between two exchanges i.e. tandem (T), high uses (H) or direct(D) circuits, is predominantly determined by the offered traffic, A, between the exchanges and the cost ratio between the incremental cost for direct and tandem circuits.

$$\text{Cost ratio } \varepsilon = \frac{B_{ij}}{B_{it} + Bt_j} \qquad 1.6$$

Where

B_{ij} = incremental cost for direct circuit from exchange i to exchange j;

B_{it} = incremental cost for circuit from exchange i to tandem t;

B_{tj} = incremental cost for circuit from tandem t to exchange j.

The network of minimum cost offered for a given quantity of traffic between two exchange i and j is equivalent to finding the number of circuits n to allocate to the high usage route i – j. The traffic carried by the (n + 1)th circuit (equal to the efficiency of the group of n+1 circuits in the direct route) when multiplied by the cost of establishing this (n + 1)th circuit in the high usage route, should be equal to the cost of a circuit in the final route multiplied by the efficiency of this circuit. This is known as **Moe's principle** [7].

The minimum network cost is calculated by solving the equation.

$$A \cdot [\, E(A, n) - E(A, n+1)] = \eta.\varepsilon \qquad 1.7$$

Where

A is the traffic offered to the direct or high usage route

N is the number of circuits (the unknown)

E is the Erlang function

η is the efficiency of final routes

The expression $A \times [\, E(A,n) - E(A,n+1)]$ represents the traffic carried by the (n+1)th circuit in the high usage route, when a quantity of traffic A is offered to the route.

Equation can be written as:

$$F(n,A) = A[\,E(n,A) - E(n+1,A)] = \eta.\varepsilon \qquad 1.8$$

Where

F(n,A) = the " improvement" function, i.e. the increase of the traffic carried by high usage junctions on an increase in the number of high usage junctions from n to n + 1.

η = the efficiency of incremental trunks.

ε = cost ratio.

However, this formula has the disadvantage of giving too many high usage circuits if the cost ratio is high and/or the traffic is small.

A better approximation is obtained by the formula

$$F(n.A) = \varepsilon.[\,1-0.3(1-\varepsilon^2)]$$

which is fitted to the result of extensive calculations on a computer [11].

The mean value M and the variance V for the overflow traffic from each high usage route should first be calculated according to formulas 1.9 and 1.10 [12].

$$M = A.\ E_N\,(A) \qquad 1.9$$

Where

A = The traffic offered

E = The Erlang function

N = The number of circuits

M = Mean of overflow traffic from a route

$$V = M.\left(1 - M + \frac{A}{1 + N + M - A}\right) \qquad 1.10$$

Where

A = The traffic offered

V = Variance of overflow traffic from a route

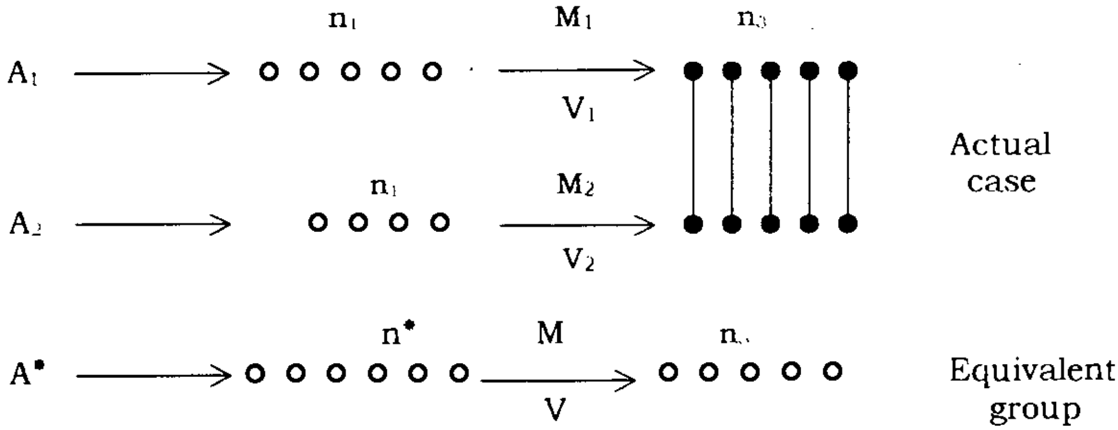
N = The number of circuits

M = Mean of overflow traffic from a route

With the aid of Wilkinson's equivalent random theory the number of circuits on high usage and tandem routes carrying overflow traffic from said routes can be determined.

For calculating the required number of circuits in alternating routing schemes almost all administrations and manufacturers use today Wilkinson's method, or further developed applications, based on this method.

The method is an equivalence method, where an equivalent full availability group is defined by the mean and variance of its overflow traffic. This mean and variance should equal the sums of the means and variances of the overflow traffic offered to the secondary group.



The values M_1, M_2, V_1 and V_2 are calculated from (1.9) and (1.10). An equivalent full availability group is sought which satisfies the condition.

$$M = M_1 + M_2$$
$$V = V_1 + V_2 \qquad (1.11)$$

The equivalent group is then defined by its two parameters A* and n*, where

$$A^* E_{n^*}(A^*) = M$$
$$M\left(1 - M + \frac{A^*}{n^* + 1 - A^* + M}\right) = V \qquad (1.12)$$

Since the numerical values for M and V are given, (1.12) implies that A* and n* have to be found by trial and error. The solution of (1.12) therefore gives some numerical problems, which are overcome with suitable graphs and algorithms for the calculations. The precision is further improved by using non-integer values for n*. Since the Erlang formula, E_n (A), is only defined for whole numbers of circuits, n, this implies that a suitable convention has to be introduced for the calculation of the formula for non-integer values.

The congestion for the actual case is then estimated as

$$E = \frac{A^* . E_{n^*+n_3}(A^*)}{A_1 + A_2} \qquad (1.13)$$

This formula provides an estimate of the total congestion. It does not specify how much of the individual traffics, A_1 and A_2, that are rejected. Different methods exist however for estimating the congestion for these traffics. It is however heuristically found that the losses in the secondary group are proportional to the value of V:M. A more degenerated traffic will namely experience more congestion than a less degenerated one, where the degree of degeneration is expressed by the ratio V:M.

The sum of these mean values is denominated Ms and of the variances Vs. Ms and Vs can be characterised in a more convenient way i.e. as overflow traffic from one fictitious group of circuits with equivalent number of circuits = n_e and equivalent traffic offered = A_e Erl [11]. Ms and Vs are then used to determine n_e and A_e in accordance with the formulas 1.14 and 1.15.

$$Ms = Ae.\ En_e(Ae) \qquad 1.14$$

$$Vs = Ms\left(1 - Ms + \frac{Ae}{1 + n_e + Ms - Ae}\right) \qquad 1.15$$

Where

Ms = Sum of the mean values of overflow traffic from a route
Ae = Wilkinson's equivalent traffic
n_e = Wilkinson's equivalent circuit
E = The Erlang function
Vs = Sum of the variance of overflow traffic from a route

Instead of using this method an approximate formula 1.16, can be used and there by making it possible to solve the problem much quicker and with sufficient accuracy.

$$Ae = Vs + 3 \cdot \frac{Vs}{Ms} \cdot \left(\frac{Vs}{Ms} - 1\right) \qquad 1.16$$

Where

Ae = Equivalent traffic

Vs = Equivalent variance

Ms = Sum of the mean values of overflow traffic from a route

From the above formula Wilkinson's equivalent Erlang Ae can be obtained.

When A_e has been determined n_e can be calculated in accordance with the exact formula 1.17 which can be derived from formula 1.15.

$$n_e = \frac{Ae}{1 - \cfrac{1}{Ms + \cfrac{Vs}{Ms}}} - Ms - 1 \qquad 1.17$$

Where

A_e = Equivalent traffic

Vs = Equivalent variance

Ms = Sum of the mean values of overflow traffic from a route

N_e = Equivalent circuit

From the above formula and the equivalent Erlang matrix Wilkinson's equivalent circuit matrix can be obtained.

If we consider the total congestion for the final route following equation can be used.

$$Eo \times M_{it} = A_{it} \times E\,(n_{it} + m_{it}, A_{it}) \qquad 1.18$$

$$Eo \times M_{tj} = A_{tj} \times E\,(n_{tj} + m_{tj}, A_{tj}) \qquad 1.19$$

Where

E_0 = Total congestion

M_{it} = Sum of the mean of overflow traffic for incoming tandem Circuit

A_{it} = Equivalent traffic for incoming tandem circuit

n_{it} = Equivalent circuit for incoming tandem circuit

m_{it} = Incoming tandem circuit

M_{tj} = Sum of the mean of overflow traffic for outgoing tandem Circuit

A_{tj} = Equivalent traffic for outgoing tandem circuit

n_{tj} = Equivalent circuit for outgoing tandem circuit

m_{tj} = Outgoing tandem circuit

CHAPTER TWO

TELECOMMUNICATION NETWORK STRUCTURE AND DESIGN

2. INTRODUCTION

Optimization and dimensioning becomes more efficient, if we have a complete knowledge of the structure of the network we are studying. This enables Planners.

- to collect reliable data for the network involved;
- to outline practical scenarios;
- to determine the transmission and switching systems to be employed;
- to judge the applicability of the results achieved of the network investigated.

An insight of the structure of local networks (Subscribers and junction network) will be provided, since this represents a substantial proportion of the investment cost. The text will conclude with a general description of the so - called hierarchical and non-hierarchical networks. Especially the latter is a consequence of the advent of SPC technology and particularly the digital technology in switching. Digital SPC switching systems allow a non hierarchical network, namely routing of traffic is not necessarily carried by specific predetermined centers. This new possibility increases the efficiency of the digital switching systems and provides economy against conventional hierarchical network [35].

2.1 NETWORK STRUCTURE

2.1.1 LOCAL NETWORKS

Local networks are divided into three subtypes, according to the size of the area and the amount of urban development.

a) Rural networks

The main characteristics of the type of network is the wide subscriber dispersion around a small or medium-size town. There are limited alternatives for exchange locations.

Subscriber lines are much longer than those of urban and metropolitan areas and therefore, special transmission equipment is required for providing telephone service. Such equipment is:

- EDM and TDM multiplexers
- Line concentrators (conventional or electronic type)
- open wire lines
- Radio relay links

b) Urban networks

These networks are characterized by the fact that several main local exchanges are necessary to which subscribers are directly connected. Planning studies are necessary to find the optimum locations, area and capacity of local exchanges.

c) Large metropolitan networks

These networks are characterized by the high concentration of subscriber in the network area. A large number of local exchanges are required to provide connection to subscriber. Planning studies are necessary to optimize the network.

2.1.2 MEDIUM AND LONG DISTANCE NETWORKS

Medium and long distance networks connect different local areas. This type of network is usually hierarchical with one, two or three levels depending on the number of these areas and the total traffic carried in the network.

2.1.3 INTERNATIONAL NETWORK

This network comprises international transit centers and transmission links to other countries.

2.2 LOCAL NETWORK STRUCTURE & DESIGN

2.2.1 GENERAL

The local switching systems, outside plant for junctions and subscriber circuits makes up the local network in figure-2.1 a local network of a small metropolitan area is shown. Some useful terms are given below for local network.

-Local exchanges:

These are the exchanges to which subscribers are connected.

-Subscribers line:

The circuit connecting the subscriber's telephone set to the local exchange.

-Local exchange area:

The area of local exchange and subscribers network.

-Direct junction circuit:

The circuits between two local exchanges.

- Primary Centre:

The Centre to which local exchanges are connected and via which trunk (long-distance) connections are carried out.

- trunk - junction circuits:

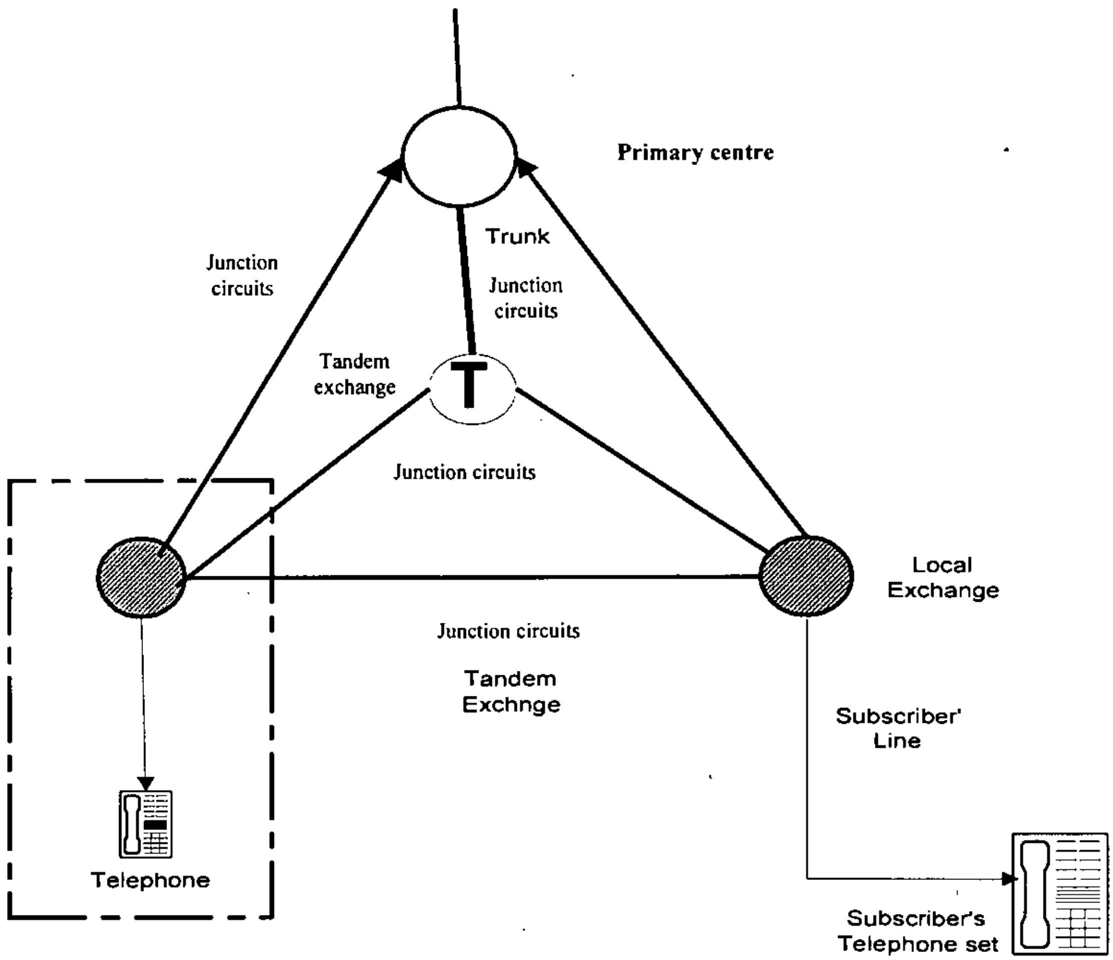


Fig. 2.1 Local network with two local exchange

The junction network between local exchanges and their primary Centre which can participate in long-distance (including international) connections.

- tandem exchange:

The exchange via which the traffic of other exchanges is served.

2.2.2 SUBSCRIBERS LINE NETWORKS

This network connects subscriber to local exchanges. In Figure 2.2 a simplified subscribers line network is shown.

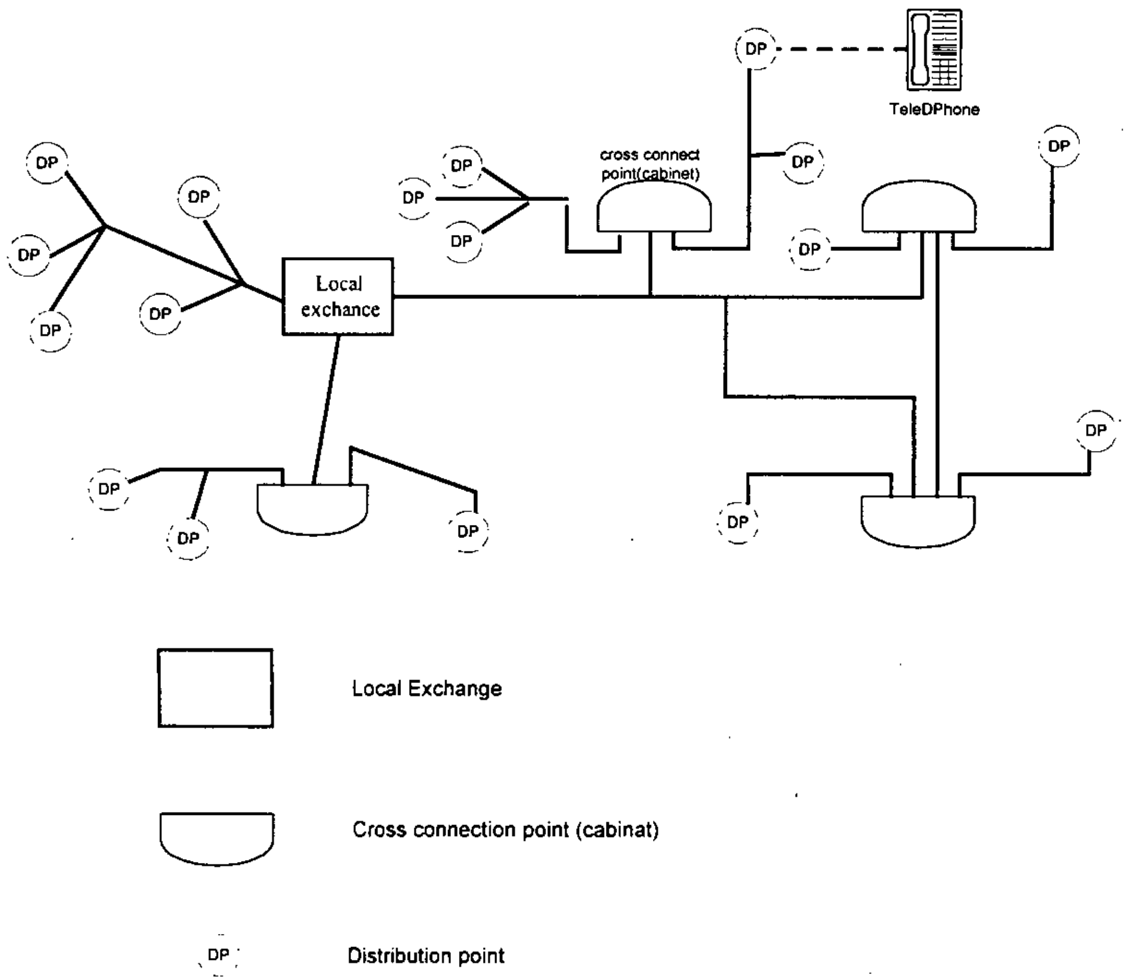


Figure 2.2 Subscriber line network

The network shown in the above figure consists of;

- Main distribution frame (MDF)

The connection frame in a telephone exchange on which the local cable pairs and exchange multiple terminate. It is arranged so that any cable pair can be cross connected to any exchange multiple number.

- Cross- connection point (CCP)

This is the equipment which enables, by use of Jumper wires or equivalent, an incoming pair, to be connected to any of the outgoing pairs.

-Distribution point (DP)

The last point in the exchange area cable network from which pairs are distributed to individual subscribers.

-Main cable

Cable, usually of large pairs, connecting the exchange to a cross-connection point.

-Distribution cable

Cable serving a distribution point or cable between two cross-connection points.

-Link cable

Cable containing link pairs to give flexibility and relief between two cross-connection points.

-Subscribers service line

The part of the subscribers line between the distribution point and the telephone set, regardless of the material or method used.

We can distinguish two kinds of local network:

-Rigid networks

In a rigid network all conductors are electrically prolonged from one cable section to another by joints i.e. the conductors are firmly jointed together and all pairs are thus taken through are firmly jointed together and all pairs are thus taken through from the MDF to DP.

- Flexible networks

  In flexible network the subscribers line network is divided into separate sections (main cable and distribution cable section) by the cross - connection point where the connection may or may not be made systematically in advance [35].

2.2.3 JUNCTION AND TRUNK NETWORK

As defined in the previous paragraph junction and trunk networks are needed to serve traffic between local exchanges and local exchange and primary exchanges for the junction network we can make following distinction:

- Star network

  A number of exchanges are said to form a pure star network when the only possible connection between them is through a single tandem or transit exchange to which all others are connected

- Star and mesh network

  The junction and trunk network is subject to optimization which leads to a compromise between the two forms. (the star form and the mesh form) having some of the characteristics of each. For instance, a set of major exchanges may be connected in mesh but each as a switching point giving access to minor exchanges in star formation around it.

Local networks design includes:

- the location of new exchanges
- the location of remote subscriber units (RSU)
- size of subscribers networks
- size of junction circuits between local exchanges and types of routes

- determination of tandem centers. For the investigation of local networks it is necessary to know not only the expected number of lines in a town or district but also their distribution over the area, if possible, to the extent of a separate forecast for each building block. From this data the exchange locations, the RSU locations, and the number of working lines in each locations at the planning dates are determined. Traffic figures and distribution enter the determination of exchange locations in the form of estimates of junction requirements. However, cost of the junction network is not a major factor in the placement of exchanges.

From the exchange location results an accurate estimate of traffic matrix is made. From this traffic matrix the size of junction network and types of routes are determined as well as the number and location of tandem centers. As regards planning periods, a twenty-year fundamental plan sounds reasonable. The intermediate plans should be elaborated for 10-years and 5-years periods. The intermediate plans form an economic step between the existing and the future desired network. In general, this simplifies many problems because a number of alternatives can be ruled out at a first examination, although, sometimes new problems arise through incompatibilities between present-day and future proposed equipments.

2.3 LONG DISTANCE NETWORKS.

Large values of traffic and low cost of circuits favour a mesh connections between exchanges. This is the rule in local networks where there are areas with large exchanges and with short distances between them. Unlike the long distance network, traffics values are rather small and the circuit cost is very high. As a result of this argument the intercity network is more like a star types network than a mesh one.

2.3.1 NOMENCLATURE

There is much confusion in terms applying to long distance systems. The term "long distance" is used for the American term "Toll" and English "Trunk". The term "Junction" is used for a short distance connection between exchanges.

- primary centers

Centers to which local exchanges are connected and via which long distance connections are established

- Secondary center

Centers to which primary centers are connected in order that long - distance connections might be established.

- Tertiary centers
- Quaternary centers
- Quirary centers

  These center can be defined in an analogous way to secondary center.

- Trunk circuit,

  These are circuits interconnecting the primary, Secondary, tertiary centers etc [35].

2.3.2 TRUNK TRANSMISSION SYSTEMS

Trunk transmission systems mostly fall into two types:

- Frequency division Multiplex systems using transmission media Radio relay links and Coaxial cables and sometimes symmetrical cables.
- Time division multiplex, especially pulse code modulation using transmission media :

  Radio relay links

  Coaxial cables

  Fiber optics cables

2.4 HIERARCHICAL AND NON HIERARCHICAL NETWORKS

2.4.1 HIERARCHICAL NETWORKS

2.4.1.1 TYPES OF ROUTING

2.4.1.1.1 DIRECT ROUTING

Direct route is a low loss route which caries all the traffic from one exchange to another. This is the simplest and commonest route. Figure-2.3 shows a direct route.

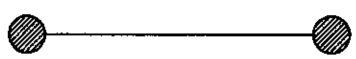


Figure-2.3 Diract Routing

2.4.1.1.2 TANDEM ROUTING

As the number of separate switching center increases in a network the number of different trunk routes between them increases. Above about ten center the number of trunk routes becomes very large and routes tend to contain too few circuits to make the network economic. This argument leads to the concept of concentrating the traffic to certain routes connecting the switching center to a specific center the role of which is to route the whole traffic. It is understandable that the

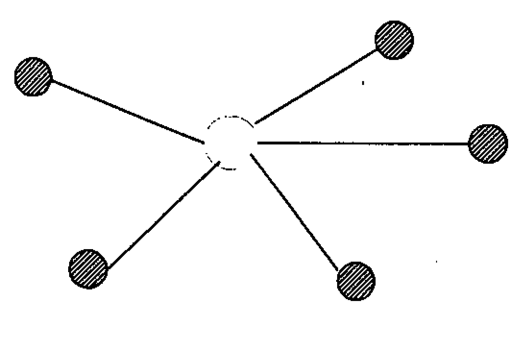


Figure-2.4 Tandem Routing

role of this switch center from the point - of view of handling the traffic is different than the rest ones. Figure-2.4. shows the configuration of a such a network.

This kind of network is called a "star network"

This consideration introduces the concept of hierarchical network namely the switching systems are classified in hierarchical levels; those which can route traffic to various destination and those which cannot. The former systems are transit (tandem) center, the latter are terminals. The routes through transit switching systems are called "tandem routes" Schematically a tandem route is illustrated in Figure 2.5.

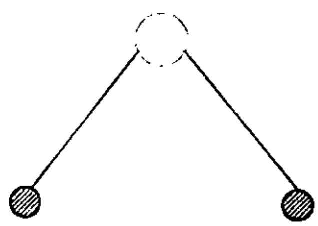


Figure-2.5 Tandem Routing

When the number of exchange is large it is economical to adopt several tandems each one serving a specific group of terminal centers.

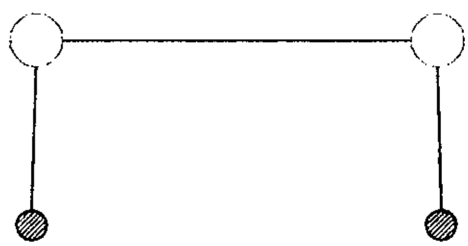


Figure-2.6 Tandem Routing

The traffic between the tandem center may be served on direct routes. The resultant network, is of double star network and is shown in Fig-2.4. Schematically the routes are illustrated in Fig – 2.6.

It is worth while pointing out that in the above route the tandem center area of the same level in the hierarchy. So this network is characterized.

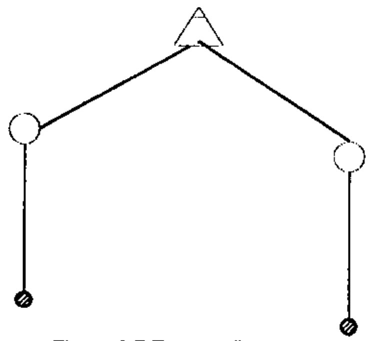


Figure-2.7 Tandem Routing

by two level switching center. When the number of tandem center becomes high the adoption of third level tandem makes the network economical. Here we speak about hierarchy with three levels of center.
In Figure-2.7.a tandem route with three level tandems is shown.

2.4.1.1.3 ALTERNATIVE ROUTING

In most of the cases it is more economical to establish a direct route between two centers for the major part of the traffic. The remainder (usually not more then 30%) of the traffic, when all the direct circuits are busy, can be routed via tandem center. This kind of routing is called "alternative routing" and can be established only when the switching systems can provide alternative routing facility.

It is worth while pointing out that alternative routing is subject to optimization: Subsequently it is the routing which play a significant role in network planning. The size of the direct route which in this case is called "High Usage "route is determined only on economic factors. Schematically the route is shown in fig-2.8.

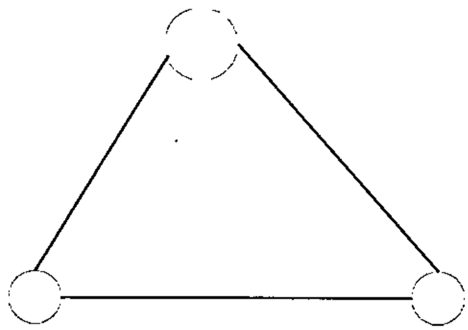


Figure -2.8 Alternative Routing

2.4.1.2 HIERARCHICAL ROUTING PLAN

As regards the routing of traffic for a particular pair of exchange, it

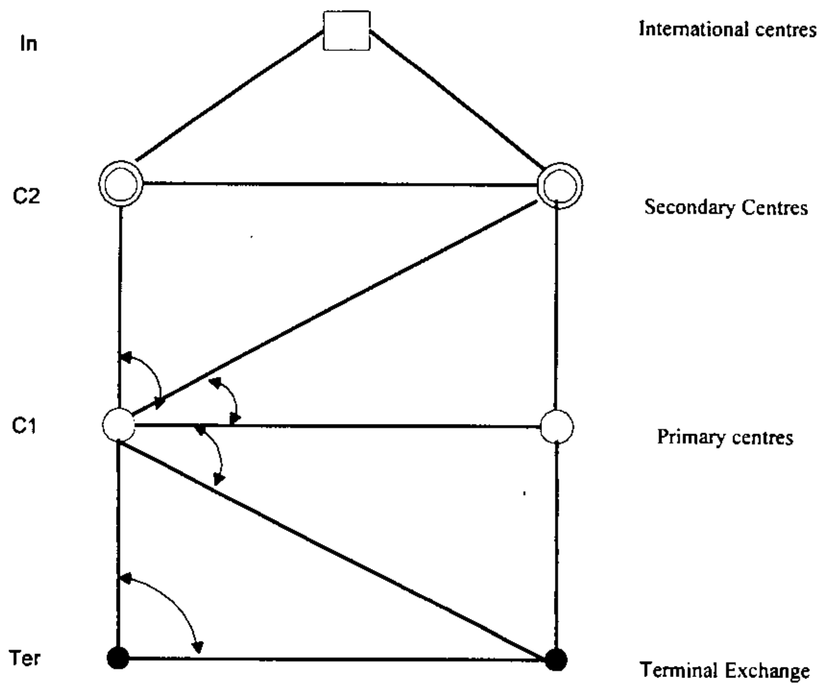


Fig.-2.9 Hierarchical routing plan

is necessary to provide all kinds of possible routes. When the number of switching center gets large it is impractical to elaborate a plan that describes the routes for each particular pair. To be able to cope with all the difficulties, it is much easier to elaborate a plan determined the routes according to the hierarchical level of the center. In figure-2.9, there is a hierarchical routing plan.

The above example concerns a "long distance" network with a hierarchy of four levels [35].

2.4.2 NON-HIERACHICAL NETWORK.

2.4.2.1 INTRODUCTION

For this type of network a lot of terms can be found. The terms "intelligent routing" networks or " Advanced traffic routing" networks are also used.

The fixed hierarchical traffic routing which is currently used in trunk networks has been in operation for about 25 years. Its design was dictated by the technology of the time and characterized by analog cross-bar switching with wired logic common control. Although in general the fixed hierarchical routing provides quite satisfactory service, the traffic efficiency, which is about 0.6 Erl per trunk today, can be improved. Since especially the long distance networks are quite expensive, even a small increase in their efficiency would result in considerable savings for the telephone administrations.

The following main reasons provide the low efficiencies of fixed hierarchical routing:

- In case all direct trunks to the desired destination are busy, the overflow traffic is handled over a limited number of dedicated tandem trunks; free trunks in other parts of the network cannot be used.
- an overflow call is set up to the tandem office without the knowledge of whether further connection is possible or not.
- small trunk routes are inefficient

The advent of stored program control (SPC) in the switching and digital technology in the switching and transmission has created suitable conditions for the introduction of a more intelligent traffic routing and network management system in trunk networks than in the case of presently used hierarchical networks. The intelligence of SPC can be used to route traffic based on the knowledge of the actual state in the trunks and in the SPC nodes. The success of a connection in a network does not only depend on accessibility to a free trunk path. To a great extent the success also depends on the availability of the switching systems in different nodes used for the establishment of the connection. Especially during peak traffic periods this situation could create severe network blockage, if uncontrolled. In an intelligent traffic routing the path selection is based on two conditions:

- the availability of the free trunks and
- the availability of the switching equipment in the various nodded needed to set up the connection.

CHAPTER THREE

PRESENT STATUS OF TELECOMMUNICATION NETWORK IN BANGLADESH

3. INTRODUCTION

The existing public network is in the transition phase of moving from an analog network to a digital network. Digital equipment installation over the past few years have tipped the balance in favour of digital technology. However, while progress is being made, there is still a significant amount of analog equipment in the network, together with the associated interworking difficulties or inefficiencies such as: different signaling types, the use of transmultiplexers, maintenance problems, spare part obsolescence, etc.

The first private cellular operator used analog (AMPS) technology, but will soon upgrade to digital (CDMA) technology. Two other cellular operators have started service with GSM digital technology, and the third will start in 1998. The three operators share the 15 MHz GSM band, each having a contiguous 5MHz of bandwidth [9].

3.1 PUBLIC NETWORK (BTTB)

The BTTB, which presently has a fixed network which is in transition from a analog to a digital network, has a firm policy to digitalise the complete network as soon as possible. Unfortunately, because of lack of funds and long procurement purchasing cycles, the realization of a total digitalization objective could be several years beyond the year 2000. Until that time, the network will suffer from the problems associated with a mixed analog / digital network.

3.1.1 NETWORKING AND SWITCHING EQUIPMENT

3.1.1.1 OVERVIEW

The digitalization situation for the switching equipment is progressing but there is still a high percentage of analog switches in existence. These are EMD switches that are long past their full depreciation duration. The digitalization is most advanced in Dhaka, but other cities are lagging behind. About 40% of subscriber lines are still connected to analog exchanges.

The exchanges in the rural areas outside the district headquarters are almost all the magneto manual type (ring down style). These system are very old and the quality is variable, some good and some bad. There are still approximately 30,000 BTTB subscribers connected in this way. These are very small capacity exchanges, typically 25 to 100 lines.

Besides the Siemens EMD exchanges there are also Alcatel (E-10), NEC (NEAX-61) and ITALTEL exchanges installed. A new project is started where another supplier is providing digital exchange equipment which is Ericsson AXE-10.

Table 3.1: BTTB's Subscriber Capacities (Nov. 1997)

REGION	**Subscriber Capacity**	
	Provided	**Connected**
Dhaka City Multi Exchange Area	229,630	200,030
Dhaka Region	243,330	212,764
Chittagong City Multi Exchange Area	49,000	43,520
Chittagong Region	77,840	29,579
Khulna City Multi Exchange Area	15,000	10,223
Khulna Region	27,900	19,274
Rajshahi City	10,000	5,136
Rajshahi Region	23,020	19.787
TOTAL BANGLADESH	**446,090**	**340,283**

BTTB's automatic telephone network accommodates approximately 450,000 subscribers, with approximately 340,000 subscribers connected by end of November 1997. An overview on a per administrative region basis is given in Table 3.1.

It should be noted that slightly more than 50% of the provided capacity and approximately 60% of the connected subscribers are situated in the Dhaka city multi-exchange area.

3.1.1.2 INTERNATIONAL NETWORK ACCESS

Three international gateway exchanges exist in Dhaka. Two of them (ITX 1 and ITX 3) are situated at Magbazar and the third (ITX 2) at Mahakhali.

In addition to the international gateway exchanges in Dhaka, the combined trunk / local exchange in Sylhet was also said to work as an international gateway exchange, at least for traffic incoming from British Telecom.

3.1.1.3 LONG DISTANCE NETWORK

BTTB's long distance network inter-links six centres of demand, which are:

- Dhaka (two trunk exchanges)
- Chittagong (two trunk exchanges)
- Sylhet (one combined trunk / local exchanges)

- Rajshahi (one combined trunk / local exchange)

- Bogra (one trunk exchange)

- Khulna (one trunk and one combined exchange)

The local exchanges in the cities and the surrounding regions are connected to the long distance exchanges in a star configuration. Trunk capacities of the exchanges are shown in table 3.2.

Table 3.2: Trunk exchange capacity provided and circuits connected (Nov. 1997)

Trunk Exchange	Type	Capacity provided	Trunk circuits connected
Dhaka TAX 1	NEAX 61K	9,361	6,708
Dhaka TAX 2	ALC.E10B		
Chittagong TAX 1	NEAX 61K	1,603	1,117
Chittagong TAX 2	ALC.E10B	2,700	
Khulna TAX	NEAX 61K	2,509	1,518
Khulna combined	ALC.E10B	2,000	
Bogra TAX	NEAX 61K	1,911	1,308
Sylhet combined	ALC.E10B	3,000	
Rajshahi combined	ALC.E10B	2,000	

All trunk exchanges are digital. However, the NEAX 61K system is a first generation digital system. The system is not marketed any more and is succeeded by the NEAX 61E. It must be considered to have reached the end of its economical life span. Up-grading the NEAX 61K, e.g. to ITU-T Signalling System No. 7 - even if technically feasible - cannot be recommended.

3.1.1.4 DHAKA CITY MULTI-EXCHANGE AREA NETWORK

As of November 1997, the Dhaka city multi-exchange area network consists of 22 local exchanges and 2 tandem exchanges. A total capacity of approximately 230,000 line units is provided, with approximately 62,000 still in electro-machanical exchanges. The digital exchange system deployed in the Dhaka multi-exchange area are ALCATEL E10B, NEAX 61E and LINEA (only one exchange). The electro-mechanical exchanges are system EMD. These are already very old and worn out, and should be replaced as soon as possible.

Approximately 200,000 subscribers are connected. A detailed list of the Dhaka local exchanges, their type, capacity and the ammount of subscribers connected can be found in Table 3.3.

It should be noted that:

- both tandem exchanges are situated in one building (SBN),
- both trunk exchanges are situated in one building (MOG),

Which in terms of network security and network resilience is not favourable. In addtion, the subscriber exchanges are connected to the tandem exchanges and to the trunk exchanges based on a system-wise allocation and not on a geographical allocation, which would be usual. So, for the local traffic, the NEAX and EMD subscriber exchanges rely, to a large extent, on the NEAX tandem exchange and for the long distance traffic on the NEAX trunk exchange. The same applies to the E10B exchanges.

Table 3.3: Subscriber Connections to BTTB Local Exchanges (Dhaka Region)

General Data						Subscriber Capacity	
No.	Code	Name	Location	Office code	Type	Provided	Connected
1	CEN 1	Central-1	Dhaka	23	EMD	10000	
2	CEN 3	Central-2	Dhaka	24	EMD	10000	19995
3	MJL	Motijheel	Dhaka	955 - 956	E – 10	20000	19962
4	GLS 1	Gulshan-1	Dhaka	60	EMD	9000	8548
5	GLS 3	Gulshan-3	Dhaka	87, 88	NEAX	12500	
6	GLS 4	Gulshan-4	Dhaka	988	E- 10	14000	16029
7	CNT	Cantonment	Dhaka	987	E10,RSU	[2500]	
8	TNG	Tongi	Dhaka	980	E10,RSU	[4000]	1968
9	UTR	Uttara	Dhaka	89	NEAX	6500	6434
10	MRP 2	Mirpur-2	Dhaka	80	NEAX	8000	
11	MRP 3	Mirpur-3	Dhaka	900	E-10	10000	16029
12	MGB1	Moghbazar-1	Dhaka	40	EMD	6000	
13	MGB2	Moghbazar-2	Dhaka	41	EMD	9000	15208
14	MGB3	Moghbazar-3	Dhaka	83, 84	NEAX	12280	
15	MGB4	Moghbazar-4	Dhaka	933, 934, 935	E-10	24000	26057
16	NYG 2	Narayanganj	Dhaka	971	LINEA	6000	4999
17	NLK 1	Nilkhet-1	Dhaka	50	EMD	10000	9997
18	NLK 2	Nilkhet-2	Dhaka	86	NEAX	9600	9055
19	NLK 3	Nilkhet-3	Dhaka	966	E-10	10000	6794
20	SBN 2	S.B.Nagar-2	Dhaka	32	EMD	7000	6970
21	SBN 3	S.B.Nagar-3	Dhaka	81, 82	NEAX	12000	30250
22	SBN 4	S.B.Nagar-4	Dhaka	911, 912, 913	E-10	22000	
23	GZP	Gazipur	Joydebp.			700	700
24	SVR	Savar	Dhaka,di.		CB,EMD	1050	1035
TOTAL, Dhaka City						229,630	200,030

For the local traffic, some direct routes between the subscriber exchanges have been established. Also, some direct routes have been made between the subscriber exchanges and the "other system tandem exchange". However, the provision of direct routes has been determined in a rather restrictive way, that is, only for traffic streams of more than 30 Erlang. Even direct routes between exchanges within the same building are not dimensioned as fully provided routes but, instead, with 20% overflow to the " own tandem exchange". It is common practice to establish a direct route for traffic streams of more than 14 to 17 Erlang, and to dimension direct routes between exchanges in the same building as fully provided routes.

As a consequence, the tandem exchanges carry an unnecessarily high traffic load. Failure of one of the tandem exchanges or even only the cross link between the two tandem exchanges would cause a serious jamming problem in the entire Dhaka multi-exchange network.

For the long distance traffic, no direct or alternative routes have been establish to the "other system trunk exchange". As a consequence, any failure of a trunk exchange will result in the subscriber exchanges of the same system being practically isolated from the long distance network.

In summary, it must be stated that the Dhaka multi-exchange network is rather vulnerable to disasters or intrusion and provides only very limited inherent resilience.

3.1.1.5 OTHER MULTI-EXCHANGE AREA NETWORKS

Multi-exchange area networks also exist in:

- **Chittagong**

The Chittagong multi-exchange area network consists of five E10B subscriber exchanges and three EMD subscriber exchanges, which are in the process of being phased-out. The provided capacity in the digital exchanges is 49,000 line units. 43,520 subscribers were connected as of November 1997, of which approximately 2,900 are still connected to the three EMD exchanges.

- **Khulna**

The Khulna multi-exchange area network consists of two E10B subscriber exchanges. The provided capacity is 15,000 line units. 10,233 subscribers were connected as of November 1997.

3.1.2 TRANSMISSION EQUIPMENT

The transmission network includes the three characteristic traffic carrying media: satellite, microwave and optical fiber. There is still some analog equipment in the transmission network and transmultiplexers are use to convert between the analog and digital signals. So far, the digital transmission equipment is the plesiochronous digital hierarchy (PDH) type, and there is presently no synchronous digital hierarchy (SDH) equipment installed, although there are plans to start an SDH upgrade in the near future. Installation will start in 1998.

Satellite transmission is used for international traffic and there is no domestic satellite system. Optical fiber systems are used to interconnect exchanges in the capital city of Dhaka and the port city of Chittagong. Microwave systems interconnect Dhaka to several major cities. Deeper penetration beyond the microwave routes is done using UHF, low capacity, mostly digital radio technology, with a smaller proportion of analog radio.

3.1.2.1 SATELLITE SYSTEM

Bangladesh has four earth stations,as follows:

- A Standard "Å" situated in Bethbunia. approximately 240 km from Dhaka. This is linked to Dhaka by an analog FDM/FM/IDR microwave link (installed 1975, renovated 1988/89 and again 1994).

- A Standard "B" located at Talibabad, about 40 km from Dhaka, connected to Dhaka by a single-hop microwave link. For its installation in 1982 it had SCPC operation, and in1992 two IDR units (with DCME) were added.

- A Standard "A" was constructed in Dhaka city in 1994, initially with 13 IDR carriers with a station capacity of 1980 telephone circuits (without DCME).

- A Standard "F3" was placed in the north eastern city of Sylhet with drop capability at Sylhet.

3.1.2.2 OPTICAL FIBER SYSTEMS

Optical fiber is present in the interexchange routes in Dhaka, with systems supplied by Alcatel and NEC. The Alcatel fiber systems operate at the 565 Mb/s PDH level between the higher capacity exchanges and

140 Mb/s between the lower capacity exchanges. The NEC fiber systems operate at 140Mb/s in a star formation centred at SBN. Figure 3.1 illustrates the exchange interconnections.

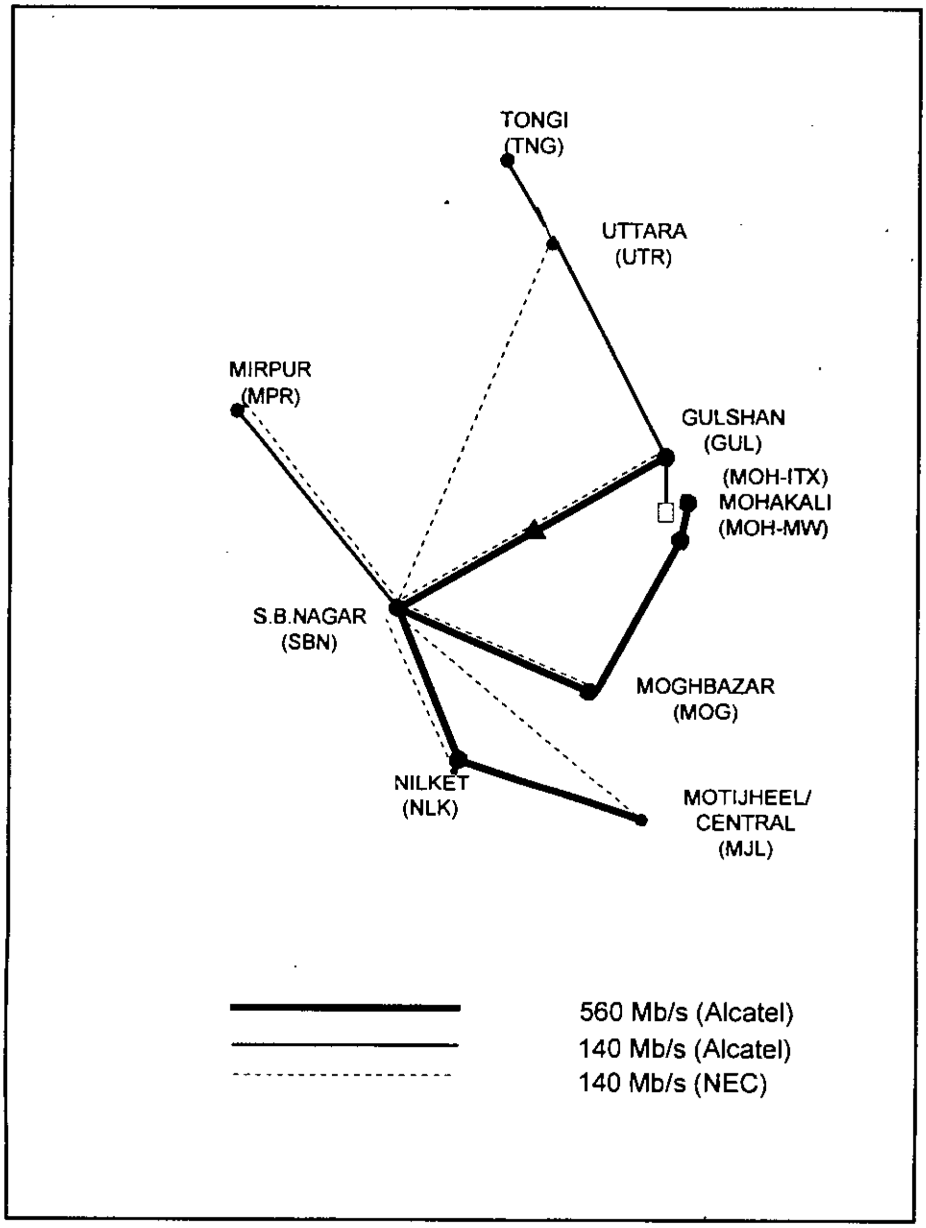


Figure 3.1: Optical Fiber Routes in Dhaka

The optical fiber line terminating equipment is directly connected to digital multiplexer equipment.

(a) Interexchange Optical Fiber Systems

These optical fiber links, installed by Alcatel and NEC, provide high quality transmission between exchanges within Dhaka and within Chittagong. The fiber cables typically contain 8 to 12 fibers, so capacity expansion can be achieved by installing additional optical line terminal equipment (OLTE) on other fiber pairs plus associated multiplexing equipment. In many locations the multiplexers are only partially equipped, so further capacity can be obtained by adding more cards in other locations sub-racks also need adding.

It must be realized that the existing OLTE and multiplexers are all of the PDH type. Any further upgrades should be SDH and therefore instead of the 565 Mb/s level the equivalent SDH 622 Mb/s should be used, or higher if the fiber allows.

(b) Long Distance Optical Fiber

There is at present no optical fiber installed in the BTTB long distance network. Plans to interconnect Dhaka and Chittagong with a high capacity optical fiber cable are in process by BTTB with assistance from the Government of France and installation is expected to begin in 1998.

A private fiber cable network, owned by the Bangladesh Railways, exists between major cities for their own communication needs. The spare capacity has been leased to the Grameen Phone private telecommunications operator.

This optical fiber cable is primarily a 2-fiber cable, based on funds available at its time of installation. This has the unfortunate disadvantage of only allowing ONE COMMUNICATION LINK (go and return). The drawback is that no protection channel can be included to maintain the link availability in the event of electronics failure within the line terminal equipment. Some route diversity protection is achieved in the north west region were an optical fiber loop (ring) is formed. And a further second ring is intended by closing the loop formed by completing the Sirajganj to Tongi route.

(c) International Optical fiber

A global transoceanic optical fiber is scheduled to connect to Calcutta and Penang (Malaysia) within the near future. If Bangladesh were to install a high capacity optical fiber cable from say Chittagong to Calcutta, India (or Penang, Malaysia) some international traffic routes would be satisfied for the very long term future.

Alternative routing would still be necessary to provide protection against failure of the oceanis optical fiber cable. The cost of international circuits via fiber is falling at a rate which must question the long term economic viability of satellite telephony. IDR with DCME, which is used by Bangladesh, is definitely the most cost effective satellite connectivity at present, but unless there are some further technological innovations in satellite technology within the very near future, it seems unlikely that it will be able to compete favourably with optical fiber for much longer.

3.1.2.3 MICROWAVE RADIO SYSTEMS

The long distance microwave network is a star topology with little or no meshing. There are still some analog microwave radio systems in service. Presently, the maximum inter-city digital transmission rate is 140 Mb/s. There are four main microwave routes from Dhaka to Chittagong, Khulna, Sylhet and Bogra, from which there are several spur routs. Table 3.4 summarises the microwave links details.

The major microwave link between the cities Dhaka and Chittagong is still analog. This is an 1800 channel NEC system which was designed for 2+1 operation, meaning 1800 channels for telephony, one full channel for TV, and spare stand by which could be automatically switched into operation in the event of failure.

Table 3.4: Microwave links in the Long Distance Network

ROUTE	No. of CHANNELS	SUPPLIER	DATE
Dhaka - Chittagong	1800 (analog)	NEC	1985
Dhaka - Khulna Spur to Kushtia	1920 (digital) 960 (analog)	Fujitsu	1991
Dhaka - Sylhet	1920 (digital)	Alcatel	1994
Dhaka - Bogra Spur to Mymensingh	1920 (digital)	Alcatel	1994
Bogra - Rangpur Spur to Thakurgaon	960 (analog)	Fujitsu	1978
Bogra - Atwari	960 (analog)	Fujitsu	1978
Bogra - Natore to Rajshahi Bogra - Natore to Chuadanga Continues to India	960 (analog)	Fujitsu	1978
Khulna - Barisal - Patuakhali - Kalapara	480 (digital)	JRC	1992-94
Chittagong - Cox's Bazar Spur to Bandarban	960 (analog) 120 (analog)	GTE MOT	1978
Chittagong - Betbunia Spur to Rangamati	1920 (digital) 300 (analog)	Alcatel GTE	1992-93

Because of the pressure to provide additional service on this congested route, the standby channel has been converted to a telephony traffic carrying channel. This is certainly non-standard practice. Clearly it has severe negative consequences on the availability of the link. The outage time recorded for the year 1996 was 273 hours. That is an availability Of 96.9%. The situation will resolved when the new optical fiber link project is completed, but not until about mid-1999 at the earliest. The channel details for the microwave links are summarised in Table 3.5.

Table 3.5: Details of the Dhaka to Chittagong Microwave Links

ROUTE	No. of MAIN CHANNELS	No. of PROTECTION CHANNELS
Total Working Channels =2700	1800 (analog) (Distributed as follows)	900 (analog) (i.e. 50% equipped)
Dhaka - Chittagong	720 (analog)	900 (analog)
Dhaka - Betbunia satellite	360 (analog)	0
Dhaka - Hajigonj / Comilla	300 (analog)	0
Dhaka - Maizdicourt	60 (analog)	0
Leased / data / Telex	360 (analog)	0

The Alcatel digital microwave radio equipment operating between Dhaka - Sylhet and Dhaka - Bogra - Mymensingh, unfortunately, has been installed without hitless switching between the main and standby (protection) channels. Consequently, when the main system becomes out of service because of fading or other failure mechanisms, manual resetting is necessary. This is a major shortcoming of this installation. Outages for these microwave links have been measured (by its supervisory system) in "hours per month", rather than the acceptable "several minutes per year" time frame.

Table 3.6: Microwave Radio Routes

Nominal Route & Capacity	Route Segment	Installed capacity	In Use	Spare (Equipped)	Equipment Type	Frequency Band
DAK - SYL	DAK-NAR	240	180	60	Alcatel	U6 GHz
(1920 Channels)	DAK-BMB	240	240	0		
	DAK-SZBR (Reptr.)					
	DAK-MVI	360	240	120		
	DAK-SYL(KAZ)	120	60	60		
	DAK-SYL(TAL)	840	660	180		
	MVI-SYL(TAL)	120	60	60		
	SYL(TAL)-SYL(KAZ)	120	120	0		
DAK - TGL	DAK-TGL(RADIO)	60	30	30	Alcatel	U6 GHz
(1920 Channels)	DAK-TGL(EXCH)	240	210	30		
DAK-TGL-MMG	DAK-MM(RADIO)	240	210	30		
	DAK-MM(EXCH)	480	240	240		
DAK-TGL-BOG	DAK - SRJ	120	90	30	Alcatel	U6 GHz
(1920 Channels)	DAK - BOG	1200	780	420		
	BOG - RAJ	120	120	0		
MOG - NYG	MOG - NYG	840	630	210	Alcatel	U6 GHz
(1920 Channels)						
MOG-MJL-KLN	MOG-MJL	90	90	0	FUJITSU	140 OLTE
(1920 Channels)	MOG-MNJ	45	45	0	FUJITSU	U6 RADIO
	MOG-FDR	120	120	0		
	MOG-MGR	90	60	30		
	MOG-KLN	480	480	0		
	MOG-KST	120	120	0		
	MJL-KLN	360	360	0		
	MJL-FDR	120	120	0		
KLN-MGR-KST	KLN-JSR	360	330	30	FUJITSU	U6 RADIO
(1920 Channels)	KLN-MGR	30	30	0		
	KLN-JND	120	90	30		
	KLN-KST	240	240	0		
					+IND-KST	L6 RADIO
Khulna-sripur-Barisal	KLN-SRPR	60	60	0	JRC	2 GHz
480(Channels)	KLN-BRL	420	420	0		
Barisal-Patuakhali	BRL - PTK	120	120	0	JRC	2 GHz
(480 Channels)						
Patuakhali-Khepupara		30	30	0	JRC	2 GHz
(30 Channels)						
Chittagong-Cox's Bazar	CTG - CXB	480	480	0	JRC	2 GHz
(480 Channels)						

The supplier, Alcatel, was appraised of this performance. A fault in the supervisory system has been corrected, but high outages are still experienced.

Table 3.6 summarises the digital microwave radio transmission route capacities together with indications of any spare capacity available for future expansion.

3.1.2.4 POINT-TO-POINT RURAL SYSTEMS

BTTB operates UHF spur routes from its microwave network to connect to towns where there are small exchanges. These systems provide a very extensive rural telecommunications network, penetrating deep into the lower population density villages. The operating frequencies are in the higher UHF range of the 1.5 GHz and 2 GHz bands. Note that some frequencies in this range are now allocated to LEO and MEO satellite systems.

The systems are provided by:

- Nokia (digital; 6 or 12 Channels equipped; system capacity:2Mbit/s)
- Harris [HRF] (digital; 120 Channels capacity)
- Bell (digital; 120 Channels capacity of which only 6 are used)
- TRT (digital; 30 Channels capacity of which only 12 are used)

There are more than 350 UHF links in BTTBs network, providing telephone service connections to a significant percentage of the 460 thanas.

3.1.2.5 POINT-TO MULTIPOINT RURAL SYSTEMS

In some areas there are multi-access radio systems. These are mainly digital point-to-multipoint radio concentrators which vary in capacity and can provide up to 120 channels to service as many as about 1200 fixed radio telephone connections, depending on the supplier and model type. There are also many analog systems in operation. The end points can be public call offices, card-phones or regular telephones.

There are two point-to-multipoint equipment suppliers:

- Motorola Multi-access Rural Systems (analog)
- NEC Digital Rural Multi-access subscriber Systems

These systems are in operation throughout the country.

3.1.3 BTTB PROJECTS IN PROGRESS AND PLANNED FOR THE FUTURE

There are several projects presently in progress which will be of benefit to BTTB and the interconnection of the private operators. However, because of a combination of lack of funds and long administrative processes, the network expansion is always in a state of catching up with pending demand rather than anticipating it. The essence of long range planning is to "lead" rather than "lag".

3.1.3.1 NETWORKING AND SWITCHING PROJECTS IN PROGRESS

The following projects could be identified:

- **The 67.5 K Lines Project (ERICSSON)**

The 67.5 K line project aims to add 67,500 subscriber lines in Dhaka in seven new subscriber exchanges associated with a new tandem exchange (at central- MJL) and a new trunk exchange as well as the necessary junction network between them. This will also be configured system-wise.

The project is approved and funded. The tendering process is finalised. However, no exact data could be obtained for the expected final cut -over to service. Present estimates are late 1998 or early 1999.

- **The 41 K Line project**

The 41 k Line project aims to add 41,000 subscriber lines in Dhaka. The project seems to be funded from remaining funds from an earlier project. An open tendering process is presently being initiated, However , not even an estimated date could be obtained for the final cut-over to service.

- **The Dhaka junction Network Expansion in Conjunction with Work C**

The Dhaka junction Network Expansion in conjunction with work C, aims to expand and reorganise the existing parts of the Dhaka multi exchange area network to accommodate the additional traffic resulting from the 67.5 K Line project and the 41 K line project.

In addition the BTTB claims that this project would also accommodate the traffic from and to 100,000 mobile subscribers.

The project seems to be funded from the remaining funds from an earlier project. The work is presently being initiated. However, not even an estimated date could be obtained for full completion of the work.

- **Proposal for a Dedicated Tandem Exchange for Mobile Traffic.**

There is a proposal to establish an additional single tandem exchange fully dedicated to the traffic from and to the mobile networks.

The proposal is neither approved nor funded or scheduled yet.

It is postulated that such a dedicated tandem exchange would allow for easy dimensioning, traffic routing and expansion as far as the provisions for mobile traffic are concerned. Arrangements for accounting data registration would also be needed only in this tandem exchange.

However, this configuration would be very vulnerable. Failure of this single dedicated tandem exchange would result in the mobile networks being completely isolated from the Dhaka multi- exchange area network. To overcome this disadvantage, it would be necessary either to have two such dedicated tandem exchanges sharing the mobile traffic or to route approximately 50% of the mobile traffic via other tandem exchanges, In the latter case, all of the above - claimed advantages would be lost.

O **Other proposals**

There are some other draft proposals related to " the greater Dhaka network" and to "EMD Replacement in Dhaka ". However, none of them is fully formulated or close to approval, for the establishment of funding and implementation. No plans concerning expansion of long distance exchanges could be identified.

3.1.3.2 TRANSMISSION EQUIPMENT

To make a general statement, some of the transmission projects planned for the near future will improve upon the present situation to some extent but most are inadequate. Even worse because they are not based on a long range rolling plan (e.g.10 to 15 years) they could seriously hamper future network development.

O **Dhaka city optical fiber ring (Triangle)**

This project called the Greater Dhaka Telecom Network Phase-2 (south), as illustrated in Figure 3.2, will partially improve the transmission situation with respect to the Dhaka inter exchange capacity.

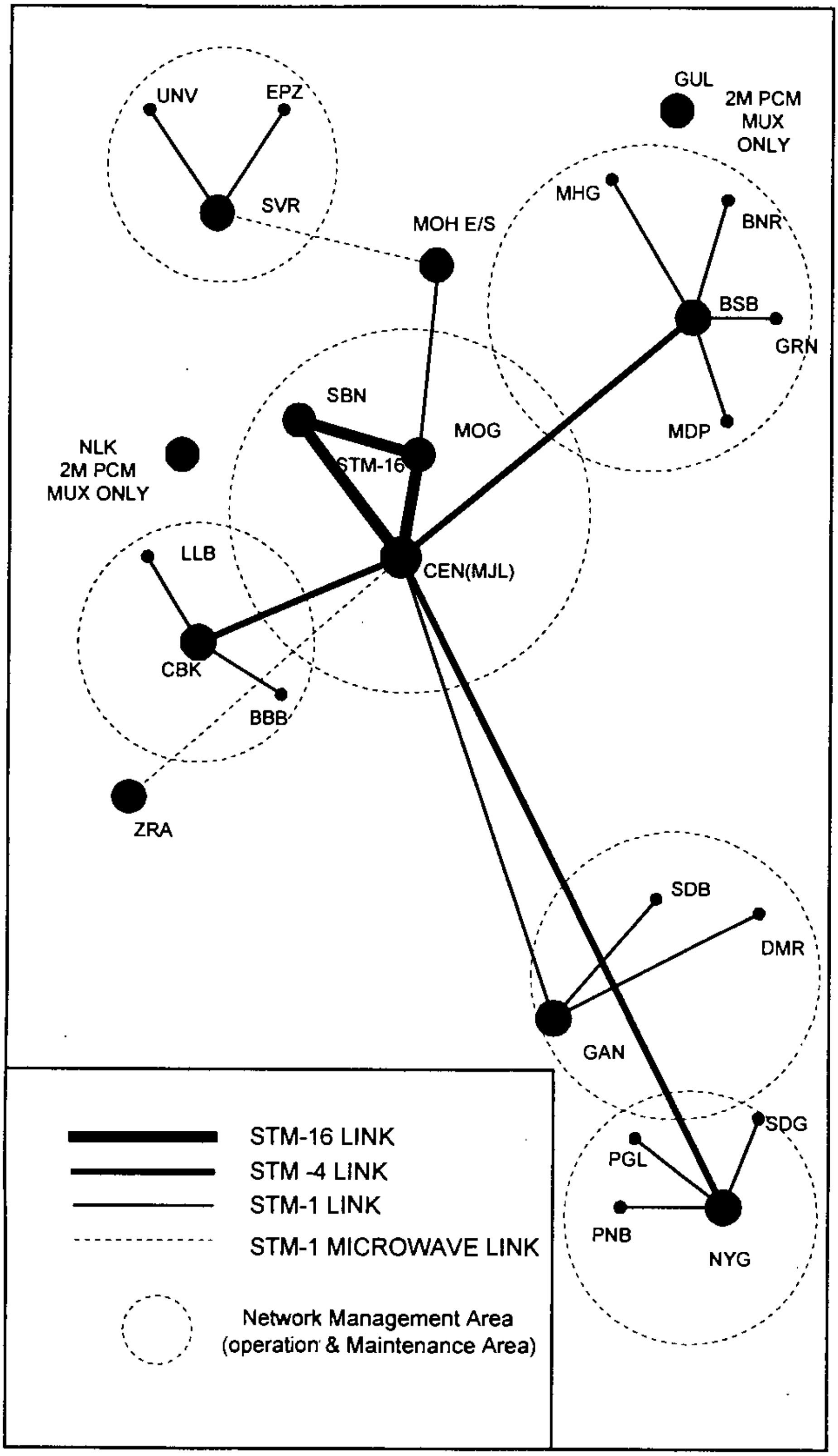


Figure 3.2: Dhaka Optical Fiber upgrade (by Japanese assistance)

Some comments on this project are noted as follows:

- The STM-16 high capacity part of this project is the smallest possible ring (i.e.a triangle). All modem high capacity network installations incorporate meshed or interlocking, multiple ring structures, incorporating all major exchanges.

- The new exchanges and RSUs are star connected to CENTRAL (MJL), which lacks the flexibility for traffic reconfigurability.

- The new exchanges which are now designed for connection at STM-4 (and STM-1 for GAN) should also be at the high capacity STM-16 level to allow for future growth.

To provide an adequate long-term solution, more exchanges need to be included in the STM-16 ring architecture, possibly using the dual bi-directional self-healing ring structure, or multiple rings topology. A better (but of course more costly) design would include, for example, exchanges at CEN, NLK, SBN, (MPR), SVR, GUL, BSB. MOH, BSB, MOG, NYG, GAN, CKB within one, two or even three interconnected rings.

- **Dhaka to Chittagong Optical Fiber Route**

This project is urgently needed as the port city of chittagong is suffering from inadequate inter - connectivity with Dhaka and the rest of the country, The route plan is shown in Figure 3.3 Severe congestion is hampering communication with the rest of the country because of the poor quality and low capacity of the existing analog microwave radio system, Implementation is starting at the beginning of 1998 with completion 12 to 18 months from then [9].

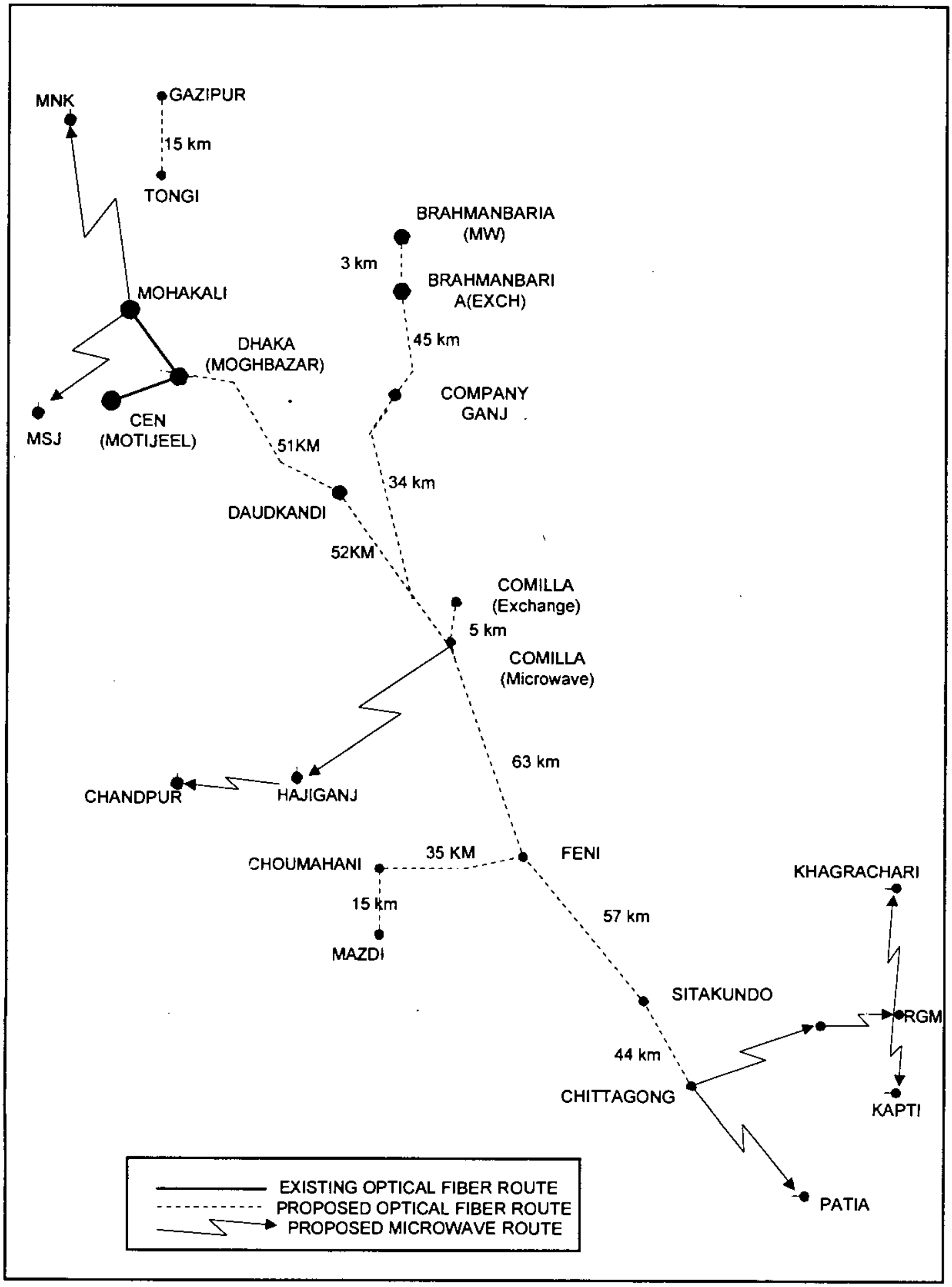


Figure 3.3: Dhaka to Chittagong Optical Fiber Upgrade (by French assistance)

3.2 PRIVATE OPERATOR NETWORKS

At present, there is one analog (AMPS) cellular operator that has been providing service since 1993. Three GSM digital cellular radio private operator licences have been allocated to national or joint-venture companies. Each GSM operator has been allocated 5 MHz within the 900-915 MHz uplink (mobile to base) and 945-960 MHz (base to mobile) downlink bands. These bands are contiguous (overlapping at the 3 dB down points), i.e 900-905 MHz, 905-910 MHz, 910-915 MHz.

3.2.1 PRIVATE OPERATOR NETWORKS IN OPERATION

There are two rural operators, one in the north and the other in the south of the country.

3.2.1.1 GRMEENPHONE (GP)

GrameenPhone is a consortium containing:

- Telnor, Norway (51% share)
- Grameen Bank, Bangladesh (36% share)
- Marubeni of Japan (9% share)
- Local partner (4% share)

GrameenPhone is presently operating in Dhaka with plans to expand to Chittagong in April 1998, and other major cities soon after, with countrywide operation within a few years from now.

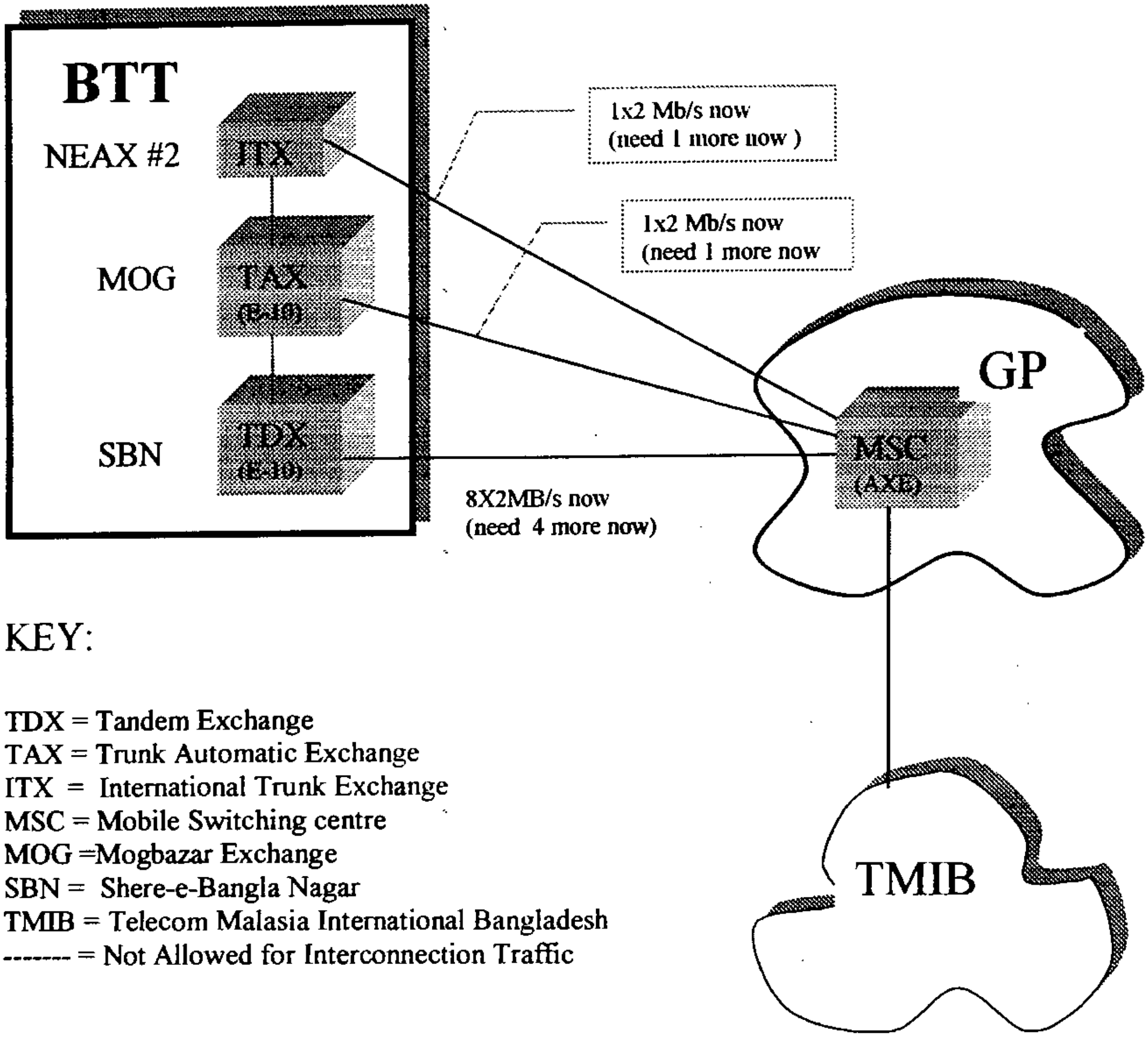


Figure 3.4 Grameen Phone Interconnection

Grameen Phone has obtained a long distance network lease from the Bangladesh Railway to operate over its extensive optical fiber routes. The transmission formates are SDH STM-16, STM-4 and STM-1, depending on span distances and capacity requirements.

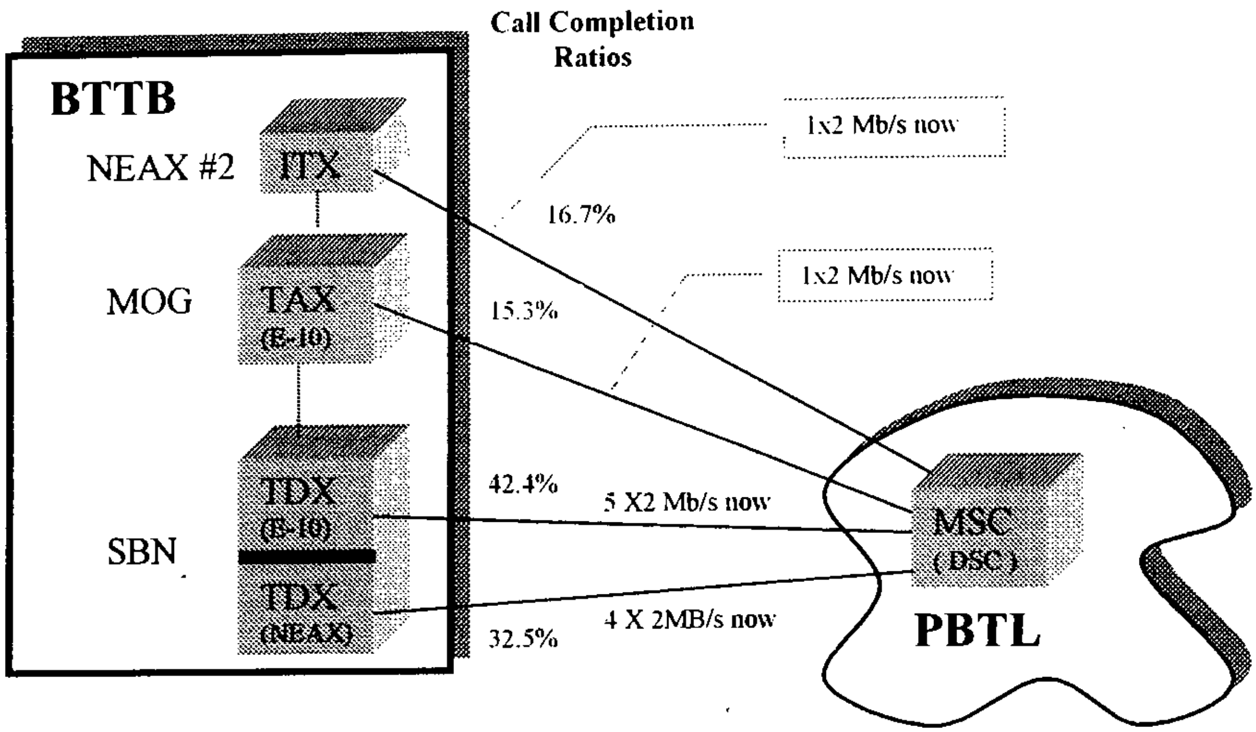
Figure 3.4 shows how Grameen Phone is interconnected to BTTB and another cellular operator TMIB. The interconnection circuit capacities to each exchange are as stated by Grameen Phone.

3.2.1.2 PACIFIC BANGLADESH TELECOM LIMITED (PBTL)

PBTL took over a license that was originally granted to Hutchison Bangladesh Telecom Ltd., in 1989. The license offered a 5 year monopoly to Hutchison. By Aug.1993 Hutchison started operating with a motorola supplied analog mobile Phone System (AMPS) and they had about 3000 subscribers by July 1995.

However, the new licenses (1996) offered to the cellular operators allow for interconnection between operators, whereas the older license inherited by PBTL does not.

The interconnection between PBTL and BTTB is shown in figure 3.5 and the statistic were provided by PBTL . Notice that PBTL has two tandem switch interconnections to the co-located exchanges at SBN.



KEY:

TDX = Tandem Exchange
TAX = Trunk Automatic Exchange
ITX = International Trunk Exchange
MSC = Mobile Switching centre
MOG =Mogbazar Exchange
SBN = Shere-e-Bangla Nagar
TMIB = Telecom Malasia International Bangladesh
------ = Not Allowed for Interconnection Traffic

Figure 3.5 PBTL Interconnection

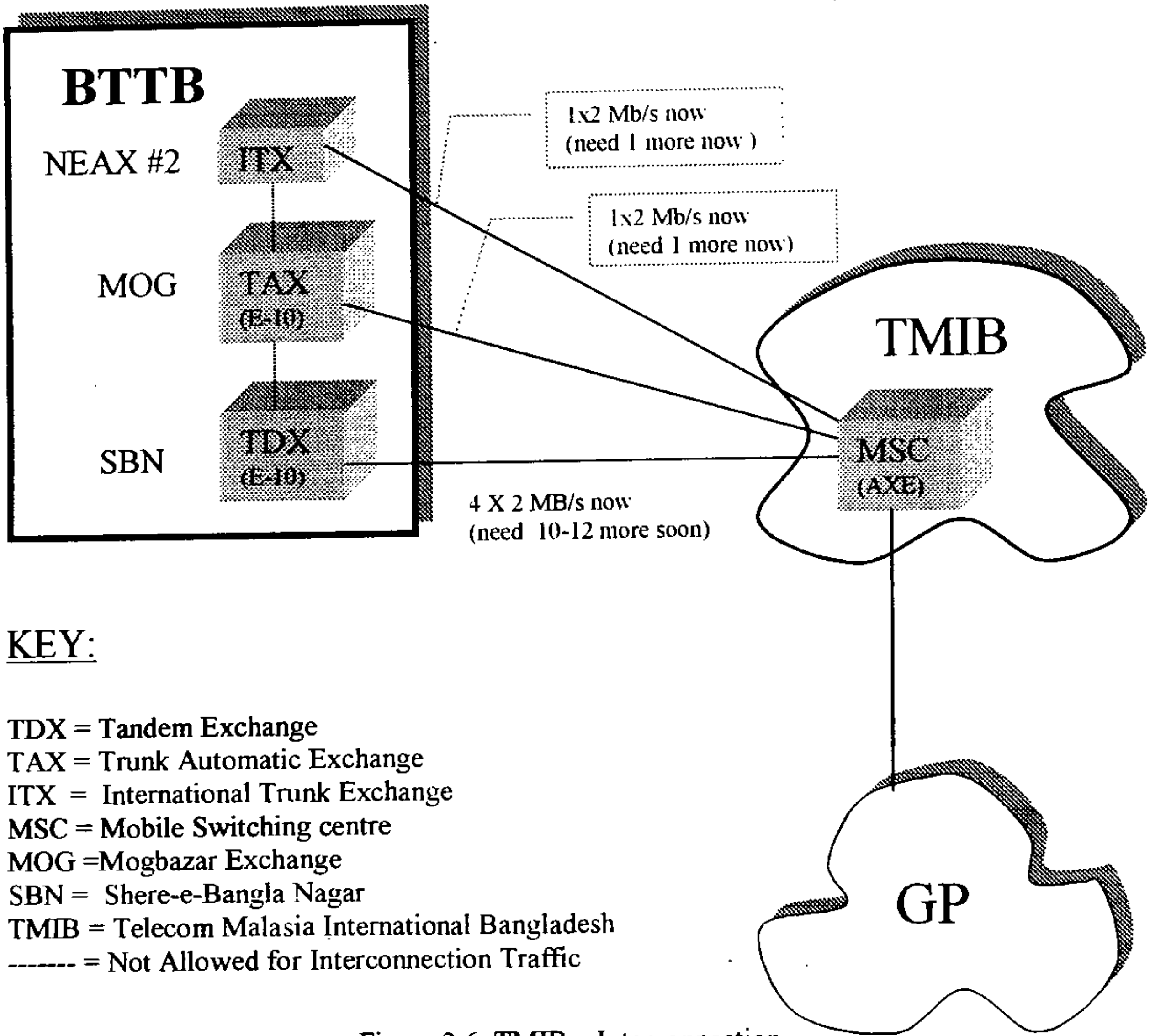
The AMPS frequency band is 824-849 MHz up link and 869-894 MHz down link. This older analog technology will be expanded by digital CDMA technology in the near future, using the same frequency bands. Further enhancements may be included by interconnecting the cellular mobile network with low earth orbit (LEO) satellite technology. At this stage (preferably now) a careful assessment of the proposed LEO frequencies must be made to ensure there is no interference with fixed terrestrial frequencies already in use.

The LEO frequencies are typically in the range 1.5 to 2.5 GHz, depending on the satellite constellation. Substantial UHF point - to-point and point-to - multi-point systems are presently operating in Bangladesh within this frequency range, therefore some interference can be expected. The extent of interference needs a careful study. Present operations are in Dhaka and Chittagong, with an MSC in each city . The interconnect form PBTL to BTTB is via digital microwave radio, using a transmission rate of 34 Mb/s and frequency of 13 GHz. PBTL would like to interconnect its operations in the two cities by a microwave link, but no frequency has yet been allocated for this purpose.

PBTL has an incoming call charge (air charge) whereas other operators do not. In terms of interconnection this has had the effect of balancing the incoming and outgoing traffic. while this is an interesting result, tariff structures and their effect on traffic are outside the scope of this study.

3.2.1.3 TELECOM MALAYSIA INTERNATIONAL BANGLADESH LTD (TMIB)

TMIB is a joint venture between:



KEY:

TDX = Tandem Exchange
TAX = Trunk Automatic Exchange
ITX = International Trunk Exchange
MSC = Mobile Switching centre
MOG =Mogbazar Exchange
SBN = Shere-e-Bangla Nagar
TMIB = Telecom Malasia International Bangladesh
------- = Not Allowed for Interconnection Traffic

Figure 3.6. TMIB Interconnection

- Telekom Malaysia (60% share)
- A.k.khan & Company Ltd of Bangladesh (40% Share)

TMIB has proposed that within a stipulated 18 months period they will invest US$ 35 million to establish cellular radio access to 34,000 subscribers requiring the installation of 60 to 65 radio base stations, covering the entire country. The interconnections between TMIB and BTTB is shown in Figure 3.6. TMIB has plans to have its own transmission network, but in the short term recognises the necessity on BTTB.

3.2.1.4. SHEBA TELECOM (PVT.) LTD (STL)

The Sheba operator has two separate licences:

- Rural operation

- GSM operation

Historically, the joint venture between integrated services Ltd, (ISL; Bangladesh) and Technology Resources Industrials (TRI; Malaysia) transferred ownership of its rural operators licence to sheba in 1995. This licence, which was issued in August 1994, allowed connection to 191 thanas, in the southern part of the country.

- **Rural**

The Sheba rural telecom system is mainly a wireless local loop (WLL) system. A regionwide cluster of 21 cells (Some overlapping) is under construction in four phases. The base station at the centre of each cell operates in a multi-access radio mode to remote locations. These scarce telephones in the rural areas are shared by as many as 100 persons. Traffic on each connection is therefore very heavy.

There is the potential to increase the rural subscriber base to about 30,000 by the end of 1999, as WLL installations enable rapid deployment.

GSM

Although STL has presently no GSM subscriber base, its business plan has ambitious countrywide deployment intentions. Using as many as 70 or more base stations and at least four MSCs, STL plans for more than 100,000 GSM subscribers within the next five years. For both the fixed wireless (rural only) and countrywide mobile installations, STL envisages problems in connection from remote base station locations into the cities. Presently, the use of the BTTB long distance network is envisioned. As STL is aware of the BTTB long distance congestion problems, it would like to have an alternative interconnection option, perhaps in the form of its own microwave interconnections. The Government of Bangladesh approval would be needed prior to the implementation of such a venture.

3.2.1.5 BANGLADESH RURAL TELECOM AUTHORITY (BRTA)

BRTA has a license to provide rural telecom services to 199 thanas in the northern region of Bangladesh. As of Nov.1997 there were telephone exchanges in 82 thanas. Altogether, by both wireline and wireless local loop connections 152 Thanas have been connected.

BRTA has only digital exchanges supplied by several companies: Daiwoo S.Korea, UTI India, Mitel Canada, and Alcatel France.

BRTA has its own trunk automatic exchange (TAX) in Dhaka, Mogbazar exchange, at which point it has a gateway to the BTTB network. BRTA has another interconnection to BTTB at the district level in Sylhet (TAX). In general, although BTTB and BRTA have co-located switches in many sites countrywide, they have only interconnections at the district headquarters.

BRTA has established its own microwave links to penetrate the rural areas. These links typically carry 60 to 240 telephone channels.

BRTA appears to be following the policy of being independent of BTTB wherever possible.

BRTA effectively has a parallel or overlay network in the northern region of the country, where it is licensed to operate.

This is leading to duplicity of equipment, but it has the advantage of autonomy and control over the reliability and therefore availability of its network elements [9].

3.2.2 PRIVATE OPERATOR PLANNED EXPANSIONS

Each of the private operators has expressed the desire for a rapid expansion of new subscribers. However, because all operators are experiencing difficulties in acquiring interconnection capacity into BTTB, they cannot increase their subscriber bases for fear of increasing the congestion within their own networks and therefore incurring the dissatisfaction of their existing subscribers.

The private operators plan to increase their service area coverage by additional mobile switching centres (MSC) and additional rural switching centres (RSC).

The present plans and dates for the service area expansions for the mobile operators are shown in Table 3.7.

Table 3.7: Planned In-Service Dates for Mobile Switching Centres

MSC Operator	**Dhaka**	**Chitta-gong**	**Sylhet**	**Comilla**	**Feni**	**Cox's Bazar**	**Khulna**	**Rajshahi**	**Bogra**	**Barisal**
PBTL	Existing	Existing	1998	1998	1998	1998	1998	1999	1999	1999
GP	Existing	1998	-	2000	-	-	1999	-	2003	-
TMIB	Existing	1998	-	-	-	-	-	-	-	-
STL	1998	2000	-	-	-	-	2000	-	2002	-

Table 3.8: Planned In-Service Dates for Rural Switching Centres

RSC Operator	**Begum-gonj**	**Chitta-gong**	**Jessore**	**Chandina**	**Shirajgong**	**Khulna**	**Barisal**	**B'Baria**	**Bhanga**
STL	Existing	Existing	Existing	Existing	1998	1998	1998	1999	1999
RSC Operator	**Dhaka TAX**	**Dhaka Tandem**	**Dhaka TAX**	**Narsingh di**	**Manik-gonj**	**Munsh i gonj**	**Naraya ngonj**	**Mymen singh**	**Kishor-gong**
BRTA	Existing	1998	Existing	1998	1998	1998	1998	1998	1998
RSC Operator	**Jamal-pur**	**Bhairab Bazar**	**Chattak**	**Srimon-gal**	**Sherpur**	**Netra-kona**	**Tangail**	**Sylhet TAX**	**Sylhet ITX**
BRTA	1998	1998	1998	1998	1998	1998	1998	Esixting	1998
RSC Operator	**Moulvi Bazar**	**Habi gonj**	**Nonann gonj**	**Rajshabi**	**Natore**	**Narvab gonj**	**Nao gaon**	**Dinaj-pur**	**Panch-gar**
BRTA	1998	1998	1998	1998	1998	1998	1998	1998	1998
RSC Operator	**Thakur gaon**	**Rang-pur**	**Nilpha-mari**	**Lalmonir hat**	**Kurigram**	**Gai-bonda**	**Bogia**	**Jaypur-hat**	
BRTA	1998	1998	1998	1998	1998	1998	1998	1998	

The present plans and dates for the service area expansions of the rural operators can be obtained from Table 3.8.

The BTTB has to provide interconnection points and interconnection capacity for these mobile switching centres and rural switching centres at the correct points in time.

3.3 INTERCONNECTION ARRANGEMENTS

The numbers of requested 2 Mb/s interconnections between the BTTB and the private operators is expected to increase significantly over the next few years. Eventually this rate of growth should stop accelerating and stabilise to a steady rate as the backlog of people wanting telephones becomes satisfied. At that point the growth rate is more dependent on the overall economic growth of the country, allowing a gradual increase in the number of people able to afford telephone services.

In some circles, there tends to be confusion concerning the definition of network capacity/growth. From the subscriber growth viewpoint, capacity means the number of lines (or WLL ports) available from the local switches to the customer premises for present and future subscribers. From the overall traffic viewpoint. route capacities and the growth of traffic throughout the network involves expanding inter exchange traffic flows and long distance traffic at a rate that can cope with the expanding subscriber base. Otherwise serious congestion can occur. It is the identification of the bottlenecks presently causing congestion and potential future bottlenecks.

At present, it is clear that BTTB does not have enough inter exchange traffic capacity to satisfy its own subscribers and planned future growth of its own subscribers. The inclusion of the private operators into the equation will eventually cause serious overloading of the existing resources if they are not expanded proportionately.

In other words it is not simply a case of increasing the number of interconnection ports (Digital Transmission Interfaces, DTIs) in the exchanges at the points where the private operators enter the BTTB network. Of course the costs of those interconnections are not negligible. The more serious problem is to upgrade the inter exchange and long distance capacities in proportion to the increasing subscriber base. This is both expensive and time consuming (years rather than months).

Some (not all) operators are licensed to interconnect between themselves, and this will promote improvement in the overall quality of service. However, until the number of subscribers serviced by the private operators increases to a point where they are self sustaining (for example, more than 50%of the total countrywide subscriber base) the operators are heavily dependent on the BTTB fixed network.

3.3.1 FREQUENCY ASSIGNMENTS

International standards on frequency allocation must be strictly adhered to. Interference between communications systems can be a very severe problem if use of the frequency spectrum is not properly managed.

Traditionally, this has involved ensuring frequencies in the various bands are allocated as indicated in ITU-R standards. Specifically, microwave radio frequencies for different routes are allocated according to well known ITU-R Recommendations (such as 383 for the lower 6 GHz band.)

Interference between satellite links and terrestrial microwave links must also receive adequate attention. A new problem is emerging with the introduction of low and medium earth orbit satellite (LEO, MEO) systems. The frequency band around 2 GHz was, until recently, used for fixed terrestrial microwave routes. Frequencies in the1.6 to 2.5 GHz range are now allocated to the new mobile satellite systems, Interference between satellites and the fixed network can be anticipated if cellular operators opt to integrate LEO or MEO communications into their mobile networks close to areas that are still using that band for terrestrial links.

On reviewing the frequency bands presently in use, it was notice that several UHF point to - point systems operating in various parts of the country are operating within, or close to, the LEO or MEO frequency bands. So far, it has been identified that the Nokia single hop UHF routes operate on a frequency intended for use by the Globalstar satellite downlink. A closer investigation may discover other potentially interfering frequencies. The Frequency and Wireless Board should take advanced action to ensure interference does not occur.

CHAPTER FOUR

ADVANCED TELECOMMUNICATION TECHNOLOGY USED IN BANGLADESH

4. INTRODUCTION

The rapid development of the technology of electronic components and computers caused a fundamental change in telephone communication equipment. The development of ICs and the establishment of control by stored program in the field of computers fulfilled a highly important role.

The first makes possible the implementation of a very sophisticated hardware in a smaller space, with smaller consumption of energy, high reliability and easy and effective maintenance.

Because of the development in the field of electronics, intigreted cheaps and computer technology now it is possible to produce digital switching equipments and digital transmission equipment. These digital switching system and digital transmission system are most modern and advanced technology in the field of telegraph switching and transmission. Allover the world analog switching system and analog transmission systems are replaced by digital system.

4.1 DIGITAL SWITCHING

Telephone exchanges, even with the advent of SPC, have remained primitive in the way in which the routing of a call requires the exclusive use of a set of switches and contacts for the duration of the call. The development of digital techniques, and low cost crosspoint devices, now offers the ability to move from space switching technique to time switching techniques.

Digital switch with stored program control (SPC) technology is being used in Bangladesh telecommunication network since 1982.

Stored program control has made possible larger versatility, due to the fact that different applications can be obtained from the same hardware only by changing the software. For example, the same hardware can work as local or toll exchange according to the selected file. Besides, it allows a larger quantity of services to be offered [28].

4.1.1 PRINCIPLES OF DIGITAL SWITCHING

4.1.1.1 SYSTEM CONFIGURATION

The electronic switching system with stored program control (ESS) as is shown in Fig. 4.1, is divided into the following 3 subsystems:

- Speech path subsystem
  This subsystem controls the speech paths to perform the connection between subscribers, between subscribers and trunks or between trunks.

- Input and output subsystem
  This subsystem performs the Man-Machine interface between the switching system and the operation and maintenance personnel.
  It is composed of input and output equipment, such as teletypewriters, magnetic tape units, etc.

- Central processor subsystem.
  This subsystem performs by stored program control the digit analysis, the control of the speech path for the establishment of a call, the control of the Man-Machine interface, etc.

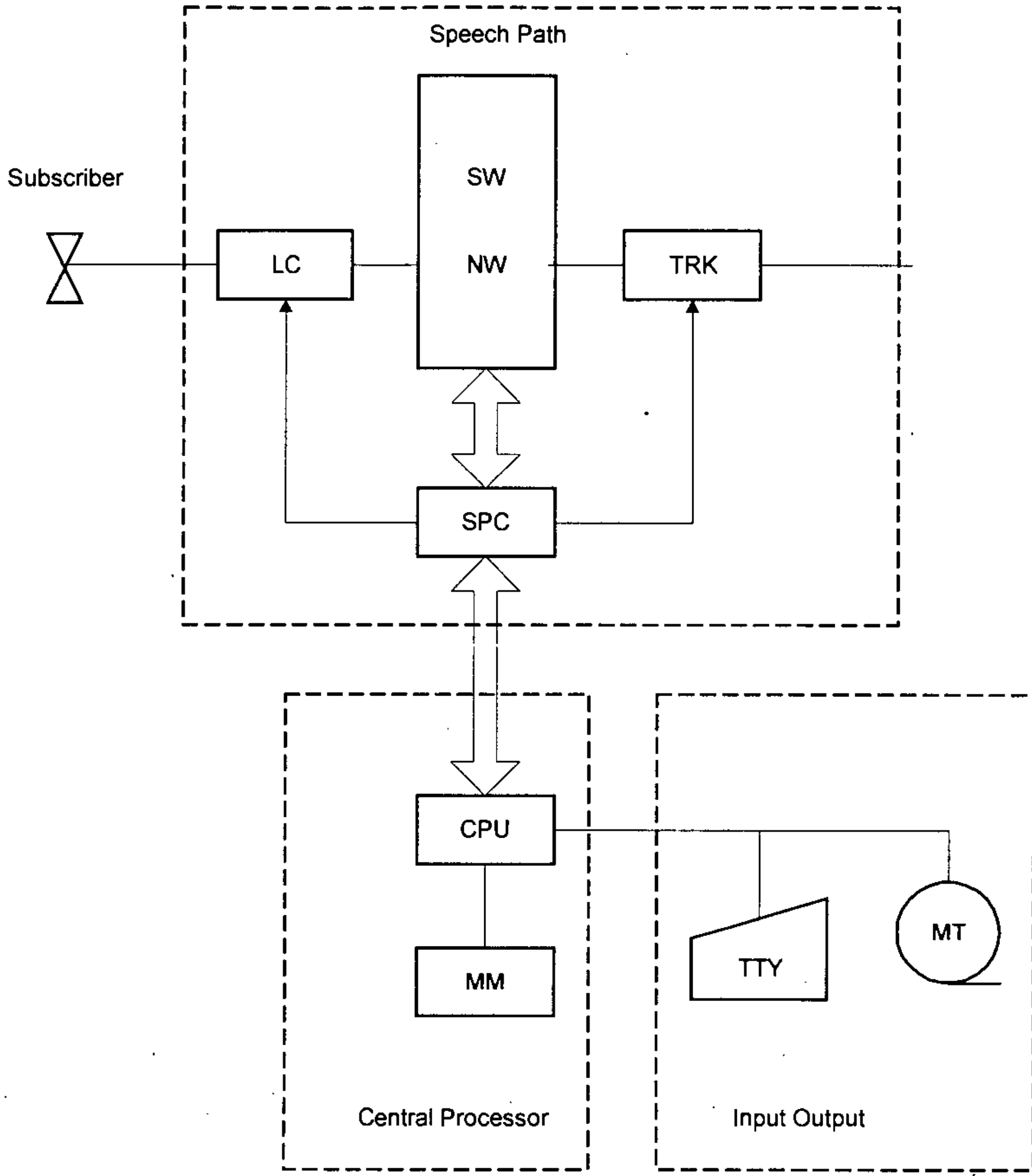


Figure 4.1: ESS System Configuration

CPU : Central Processor Unit

MM : Main Memory

TTY : Teletypewriter

MT : Magnetic Tape

LC : Line Circuit

SWNW : Switching Network

SPC : Speech path Control

TRK : Trunk

In the conventional space division switching system, the speech path system employs crossbar switch, reed switch or electronic devices such as PNPN. With these elements the contacts of the switching matrix, that has physical continuity, are opened or closed, meanwhile, in the digital switching system the switching is performed by interchange of the time slot assigned to each channel (channel time slot), in accordance with the principle of time multiplexing.

In this way, the digital switching system speech paths are completely different from those of the conventional space division switching system however, as regards the central processor and input-output subsystems, it shall be noted that the digital switching does not use different technology from that of space division with stored program control.

In this section focus will be given on the speech path, the most typical element of the digital switching system.

4.1.1.2 COMPOSITION OF THE SPEECH PATH

The speech path of the digital switching system, for example, in case of subscriber to subscriber connection, is composed by the following components as shown in Fig. 4.2

* Line circuit	:	Provided to each subscriber line, it supplies the ringing and talking current and performs the 2 to 4 wire conversion. This circuit has the BORSHT function.
* Line switch	:	Generally the subscriber lines have a very low traffic, therefore it will be uneconomical to realize the switching under these conditions, provided that it would require a large volume of installation. Accordingly, the subscriber lines are concentrated by means of this switch to use these terminals with higher efficiency.
* Coder and Decoder (CODEC)	:	Performs the A/D conversion of the signals coming from LSW, thus obtaining PCM signals of first order.
* Multiplexer (MUX)		Performs the multiplexing of the first order PCM signal. In the case of NEAX61.from the primary multiplexer (PMUX) 120 channels are obtained and from the secondary multiplexer (SMUX) 480 channels are obtained. The primary demultiplexer (PDMUX) and the secondary demultiplexer (SDMUX) perform the opposite operations.
Time Division Switch (TSW)	:	Switches the multiplexed signals according to the stored switch program control, performing interchange of time slots and between Highways that will be explained later. The TSW is composed of combined time and space switches.

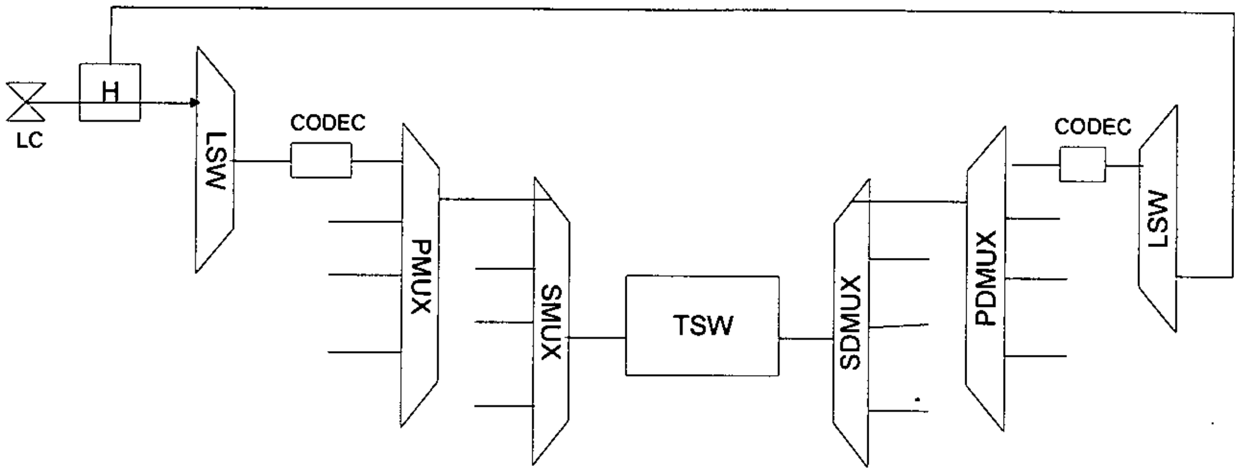


Figure 4.2: Structure of the Speech Path

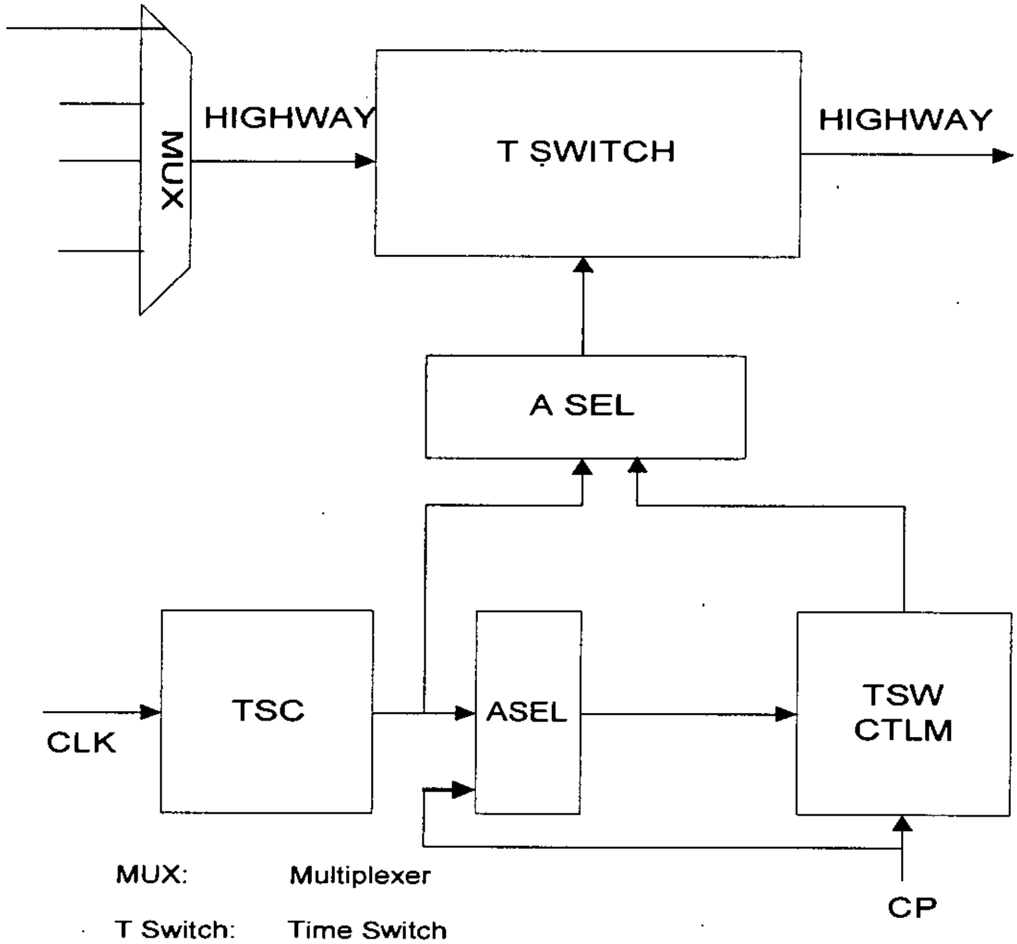
The composition of circuits in figure 4.2 is closely related with the BORSHT function. The multiplexer and the time division switch will be explained here.

4.1.1.3 MULTIPLEXER

The time multiplexing consists of reducing the time occupied by a signal (time slot) to increase the number of signals transmitted by time unit. That is to say if we read a relatively slow pulse stream by means of a gate pulse with a high speed, four times the amount of information can be transmitted to the line (called sub-highway or Highway at the same time interval of one channel (time slot) in the input.

Generally there are limits of multiplexing, caused by the magnitude of the exchange or by the cost of the components, since according to the increase of switching speed. The cost of the components also increases. However, it is desirable to increase as much as possible the order of multiplexing. This is because the inner congestion of the time switching network depends on the grade of multiplexing. When this increases, as a consequence, the size of the logical matrix increases, and in this way the inner congestion is reduced. As the physical size of an IC of small or large capacity does not vary in the same proportion, this is equivalent to have a reduction in the hardware.

4.1.1.4 TIME SWITCH



MUX: Multiplexer

T Switch: Time Switch

A SET: Address Selection Gate

TSC: Time Slot Counter

TSW-CTLM: Time Switch Control Memory

CP: Central Processor

CLK: Clock

Figure 4.3: Time Switch Control

The time switch is implemented with random access memories (RAM) . As is shown in figure 4.3 the digital signal is multiplexed in the MUX before entering the time switch. This has memory for all the multiplexed time slots coming from the highway which are written in this memory in sequence according to the clock frequency [28].

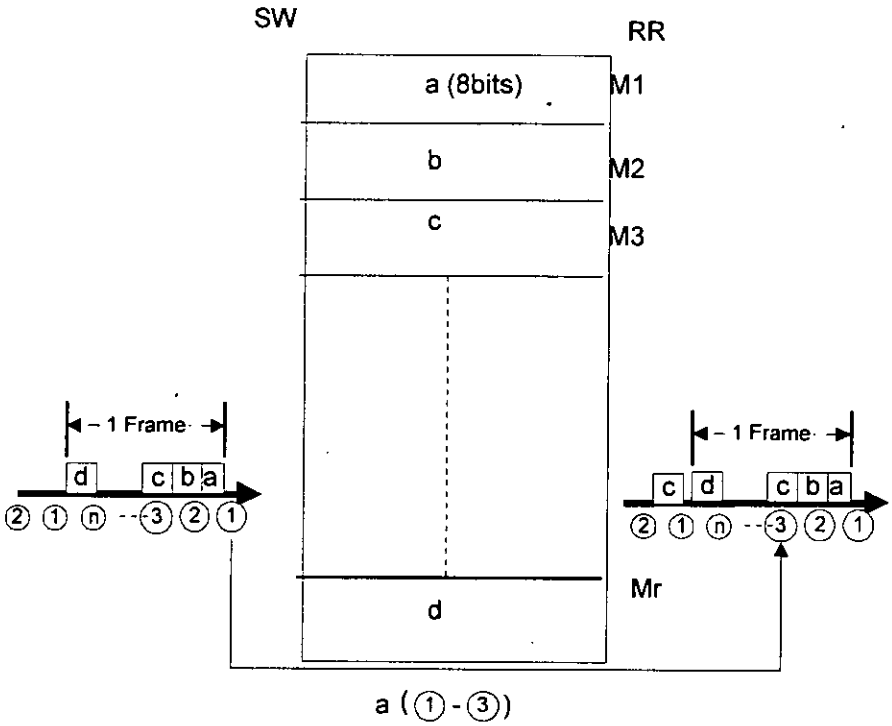


Figure 4.4 Switching of Time Slots

The central processor controls the output sequence of the time slots that are read out from the time switch memory.

In other words the sequence of the addresses to be read from the time switch is written in the TSW-CTLM. The reading is performed with clock according to the sequence of the addresses indicated in the TSW-CTLM. Thus in the output highway, the time slots have their positions interchanged.

Namely, the switching of time slots is the fundamental function of the time switch.

This switching is elementarily shown in Figure 4.4 The time slots that come from highway are written in sequence in memories M_1 M_2...M_r of the time switch.

This writing operation is called sequential writing (SW) because it is executed in accordance with the sequence established by the hardware at the clock frequency.

However, the reading sequence is determined by software, and as a fixed reading order does not exist. It is called random reading (RR) .

For example, take the switching of the time slot TSI with TS3, the writing is executed in the same order that they have in the highway, the contents of TSI "a" are written in the memory M 1 of the time switch, the contents of TS2 are written in M2, that of TS3 in M3 and thus successively.

As we have to switch TSI and TS3, M3 is read at the time that correspond to TSI, M2 is read at the time of TS2 (There is no switching) and M1 is read at the time of TS3. Thus "a" is switched from TSI to TS3 and the contents of TS3 "C" switched to TSI .Through this control of reading, any TS can be switched to any TS.

Compared with the conventional space division switching network, it is equivalent to a matrix n x n, as shown in Figure 4.5

As is seen in the figure, the output quantity is equal to the input quantity (that is n), accordingly, in the time switch, switching is performed without blocking.

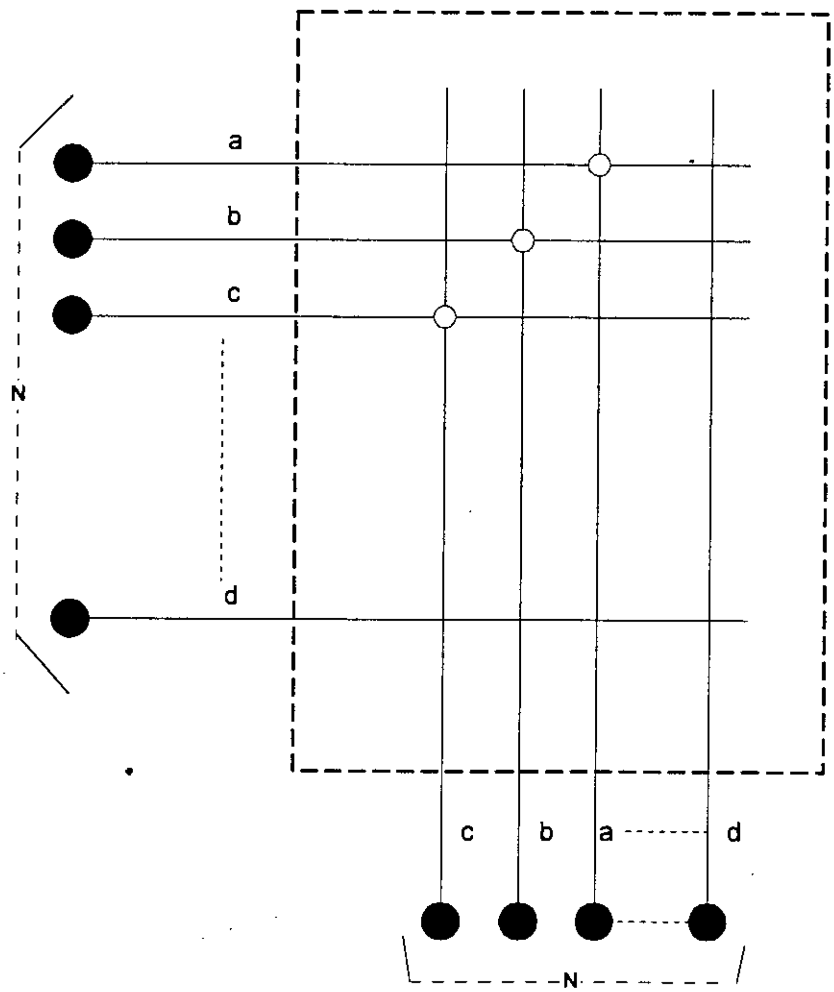


Figure 4.5: Equivalent Space Division Switch

In the space switch, a communication is established retaining a cross point of the matrix, in the time switch " the retention" is performed by cyclically reading (each 125 μ sec) the memory for a time slot, whose address is written in the TSW - CTLM.

Accordingly, the control of the time switch connections is performed by changing the contents of the TSW-CTLM, operation that is executed under the control of the central processor.

4.1.1.5 SPACE SWITCH

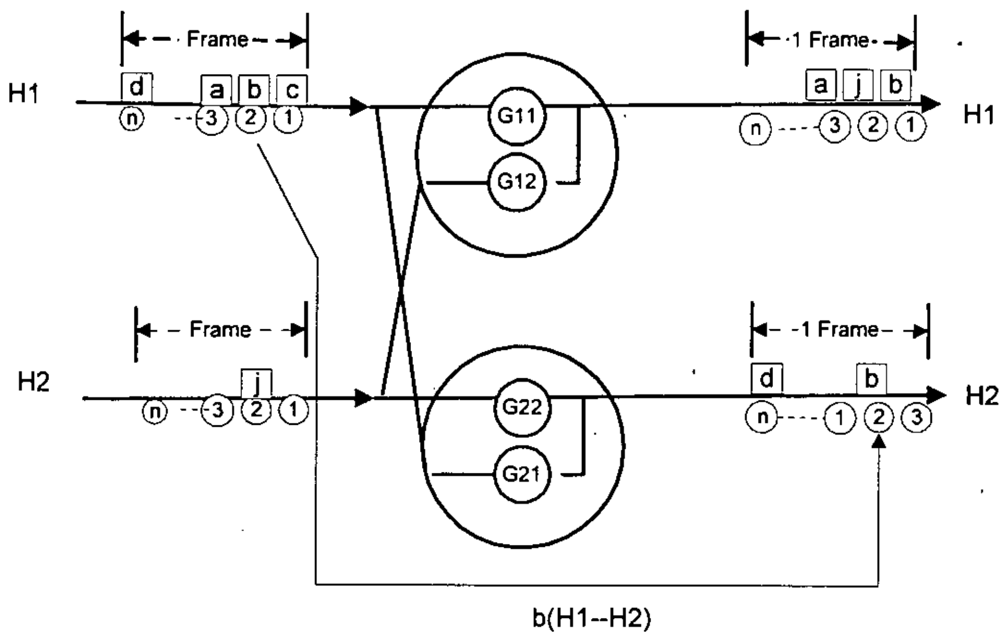


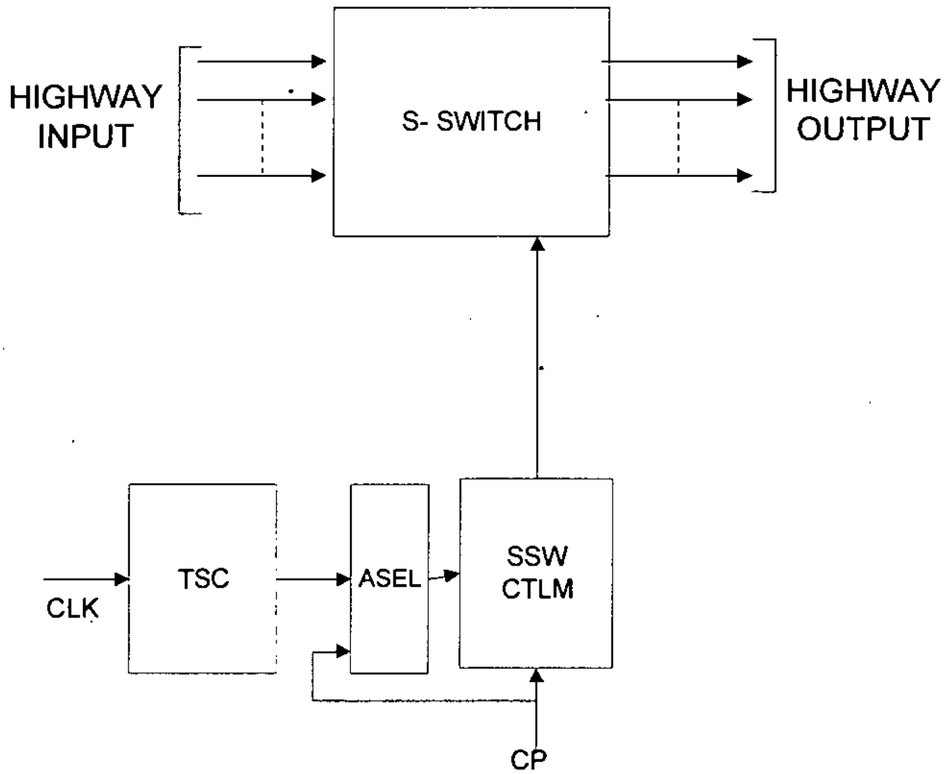
Figure 4.6: Highway Conversion

To realize a large switching network using only time switches, high speed writing and reading and a high grade of time multiplexing is required.

Therefore, in large digital switching systems, the different highways of the time switches are "crossed" in such a way that they can be switched among themselves. With this composition, it is possible to get high capacity switching matrixes.

The switch that enables linkage of different highways is the space switch.

The fundamental components of this switch are gates. As indicated in Figure 4.6, to transfer the time slot TS2 from highway H_2 to highway H_1, it is enough to open gate G_{12} at the time of TS2. In the same way, to transfer TS2 from highway H_1 to highway H_2 gate G_{21} is opened.



S-Switch: Space Switch

SSW-CTLM: Space Switch Control Memory

A SET: Address Selection Gate

TSC: Time Slot Counter Memory

CP: Central Processor

CLK: Clock

Figure 4.7 Space Switch Control

We can see then, that it is possible to transfer a time slot of any incoming highway to any outgoing highway, through the high speed opening and closing of the gates that are located at the each "cross point". this is operation is called highway conversion.

The speech path is retained to transfer a time slot from one highway to another every 125 μ sec by opening and closing a particular gate.

The space switch shown in Figure 4.7 is equivalent to a group of matrixes (Figure 4.8) whose number is equal to that of the multiplexed channels (in this case n). The number of inputs in each matrix is equal to that of the incoming highways (in this case 2) and the number of outputs of each matrix is equal that of outgoing highways (in this case 2).

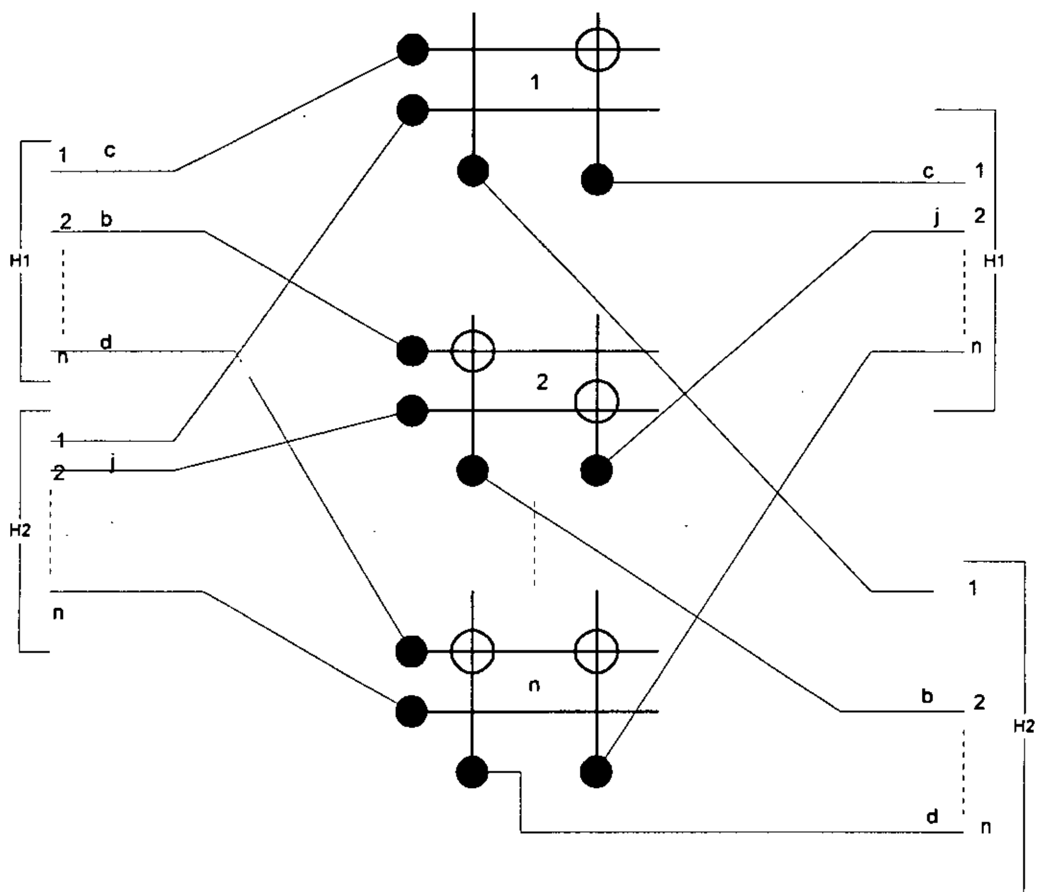


Fig. 4.8. Equivalent Space Division Switch Structure

4.2 DIGITAL TRANSMISSION

The cost per channel for transmission equipment has shown a continual decline as digital transmission technology, and the move to time division multiplexing, has allowed more and more circuits to use the same transmission medium.

The advantage of digital transmission is that voice, data, music, and images (e.g., television, fax and video) can be interspersed to make more efficient use of the circuits and equipment. Another advantage is that much higher data rates are possible using existing lines.

The digital transmission is much cheaper than analog transmission, since it is not necessary to accurately reproduce an analog waveform after it has passed through potentially hundreds of amplifiers on a transcontinental call. Being able to correctly distinguish a 0 from 1 is enough [28].

4.2.1 PULES CODE MODULATION (PCM) TECHNOLOGY

PCM (Pules Code Modulation) is the method of modulation, in which the amplitude of the voice signal, which changes at each moment, is measured cyclically, and the measured value converted in a binary code.

4.2.1.1 SAMPLING

To use a transmission line to send various signals sequentially along the time means that no one of these signals will be transmitted continuously, but at periodic time intervals. In other words, only part of the signal (sample) is transmitted periodically.

The input wave form of each voice signal is extracted easily and is sent to the transmission line.

The amplitude of the extracted pules is a sample corresponding to the amplitude, at the moment at which the sample is taken, of the original wave form. Accordingly, this operation is called "Sampling".

Generally, it is performed by gate circuit instead of the switch. If the cycle of this sampling is short, or the sampling is done frequently, the original wave form is transmitted and regenerated more faithfully.

However, in order to reduce the sampling cycle , a high speed pules circuit is required. If pulses are transmitted at high speed, the band width of frequency transmission is widened; the higher the transmission speed, the wider band width is required for the transmission line. The more adequate sampling cycle is obtained by the Shannon theorem, which says:

"The sampling that is done with a frequency higher than twice the highest frequency included in the wave form of the original signal makes it possible to perfectly regenerate the original signal". For the voice signal, it is enough with components of frequency up to a maximum of 4 kHz. Therefore, if a 8 kHz frequency (Twice the above-mentioned highest component or higher is taken for sampling the amplitude of the wave form of the voice signal (cycle lower than 125 μs) , the original wave form can be perfectly regenerated . Actually, 8 kHz is used as sampling Frequency .

The Shannon theorem is explained below.

The voice signal consists of a great amount of components of frequencies. To regenerate the component of 4 kHz, the sampling shall be performed, at least, at a peak and at a valley of a cycle of 4 kHz, in order to distinguish it from other component of frequency. Even if the wave form of the above-mentioned voice signal consists of many frequency components, as is shown it is enough to transmit the frequency components taking 4 kHz as a maximum.

To enable reconstruction of the components the highest voice frequency (fo: 4 kHz), the sampling shall be performed, at least, at a cycle higher than 2 fo (8kHz).

4.2.1.2 QUANTIZING

The wave form obtained by the above-mentioned sampling is one kind of pulse Modulation (PAM) according to the amplitude of the input signal. If the wave form is sent to the transmission line as it is, analog transmission is performed, which is week against disturbances .

Accordingly, in the PCM system PAM pulses are represented by combinations of binary code (0 or1) in accordance with the amplitude of the pulses.

The samples taken from a voice signal have a continuous range of amplitudes.

The next step is to divide this amplitude range into a limited number of intervals and all samples (amplitudes) within a certain interval are assigned with the same value. This principal is known as "Quantizing".

As a continuous signal (analog signal) is transformed in a discontinued coded signal (digital signal), forcibly, it introduces a distortion in the form of noise . This is called "Quantizing noise".

On reading the PAM pulses sampled in fixed quantizing intervals, the distortion is relatively larger for small input pulses than for large pulses . That is , the ratio of signal to noise (S/N) is poorer.

Characteristics of the voice signal are that the probability of occurrence of small amplitudes is high and those of large amplitudes is low. Therefore, it is necessary to improve the S/N by some method.

For this purpose the following two methods are considered:

a) When the amplitude of the input pulses is small, the intervals of quantizing shall be short to enable reading with accuracy, resulting in a small reading error.

   When the amplitude of the input pulses is large, large intervals are used , since it is allowed to have a relatively large error.

b) The intervals shall remain uniform and before the quantizing , the amplitude of the small pulses are expanded and the pulses of large amplitude are compressed

Actually, the second method is adopted. The operation executed on the transmission side is called "Compressing (COMP) "and that on the receiving side is called "expanding (EXP)"

CCITT recommends the following two laws as compressing/ expanding method, These laws are known as

"A-law"and "μ-law", respectively.

"A-law ....32 channels in Europe (CEPT)

$$Y = \frac{AX}{1+\ln A} \quad (0 \leq x \leq \frac{1}{A})$$

A = 87.6 13 segments

μ - law . . . . 24 channels in USA and Japan

$$Y = \frac{\ln(1+\mu x)}{\ln(1+\mu)} \quad (0 \leq x \leq 1)$$

μ = 255 15 segments

When, x is the input signal and y is the output signal.

4.2.1.3 CODING

" Coding " in the PCM system is for converting each quantized value of the amplitude of the PAM pulses, after the compression, into a combination of presences and absences of a determined number of unit pulses.

The reverse operation is called "Decoding "The expression 2^n can be realized with the combinations of presence and absences of n unit pulses. Accordingly, to code 256 quantizing intervals, $2^8 = 256$ that is, 8 unit pulses are required . In the A-law and μ-law, previously described, the characteristic curve of compression-expansion is not continuous, but a discontinued characteristic curve approximated by segments, and called Segment Coder.

4.2.1.4 TRANSMISSION

- Conversion of Polarity

A train of unipolar binary pulses have a D.C. component.

Within the equipment of the terminal exchange, the unipolar pulse dose not cause any problem, but in the transmission line the D.C. component is difficult to be transmitted, equal to the low frequency components, which produce distortion in the wave form of the pulse. Accordingly, "Unipolar-Bipolar" conversion, which is to convert the positive pulse stream into positive and negative pulse stream alternatively, reduces the low frequency components, and thus the pulse stream is transmitted with less distortion.

Further, in the stream of bipolar pulses, it is possible to reduce the intersymbol interference by the Return to zero (RZ) feature.

- Regeneration

In the PCM transmission system, the wave form of the pulse transmitted from the terminal equipment is deformed in the transmission line, even if it is bipolar, but it can be regenerated in the original wave form without distortion by means of repeaters installed at adequate intervals.

That is to say, the PCM Transmission system does not send out the wave form, which is distorted, attenuated and added with noise during the transmission as in conventional transmission (frequency Division), when the waveform is amplified as it is. The PCM transmission system can regenerate the same signal which was or originally sent out, removing these disturbances from the deformed signal, and send it again to the subsequent repeater section.

Accordingly, if complete regeneration is performed, the transmission quality will not degraded even over a long distance. In addition, distortion and noise such as those in the conventional transmission system will not accumulate at each transmission section. These are the excellent features of PCM transmission system [28].

4.2.2 MODULATION TECHNIQUE:

FSK, PSK and QAM are the most commonly used modulation technique for digital transmission system.

4.2.2.1 FSK

In frequency modulation systems, the frequency of the carrier is altered in sympathy with the modulating waveform. System in which the modulating waveform is a binary signal, so that the carrier is switched abruptly from one frequency to another are referred to as frequency shift keying (FSK) systems. In this system, binary '1' and binary '0' from the calling and answering modem are represented by 4 different frequencies. Hence, full duplex operation is easily obtained.

A large number of data transmission system utilize FSK. The two binary states are represented by two different frequencies (Mark & Space).

Digital transmission using FSK has following advantages:

(1) The implementation is not much complex than an AM system.

(2) Three to four dB improvement over AM is most types of noise environment.

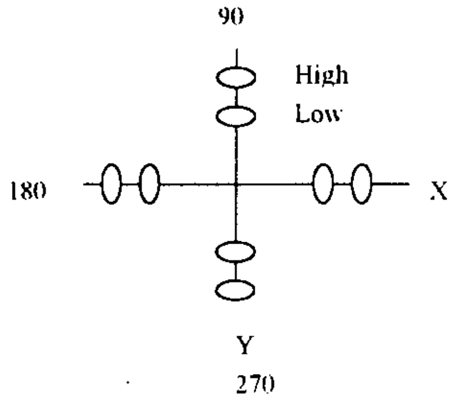
The FSK technique is used for the speed up to 1200 bps. Two center frequencies within the audio band are selected as center frequencies for each direction. These frequencies are shifted by 100 Hz up and down to represent mark and space.

4.2.2.2 PSK

For system using higher data rates, PSK becomes more attractive. Various forms are used such as two-phase and quadrature-phase. Phase shift keying is one method of encoding binary data on to a transmission line. The simplest example of PSK is where binary '0' and binary '1' are represented by a sine wave at the carrier frequency, but 180° out of phase respectively, i.e. a binary '1' is represented by a certain carrier frequency and a binary '0' is represented by the same carrier frequency but displaced 180° along the time axis.

Another technique is differential phase modulation. Each bit in the data signal is coded as a phase change relative to the previous phase of the carrier. For example, a '0' bit could be coded as a 90° phase change and a '1' bit as a 270° phase change.

4.2.2.3 QAM



Bit Combination	Line Signal	
	Amplitude	Phase Shift
000	low	0°
001	high	0°
010	low	90°
011	high	90°
100	low	180°
101	high	180°
110	low	270°
111	high	270°

Figure 4.9

QAM is a technique using a complex hybrid of phase as well as amplitude modulation, hence the name.

Figure 4.9 shows a simple eight-state form of QAM in which each line signal state represents a three-bit signal. The eight signal states are a combination of four different relative phases ant two different amplitude levels. The table of figure 4.9 relates the individual 3-bit patterns to the particular phases and the amplitudes of the signals that represents them.

CHAPTER

FIVE

DATA AND COMPUTER COMMUNICATIONS

5. INTRODUCTION

The 1970s and 1980s saw a merger of the fields of computer science and data communications that profoundly changed the technology, products, and companies of the now-combined computer-communications industry. Although the consequences of this revolutionary merger are still being worked out, it is safe to say that the revolution has occurred, and any investigation of the field of data communications must be made within this new context.

The computer-communications revolution has produced several remarkable facts:

- There is no fundamental difference between data processing (computers) and data communications (transmission and switching equipment).
- There are no fundamental differences among data, voice, and video communications.
- The lines between single-processor computer, multi-processor computer, local network, metropolitan network, and long-haul network have blurred.

One effect of these trends has been a growing overlap of the computer and communications industries, from component fabrication to system integration. Another result is the development of integrated systems that transmit and process all types of data and information. Both the technology and the technical-standards organizations are driving toward a single public system that integrates all communications and makes virtually all data and information sources around the world easily and uniformly accessible [34].

5.1 DATA COMMUNICATIONS

Data communications has a much wider meaning than data transmission and embraces not just the electrical transmission but many other factors involved in controlling, checking and handling the movement of information in a communications-based computer system. For example, it includes the physical transmission circuits and networks; the hardware and software components required to support the data communications functions; procedures for detecting and recovering from errors; standards for interfacing user equipment to the transmission network; and a variety of rules or protocols for ensuring the disciplined exchange of information.

5.1.1 DATA

Data is defined as entities that convey meaning. Types of data are: Analog & Digital data. The concepts of Analog & Digital data are simple enough. Analog data take on continuously varying values over the period of time. For example, voice & video are continuously varying patterns of intensity. Most data collected by sensors, such as temperature and pressure, are continuously varying and therefore analog. Digital data take on discrete values; examples are text and integers.

5.1.2 SIGNALS

Signals are electric or electromagnetic encoding of data. In a communications system, data is propagated from one point to another by means of electric signals. An analog signal is a continuously varying electromagnetic wave while a digital signal is a sequence of voltage pulses.

The signal may be propagated over a variety of media, depending on the spectrum: Examples are twisted pair of wires, coaxial cable, fiber optic cable, radio and atmospheric or space propagation.

5.1.3 BANDWIDTH

The absolute Bandwidth of a signal is the width of the spectrum. The energy of a signal is spread over it's entire spectrum. However, most of the energy in the signal is contained in a relatively narrow band of frequencies. This band is referred to as the effective bandwidth, or just bandwidth.

5.1.4 RELATIONSHIP B/W DATA RATE & BANDWIDTH

Effective bandwidth is defined as the band within which most of the signal energy is confined. Thus a signal may contain frequencies over a very broad range but in practice any transmission medium that is used will be able to accommodate only a limited band of frequencies. This in turn limits the data rate that can be carried on the transmission medium.

In general, any digital waveform will have infinite bandwidth. If we attempt to transmit this waveform as a signal over any medium, the nature of the medium will limit the bandwidth that can be transmitted. Furthermore, for any given medium, the greater the bandwidth transmitted. The greater the cost Thus on the one hand, economic and practical reasons dictate that digital information be approximated by a signal of limited bandwidth. On the other hand limiting the bandwidth creates distortions, which makes the task of interpreting the received signal more difficult. The more limited the bandwidth the greater the distortions and the greater the potential for error by the receiver. It is established by Nyquist theorem that if the data rate of a digital signal is 'W' bps then a very good representation can be achieved with a bandwidth of' 2W' hertz. Thus there is a direct relationship between the data rate and bandwidth the higher the data rate of a signal the greater is its effective bandwidth.

5.2 OSI REFERENCE MODEL

One of the most important concepts in data communication is the open system interconnection (OSI) reference model. This model serves as a frame work within which communication protocol standards are developed. It also serves as frame of reference for talking about data communication [36].

5.2.1 PURPOSE OF THE OSI MODEL

The purpose of this International Standard Reference Model of Open Systems Interconnections is to provide a common basis for the co-ordination of the standards development for the purpose of systems interconnections, while allowing existing standards to be placed into perspective within the overall Reference Model.

The term "Open system Interconnection (OSI)" qualifies standards for the exchange of information among systems that are "Open" to one another for this purpose by virtue of their mutual use of the applicable standards.

The fact that a system is open doesn't imply any particular systems implementation technology, or means of interconnection, but refers to the mutual recognition and support of the applicable standards.

5.2.2 THE OSI LAYERS

1. Physical

   Concerned with the transmission of unstructured bit stream over physical link: involves such parameters as signal voltage swing and bit duration; deals with the mechanical, electrical and procedural characteristics to establish, maintain and deactivate the physical link.

2. Data Link

   provides for the reliable transfer of data across the physical link; sends block of data (Frames) with the necessary synchronization, error control, and flow control.

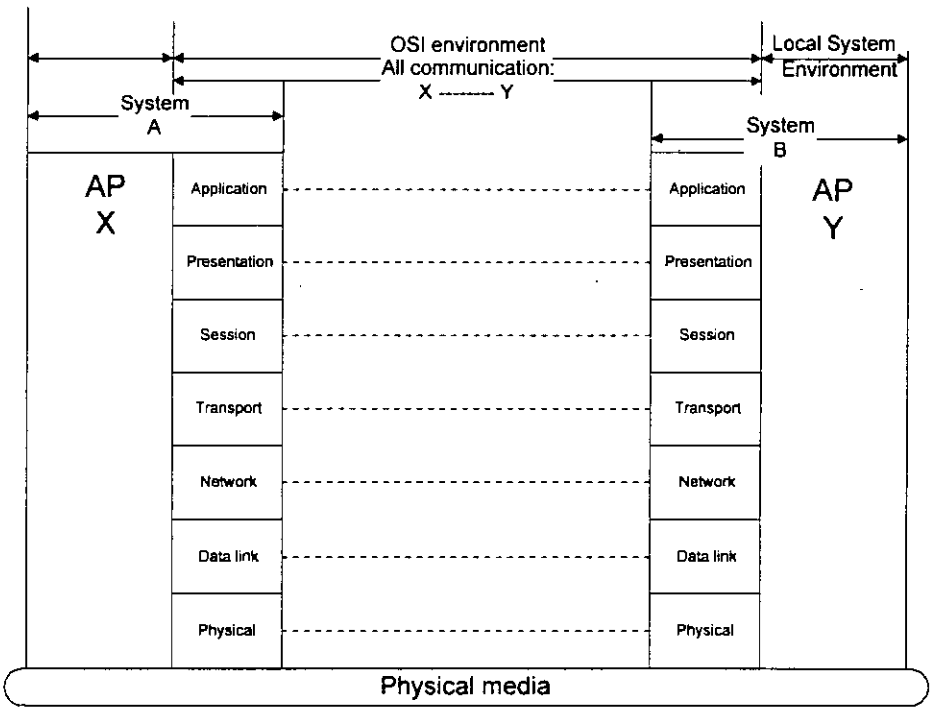


Figure 5.1:The OSI Layers

3. Network

Provides upper layers with independence from the data transmission and switching technologies use to connect system; responsible for establishing, maintaining, and terminating connections.

4. Transport

Provides reliable, transparent transfer of data between end points; provides end-to -end error recovery and flow control.

5. Session

Provides the control; structure for communications between applications; establishes, manages, and terminates connections (sessions) between applications.

6. Presentation

Performs generally useful transformations on data to provide a standardized application interface and to provide common communications services, examples, encryption, text compression, reformatting.

7. Application

Provides services to the users of the OSI environment; examples, transaction server, file transfer protocol. Network management. Figure 5.1 illustrates the OSI model. Each system contains the seven layer Communication is between applications in the Labeled AP X and AP Y in the figure. If AP X wishes to send a message to AP Y, it invokes the application layer (layer 7). Layer 7 establishes a peer relationship with the layer 7 of the target machine, using a layer 7 protocol. This protocol requires services from layer 6, so the two layer 6 entities use a protocol of their own, and so on down to the physical layer, which actually passes the bits through a transmission medium.

5.3 DATA COMMUNICATION NETWORK

In a switched communication network, data is transferred to destination through a series of intermediate nodes. These nodes are not connected with the content of data, rather their purpose is to provide a switching facility that will move data from node to node until they reach their destination.

5.3.1 CIRCUIT SWITCHED NETWORK

In a circuit-switched network, a dedicated communication path is established between two stations through the nodes of the network. That path is a connected sequence of physical links between nodes. On each link, a channel is dedicated to the connection. Data generated by the source station are transmitted along the dedicated path as rapidly as possible. At each node, incoming data is routed or switch on to the appropriated outgoing channel without delay. The most common example of circuit switching is telephone network:

5.3.2 PACKET SWITCHED NETWORK

A quite different approach is used in packet-switched network. In this case, it is not necessary to dedicate transmission capacity along a path through the network. Rather, data is sent out in a sequence of small chunks, called packets. Each packet through the network from node to node along some path leading from source to destination. At each node, the entire packet is received, stored briefly, and then transmitted to the next node packet-switched networks are commonly used for terminal to computer and computer to computer communications.

A packet is a continuos sequence of binary digits transmitted through the network as a unit. Network identification and control information is appended to this user data to route the packet towards its destination.

"packet Switching" is the transmission of data by means of addressed packets, whereby a transmission channel is occupied only for duration of the packet transmission. The channel is then available for use by packets being transferred between different data terminal devices.

Data coming from an end point device is collected (larger messages are segmented) in a buffer (area of memory) by packet assembly software, and addressed. The variable length packets are then routed (switched) on a "best path" bases towards the destination. Packets from many user may be interleaved on the same transmission facility, allowing a high degree of resource sharing.

5.3.3 BROADCAST NETWORK

In a broadcast communications network, there are no intermediate nodes. At each station there is a transmitter / receiver that communicates over a medium shared by other stations. A transmission from any one station is broadcast to and received by all other stations. A simple example of this is commercial radio & television broadcasting

5.4 PRESENT DATA COMMUNICATION STATUS IN BANGLADESH

Individual use of computer started increasing in Bangladesh which created the need for Data Network. Some private Organization satisfy their need for Data Communication by installing point to point Data circuit by taking leased lines from BTTB.

5.4.1 PACKET SWITCHED NETWORK

Recently project was taken to install Packet Switched Public Data Network (PSPDN) by Bangladesh T & T Board. In the network Data switching Nodes are placed in eight major cities of Bangladesh. Installation and testing of the network is completed and subscriber connection has already been started.

International gateway and Network Management and operation Centre for the Data Network is installed at Dhaka Node (Fig 5.2). It can

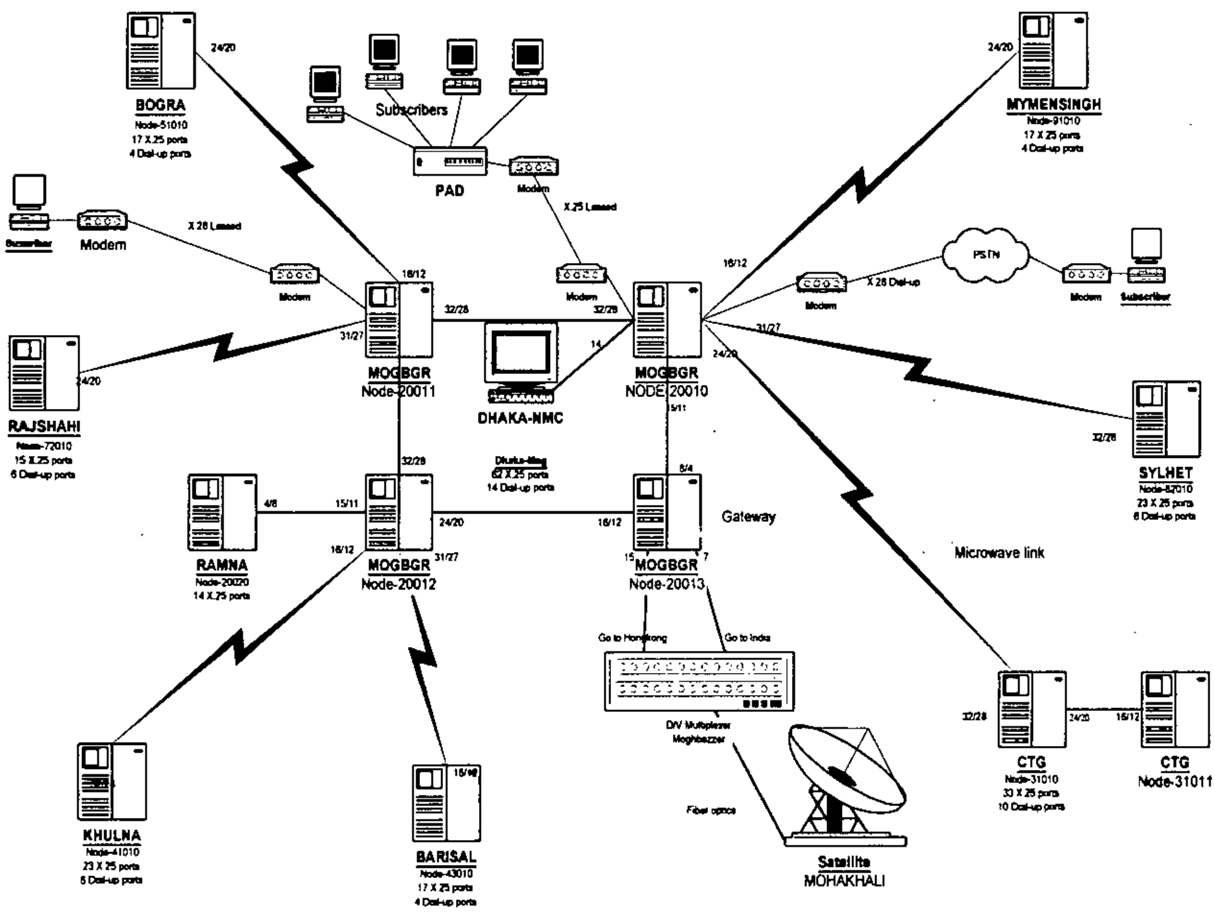


Figure 5.2 PACKET SWITCHED PUBLIC DATA NETWORK(PSPDN)

support CCITT recommended protocol X.25 for national subscriber and X.75 protocol for International subscriber. It can provide X.25 synchronized leased line, X.28 asynchronous leased line and X.28 dial up line. The installed capacity of Dhaka Node is 62 number of X.25 port and 16 number of X.28 dial up port which is the largest Node of the Network. The total installed capacity is 207 number of X.25 port and 50 numbers of X.28 dial up port.

5.4.2 INTERNET SERVICE:

Internet is the Network of Network which can share global

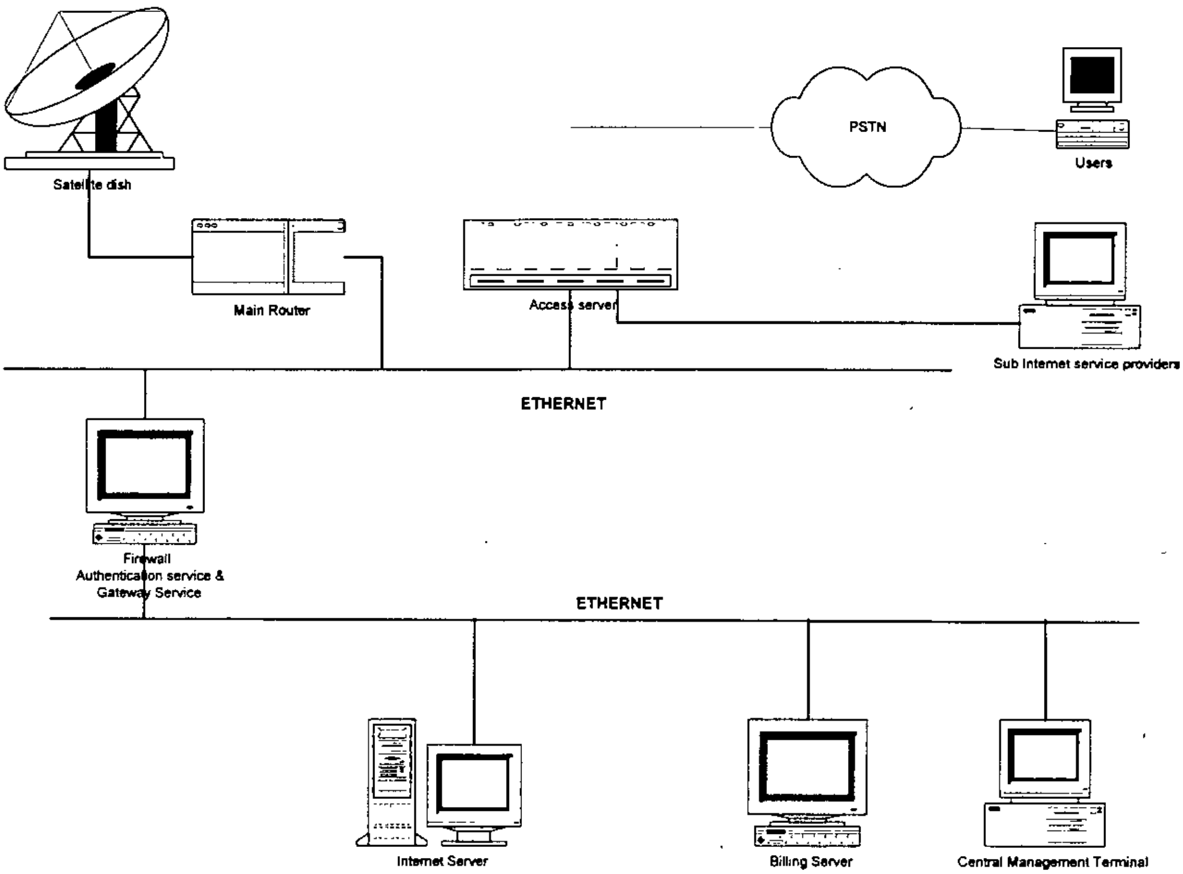


Figure-5.3 Internet Service Access Platform information, Internet is gaining its popularity quickly all over the world. Authority of B.T.T.B has decided to provide Internet gateway access and also to provide different services available in the Internet for public use.

The Internet service Access Platform (ISAP) (Fig 5.3) shall be targeted to provide service initially only to the dial up users from PSTN at a maximum speed of 28.8 kbps. The system will have capability to provide digital leased line connection at a speed of 64 kbps or higher for future requirements. This station is connected to the access point of Teleglobe Canada with a gateway speed of 128 kbps.

At present 32 access points are provided for the subscriber, This service is extended to seven other important cities outside Dhaka with the help of X.25 connectivity. Initially BTTB will provide the services as follows:

a) E-mail

b) WWW

c) File transfer protocol

d) Telnet

In private sector approximately 18 Companies have already started providing Internet service in the country. 17 of them are in Dhaka and one in Chittagong. Approximately seven of them have international connectivity through V-sat links provided by BTTB, others are operating as subnet of them.

CHAPTER

SIX

TELETRAFFIC ENGINEERING

6. INTRODUCTION

6.1 FUNDAMENTAL DEFINITIONS

telephone call.

The interconnection of two telephone stations.

call request

The first application (action) made by the caller for a telephone call is called the call request. In automatic service, the operation of the dial (or key-set) by the caller to obtain a call with his correspondent is comparable to the call request.

telephone message

An effective call over a connection established between the calling and the called stations.

telephone circuit (international or trunk circuits)

a) The whole of the facilities whereby a direct connection is made between two exchanges (manual or automatic) is called a telephone circuit.
b) A circuit is called an international circuit when it directly connects two international exchanges in two different countries.
c) The term trunk circuit is reserved for the designation of exclusively national circuits.

automatic service

In the automatic service, the calling subscriber himself dials (or operates the key-set) the number necessary for connection with the called station.

routs

The routs followed by international telephone traffic are designated by agreement between Administrations. A distinction is made between:

- primary routs
- secondary routs
- emergency routs

Primary routs: The circuits normally used in given relation.

Secondary routs: The circuits to be used when the primary routs are congested, or when the transmission of the primary routs is not sufficiently good, it is outside the normal hours of service on the primary routs.The secondary routs(s) may pass through the same countries as the primary routs or through different countries.

Emergency routs: The circuit or circuits to be used in case of complete interruption or major breakdown of the primary and secondary routs. The emergency routes may pass through any country.

duration of a call (conversation time)

The interval between the instant the call is actually established between the calling and the called stations and the instant the calling station gives the cleaning signal (or the instant when, although the caller has not replaced his receiver, the call is:

- in manual or semi-automatic service, officially cleared down by an operator,
- in fully automatic service, cleared down after some slight delay by the action of the called subscriber's clear-back signal).

trafficd carried (by a group of circuits or a group of switches)

a) amount of traffic carried

The amount of traffic carried (by a group of circuits or a group of switches) during any period is the sum of the holding times expressed in hours.

b) traffic flow

The traffic flow (on a group of circuits or a group of switches) equals the amount of traffic divided by the duration of the observation, provided that the period of observation and the holding times are expressed in the same time units. Traffic flow calculated in this way is expressed in erlangs.

traffic offered (to a group of circuits or a group of switches)

It is necessary to distinguish between traffic offered and traffic carried. The traffic carried is only equal to the traffic offered if all calls are immediately handled (by the group of circuits or group of switches being measured) without any call being lost or delayed on account of congestion. The flow of traffic offered, and of traffic carried, is expressed in erlangs. The amount of traffic offered and of traffic carried is expressed in erlang-hour.

measurement of busy hour traffic

a) busy hour (of a group of circuits, a group of switches, or an exchange, etc). The busy hour is the uninterrupted period of 60 minutes for which the average traffic is at the maximum.

b) mean busy hour (of a group of circuits, a group of switches, or an exchange, etc). The mean busy hour is the uninterrupted period of 60 minutes for which the average total traffic of a sample is the maximum.

blocking - congestion

The condition where the immediate establishment of a new connection is impossible owing to the unavailability of connecting path.

alternative routing

A procedure whereby several routes are searched to complete a connection. The different routes involve different switching stage or switching networks.

call congestion ratio

The ratio of the number of call attempt, which cannot be served immediately to the number of call attempts offered.

delay system

A switching system in which a call attempt, which occurs when all accessible paths for the required connection are busy, is permitted to wait until such a path becomes available.

availability

The number of appropriate outlets in a switching network which can be reached from an inlet.

full availability

Full availability exists when any free inlet can reach any free outlet of the desired route regardless of the state of the system.

limited availability

Exists when access is given only to limited number of trunks of a given route.

grade of service (GOS)

Practical interpretation of a congestion function. Usually expressed as percentage of calls lost.

holding time

The total duration of occupation. There may be many classes of holding time, e.g. setting-up, conversation, etc.

link

The device in a switching network connecting one outlet of one of the connecting stages to an inlet of the next connecting stage. The term is used mainly in conditional selection systems.

overflow traffic

When facilities are provided to handle the traffic that cannot be carried by a group of circuits, the traffic which is not carried by a group in question - is called overflow traffic [4].

6.2 TRAFFIC ROUTING WITHIN AN EXCHANGES

6.2.1 TRAFFIC FLOW FOR LOCAL CALLS.

Call generated by the subscriber passes through various stages before it is finally set up. In the initial stage register must be seized and dial tone returned back to the subscribers. During this time equipment involved is related to detection of line condition, register selection and setting up the path between the subscriber's line and the register occupation time of a register usually short and after few seconds it is released. Initially therefore, traffic generated involves switching matrix, registers and appropriate controls.

In the following stage both subscribers are connected together via suitable junctor circuit which provided supply current to both lines and performs supervisory functions Junctor will be occupied throughout the duration of a call and therefore their quantities will strongly depend on the volume of traffic .

6.2.2 TRAFFIC FLOW FOR JUNCTION (TRUNK)CALLS

Initial stages of a connection involving register are identical to the local call. However, as soon as enough information is stored in the register, appropriate trunk circuits are seized and register transmits information related to the called subscribers to the distant exchange. After complete information is transferred register may be released leaving only supervisory circuits connected to the trunk.

6.2.3 TRAFFIC FLOW IN TRUNK EXCHANGE (TRANSIT SWITCHING CENTRE)

Traffic flow in the trunk exchange is basically very similar to the outgoing trunk call case as previously described . Incoming call will seize incoming trunk supervisory equipment and appropriate incoming register. Immediately when sufficient information is received by the register and outgoing trunk will be seized and register may be disconnected. Register occupation time, therefore, is relatively short.

6.3 ELEMENTARY TELETRAFFIC THEORY

6.3.1 TELEPHONE TRAFFIC.

Telephone or telegraph traffic consists of calls (or message) which can be regarded as passing or flowing through the system. Telephone traffic varies greatly from one period to another and is theoretically impossible to predict precisely. By measuring traffic variations over many years it has become possible to make some general rules regarding the variations of traffic that are likely to occur in some situations.

The basic component of a telephone traffic is a telephone call. When subscriber generates a call it occupies a circuit in the exchange or in the network. The total traffic carried is measured in call-hours or call minutes, i.e, number of calls multiplied by their average duration. The more important traffic quantity, however, is the rate of flow of traffic or traffic intensity. The average number of calls which a subscriber originates in some period is known as his calling rate usually expressed in calls. Traffic intensity is defined as the average number of calls in progress simultaneously.

6.3.2 TRAFFIC INTENSITY.

If there are **N** calls in progress at a time, they give rise to a total traffic of **N** call-minutes every minute so that traffic intensity is the same thing as the rate of flow of total traffic in unit time. The unit of measurement is therefore effectively call minute per minute, or call hours per hour. Therefore, if there will be one call, lasting for one hour the traffic intensity then will be one unit. This unit is called the Erlang, after the Danish engineer and mathematician A.K. Erland.

Simple formula can be derived as follows:

If the number of calls is **c,** and their average duration is **t** minutes

the total traffic is = **c t** call-minutes

if this total traffic occurs in a period of **T** min, the traffic intensity **A** is given as

Traffic Intensity $$A = \frac{C\,t}{T}$$

Since in most practical cases T = 60 min, the formula then becomes

$$A = \frac{C\,t}{60}$$ if **t** is measured in minutes

If **t** is expressed as a fraction of an hour, however, and **T** is the one hour period, then **T = 1h** and the formula simplifies to [4]

$$A = C\,t$$

6.3.3 AVERAGE TELEPHONE TRAFFIC.

The telephone traffic carried by a group of circuits, during any specified time. is equal to the average number of simultaneous taking place in the group during the period concerned. If in a group of **N** circuits, the average number simultaneously engaged during an observation period is **A** circuits, then traffic of **A** erlangs is said to be flowing during this period. From this it follows that the occupancy time of a circuit group during a time **T** is equal to **AT.**

6.4 TRAFFIC THEORY

The general basis of circuit provision is a compromise between the standard of service to the subscribers and the cost of providing circuits. It is uneconomic to provide sufficient circuit to meet subscribers demands for service at all times. On the other hand the provision of too few circuits will produce serious subscriber inconvenience due to the inability to obtain service of demand. A solution between these conflicting requirements is achieved by presenting a probability that a subscriber will fail to obtain a free circuit when attempting to make a call. In the case of a busy signal system this probability is termed "probability of loss" or "grade of service" . In the delay system it is termed to "probability of delay"

6.4.1 TYPE OF TELEPHONE SYSTEM

If subscriber attempts to make a call when all the circuits are busy, one of two things may happen, depending on which type of telephone system is in use at the particular switching stage:

Busy signal System. In this system, busy tone is connected to the calling subscriber's line if all circuits are busy and the attempted call is said to be lost.

The subscriber must call again in order to establish connection. Typical examples are uniselectors and group selectors.

Delay System. This type of system is one in which those calls which find all circuits busy are stored until a circuit becomes available. Typical examples of Delay Systems are call queues.

Combination System - In some networks both Busy Signal and Delay Systems are used at different switching stages, giving rise to the combined systems.

6.4.2 GRADE OF SERVICE

Grade of service can be considered one of the measures of subscriber satisfaction. The grade of service that a subscriber receives is that proportion of his total attempts to reach the called party that fail due to an insufficiency of circuits, trunks and equipment. It does not include those attempts that fail due to faults, called party occupied, daiiling errors, called party not answering, etc.

In Busy Signal Systems the grade of service is the proportion of call attempts which are lost, that is

$$\text{Grade of service} = \frac{\text{Calls lost}}{\text{Total calls offered}}$$

Typical Busy Hour grades of service which are used in local networks during the busy hours and busy seasons of the year are 0.01 (one call lost in a 100), 0.005 (one call lost in 200) and 0.002 (one call lost in 500).

The following terms are sometimes used instead of Grade of Service.

$$\text{i. Time Congestion} = \frac{\text{Time all circuits are busy}}{\text{Total time}}$$

$$\text{ii. Traffic Congestion} = \frac{\text{Traffic overflowing}}{\text{Traffic offered}}$$

For smooth traffic such as that which flows from a well balanced and mixed groups less circuits are required to give the same grade of service that if the traffic were pure chance.

For rough traffic, such as that which is offered to a backbone route from a desired route, more circuits are required.

Note that for a single circuit probability of it being engaged is equal to the traffic it carries expressed in erlangs. The grade of service on a single circuit is thus also equal to the traffic in erlangs, in the busy hour [4].

6.4.3 THE ERLANG FORMULA

The erlang is the unit of traffic intensity or flow and for a specified period, usually the busy hour, the traffic on a group of circuits expressed in erlangs is equal to the average number of simultaneous calls during that period. For a single circuit the traffic can never be more than 1 erlang because it can carry only one call at the time. The erlang can thus be defined as that traffic flow which would continuously occupy one circuit. In a practical case no circuit can ever be continuously occupied because it must become free for a short period after each call in order to be seized by the next call. The traffic on one circuit is, therefore, always a fraction of an erlang.

Theories have been developed to determine the relationship between the Grade of Service (B), the number of circuits (N) and the average traffic (A) for a particular type of trunking.

In this relationships, A is the average traffic offered to the group of circuits, not the average traffic carried by the group. However, for good grades of service the traffic offered and the traffic carried differ only slightly. Several relationships have been derived for Grade of Service which use different assumptions regarding the way in which calls arise and are dealt with by the switching system.

The most commonly used relationship for grade of service with full availability trunking is that due to A.K.Erlang. This is given by the following expression.

$$B = \frac{\dfrac{A^N}{N!}}{1 + A + \dfrac{A^2}{2!} + \ldots + \dfrac{A^N}{N!}} \qquad \ldots\ldots\ldots\ldots(1)$$

Where
A is average traffic offered in erlang,
N is number of circuits provided.

A.K. Erlang showed also that the probability of exactly X out of N circuits being engaged is

$$P(X,N) = \frac{\dfrac{A^N}{X!}}{1 + A + \ldots + \dfrac{A^N}{N!}} \qquad \ldots\ldots\ldots\ldots(2)$$

For the special case of $X = N$

$P(X,N) = P(N,N) = B =$

= Probability of all circuits being busy.

or = Probability of loss (as shown in formula 1).

The Erlang formula has been derived with certain assumptions made: The theory applies if the following assumptions are valid.

a) The individual subscribers are each as likely to originate a call at one instant as at any other during the busy hour.

b) The probability of a further call arising is independent of the number of calls already in progress.

c) Lost calls are cleared from the system. This means that subscribers who seek to make a call when all the circuits are busy, abandon the call, that is they do not attempt to gain service by making repeated attempts until a circuit becomes available.

d) The traffic "A" is the true average traffic offered to the group of circuits.

e) Conditions of statistical equilibrium apply, that is the average traffic is not changing with time.

Validity of the assumptions: In practice these assumptions are good approximations to reality but several of them break down under special conditions.

Assumption (a) is true unless the individual subscribers commence to make bursts of calls in rapid succession. This only happens when the Grade of Service is poor and the bursts of calls are abortive attempts to obtain service.

Assumption (b) is true if the number of calls in progress is always very much smaller than the number of subscribers producing the traffic. Theoretically this assumption is only true if the number of subscribers is infinite, but in practice any number in excess of 200 is satisfactory.

Assumption (c) is frequently questioned since,. in practical, a subscriber who encounters congestion makes a repeat attempt fairly promptly. This mode of behaviour, whilst common, does not lead to serious errors unless the grade of service is bad. Even in this case the input traffic is very nearly Pure Chance although its value is inflated by the additional call attempts. If the subscribers concerned wait between repeat attempts the input traffic will not be greatly inflated and the repeats can be regarded as pure chance calls. When this assumption breaks down completely an alternative theory of "Lost call held" is used.

Assumption (d) is correct if traffic measurements have been made for a sufficient number of busy hours. In most cases readings made for five busy hours are sufficient accurate for practical purposes.

Assumption (e) is correct because the average traffic does not change significantly during the busy hour.

CHAPTER SEVEN

DIMENSIONING AND OPTIMIZATION

7. INTRODUCTION

From the point of view of planners dealing with dimensioning and optimizing, local networks may require a different approach and treatment. The treatment of rural areas and other areas having a low subscriber density will be separated from the treatment of urban areas. In these areas the subscriber density is high and, in general, the topological conditions, street layout and building characteristics differ from those in rural areas.

In areas of high population and high telephone density (urban areas), the dimensioning and optimizing problems in a one-exchange town are quite different from those in a medium size town with four to eight exchange buildings, and different again from those in a metropolitan area, i.e., a city and its suburbs.

7.1 DIMENSIONING AND OPTIMIZATION OF LOCAL NETWORKS

The basic problems of dimensioning and optimizing local networks are the following:

- determination of the number of exchange, their location and service area boundaries;
- design and implementation of the subscriber network, i.e., the link between exchange and customer premises;
- definition of the optimum structure and dimensions of the network linking the local exchanges with each other and with the long-distance centre(s).

According to the size and characteristics of the local area, solving these three problems present different degrees of difficulty. There is no doubt the three problems are interrelated, in spite of the fact that for urban areas they have traditionally been approached and solved separately.

However, for low subscriber density or rural areas the three problems have been treated simultaneously.

The reasons for subdividing the urban network dimensioning and optimizing exercise are the following:

- To study optimizing a network in its entirety is rather difficult, not only with manual methods, but also with sophisticated computerized methods.

- The subdivision into the dimensioning and optimization of the subscriber network, the rest of the local network and the placement of exchanges are not conventional but accords with reality.

- The planner may not be sure theoretically that the optimum urban network is provided by the combination of optimum solutions for each of these three subdivisions. This will depend on the extent to which the influences of other parts of the network are considered when optimizing each subdivision. In practice this can be achieved satisfactory.

It must be understood that the main reason for subdivision is the first, i.e. the practical impossibility of optimizing the entire urban network in a single study.

7.1.1 STATEMENT OF THE PROBLEM

The first step of planning an urban network is to define its configuration (the number, location and boundaries of the service areas of the local exchanges) throughout the planning period. This implies, in particular, the definition of the time when new exchange will be put into service, the evolution of exchange areas, and how the service capacity of each exchange varies with time.

The problem now can be stated in more general terms, and dynamic planning, which takes the factor time into account, pays a role. In the general case, the problem is to find the cost-optimized evolution of the network configuration to satisfy a given demand with a pre-established quality of service. The optimum time to open a new exchange and the evolution of exchange areas are particularly significant for long-term planning.

7.1.2 ANALYSIS OF THE URBAN NETWORK CONFIGURATION

The configuration of the network has been defined as being constituted by the number and location of the exchanges and the boundaries of their service areas. The right solution for each of these was previously sought simultaneously, because with a predetermined number of exchanges, the optimum exchange location depends upon the solution adopted for the boundaries of the service areas, and vice versa [7].

The main factors used in finding the optimum configuration are:

- demand: subscriber demand, traffic demand;
- costs: exchanges, junction network, subscriber network;
- service criteria: traffic grade of service, transmission plan, satisfaction of demand;
- constraints: natural or man-made obstacles to cable routing;
- existing plant: exchanges, junction network, subscriber network;

7.1.3 LOCAL NETWORK

For the cases of rural, urban and metropolitan areas it has been found convenient to subdivide the total network area into a number of so-called traffic areas. The traffic properties for all subscribers in such an area are assumed to be uniform; in defining such areas attention has to be paid to the present and future "mix" of categories, and the possibilities of making traffic measurements to obtain the necessary "raw data" for the traffic forecasting process.

The traffics between such traffic areas can then be described in matrix form. As the exchange area boundaries will usually not coincide with the traffic area boundaries, traffic between exchanges will then be found by simple calculations involving the subscribers per exchange per traffic area.

Traffic zones and subscribers

For local networks, traffics calculations are based on subscribers/ exchange, subscriber's categories and traffic zones.

Assumptions:

- the area under consideration has been divided into traffic zones; the subscribers belonging to such a zone are assumed to have uniform traffic properties such as traffic originated and terminated per subscriber, and traffic dispersion to other zones;
- the number of subscribers of any such zone, T, are known for any given exchange, E, they have been defined in the input data, or calculated in the previous boundary optimization: NSUB(E,T);

- the total number of subscribers belonging to any traffic zone, T, is known; this has been calculated after reading the input data concerning zone definition and subscriber distribution: $SUBTZ_T$.
- the total traffic from any traffic zone, T, to any other traffic zone, U, is known from input data : A_{TU}.

The specific traffic interest between one subscriber in traffic zone T and one subscriber in traffic zone U can then be expressed as

$$a(T,U) = \frac{A_{TU}}{SUBTZ_T \ SUBTZ_U}$$

Finally, the traffic from any exchange, E, to any other exchange, F, can now be written as

$$\text{Traffic } (E,F) = \sum_{T,U} NSUB(E,T).\ NSUB(F,U).\ a(T,U)$$

7.2 JUNCTION NETWORK

Of the three local network components the junction network is the least significant economically. Its relative cost increases with the number of exchanges, i.e. with the complexity of the local network. That definition of the local network structure is the first step in local network planning and so the number and locations of local exchanges form input data for the junction network design.

In spite of the relatively minor economic importance of the junction network the planner must pay proper attention to its design for two reasons:

- The junction network has a major impact on the quality of service (Whereas exchange locations have a negligible impact).

- The number of junction network designs for a given local network is practically unlimited. Their cost and adaptability to future requirements, vary widely with the amount of local traffic and its distribution, and with the constraints imposed by the present network and switching equipment.

The design of the local network normally includes the design of the arrangements to provide access to (from) the local exchanges from (to) long distance switching center (s) in the town.

Statement of the junction network design problem

In the most general case the design of the junction network consists in:

a) the definition of the network structure i,e, determination of the number of transit exchanges, if any, and their allocation;

b) the definition of the routing rules, i.e, how the traffic flows in the structure;

c) the dimensioning of the network, i.e, determination of the number of circuits to be established between exchanges to carry the specified traffic with a given grade of service;

d) the definition of the physical network i,e, the selection and topological layout of the transmission media.

The determination of minimum cost junction network is generally the objective. The problem nay be considered either as cross sectional i.e, the determination of the minimum cost junction network at a particular time; or as dynamic, i.e, the determination of the junction network and its evolution during the study period to give a minimum total cost. In particular a dynamic approach must consider the opening of new local exchanges, the opening of new transit exchanges the evolution of network structure and routing rules and the opening and evolution of physical transmission routes. These four network evolution activities have different characteristics.

The network structure and routing rules are rather static, in that their evolution is slow, with infrequent changes in the network structure, This means that the planning period must be from medium to long term.

The network dimensioning exercise must be a frequent planning activity in order to adapt the number of junctors at the exchanges and junctions between exchanges to the traffic demand. Periods from one to four years are normally used depending on the growth of lines and traffic.

The definition of the topological layout of the transmission media has two characteristics. The establishment of the basic transmission routes is static. New routes are opened based both on present and long term equipment requirements, and once opened, a route is generally maintained indefinitely. At the same time the installation of new transmission equipment (cables or transmission systems) on existing transmission routes is a dynamic exercise which aligns the equipment supplied with traffic growth.

The junction network involves two aspects;

- Physical network;
- functional network.

The physical network refers to the physical organization of the network, i.e. the topological layout of the transmission and switching equipment. It specifies the locations of transit exchanges and of cable pairs and transmission system runs.

The functional network specifies the logical organization of the network i.e. how the traffic is routed between exchanges.

7.2.1 OPTIMIZATION OF THE PHYSICAL NETWORK

The aim of optimizing the physical network is to define the minimum physical layout cost of the transmission media consistent with satisfying a given demand for junctions between switching centres.
As previously mentioned the physical network design has two aspects:

1) the optimization of basic network structures including the layout of the transmission routes and the timetable for opening new routes. Most of the material below refers to this aspect of the physical network;

2) dimensioning of the transmission routes i,e, determining the number of pairs and / or transmission systems needed in a route or section to meet the junction demand and when to install a new cable or system in an existing route.

7.2.2 ANALYSIS OF THE PROBLEM

The goals of physical network optimization are:

a) to minimize the run length of any group of junctions interconnecting two switching centres;

b) to maximise the number of junction groups which share the same path;

c) to select for each connection the most economical transmission medium.

In considering the dynamic aspect of the design of the physical network, it is important to keep in mind that network evolution nearly always tends to require the opening of new routes at least in those areas where the telephone density is far from saturation and there is continuously growing demand, However, in areas near saturation, and when introducing digital technology, planners must be aware that not all the present routes need necessarily be digitalized or maintained in service.

7.2.3 RESOLUTION OF THE PROBLEM

There is no commonly accepted method for optimizing the physical network. The optimization method described here has the characteristics of being relatively easy to apply and providing reasonably good solutions although the optimum solution is not mathematically guaranteed. The basic ideas of the method will be explained, assuming that the object is to design the physical network of a virgin area using only voice frequency transmission facilities. Afterwards, the following points will be discussed: the influence of an existing network on the solution, selection of the transmission medium and network security implications.

a) the geographical description of the area which will permit determination of the possible cable runs;

b) locations of the switching centres;

c) circuit requirements between the switching centres.

d) circuit cost per unit length, as a function of the number of circuits.

7.2.4 OPTIMIZATION OF THE FUNCTIONAL NETWORK

The objective of optimizing the functional network is to find the minimum cost network able to provide a pre-established grade of service. As previously mentioned, to find the optimum network implies the determination of the structure of the network, the routing rules and the number of junctions between each pair of exchanges.

In general, finding the minimum cost network is equivalent to determining the network with the minimum equipment (i.e. junctors at exchanges and junctions between exchanges). This is only completely true when the cost of junctors and junctions is uniform throughout the network.

Since the amount of traffic to be carried by the network is predetermined, optimizing the functional network is equivalent to maximizing its efficiency, i.e. plant utilizing. Given the characteristics of the traffic and grade of service functions, high efficiency in junctors and junctions is achieved by concentration of small packets of traffic. Concentration implies the use of transit functions, which in turn implies duplication, triplication etc. of equipment involved in the establishment of a call. To find an economically balanced position between these two factors (i.e. concentration for increased efficiency and decreased equipment, versus equipment duplication to achieve that concentration) is the objective of the optimization of the functional network [7].

7.2.5 ANALYSIS OF THE PROBLEM

The basic items of input data for the optimization of functional junction networks are:

- locations of the local exchanges and the long-distance exchange(s) in the town;
- traffic matrix corresponding to these exchanges;
- grade of service;
- costs;
- constraints: the present network state, exchanges' capabilities, etc.

The main factors for optimizing the functional network are:

- efficiency of junctions;
- traffic: amount and distribution;
- service criteria: grade of service and transmission plan;
- switching and transmission costs;
- number and location of transit exchanges;
- routing disciplines;
- existing plant;
- constraints: switching capabilities, security, etc.

7.2.6 NUMBER AND LOCATION OF TRANSIT EXCHANGES

The analysis of the number of transit exchanges may be presented as follows: when the number of transits increases, the length of transit junctions will decrease because each local exchange is closer to a transit. The efficiencies of the junctions will decrease because the traffic will be split between more paths.

The combined effect of the above on costs will be:

- an increase in costs of local exchanges caused by low circuit efficiencies, leading to an increased number of junctors;

- an increase in costs of transit exchanges due to lower efficiency and to start-up costs associated with any new transit exchanges;

- although the transmission costs normally decrease, an increase of these costs in certain circumstances depending on the balance between shorter lengths of circuits and the need for more circuits (caused by lower efficiency and meaning that more terminal equipment is required when transmission systems are used).

The network cost is, in general, relatively insensitive to the number of transit exchanges. A relatively wide range in that number gives approximately equal costs if locations are optimum. In this sense the problem is not critical. However, both the dynamic evolution of the network and the uncertainty of the demand forecast must be considered, if the solution is to be flexible (i.e. costs should not rise dramatically if small changes in the forecast occur). For this aspect, it will be better in general to avoid the risk of having too many transits because some will have little use and the costs incurred will not be recovered. It is easier and cheaper to create new transits and rearrange the routing of junctions than to dismantle transits. Thus the strategy to be followed here will be to keep the number of transits to a minimum.

Decisions about transit exchange locations cannot be separated from transit exchange numbers. When an additional transit exchange is considered, so must the area to be served by it be considered. The only factor that affects the location of a transit exchange is the transmission cost of connecting it to the local exchanges in its area and to other local exchanges and/or transit depending on the chosen arrangement. In a local area, it is basically a problem of minimizing kilometers of wires and cables.

The location of transit exchange is normally not at all critical, so long as the distance between it and the source and main sink traffic zones is not large.

7.2.7 DEFINITIONS

The mathematical statistics uses frequently the moments to describe the properties and shape of a distribution. These moments have frequently a simple relation to the parameters of the theoretical distribution. The moments are also useful for the description of traffic distributions.

First moment (Mean):

The first moment is defined as

$$\mu_1 = \sum_{P} P\,[P] \qquad (7.1)$$

The first moment gives the mean value of the distribution. This mean is frequently denoted Σ (p) (expectation of p), M or m. For a traffic distribution μ_1 is the traffic carried if p is summed over all possible occupation states.

Second Central Moment (Variance):

The second central moment is defined as

$$\mu_2 = \sum_{P} (p - \mu_1)^2\ [P] \qquad (7.2)$$

Here, μ_2 is also called the variance of the distribution, since it describes how much the distribution deviates from its mean. Or, in other words, the concentration around the mean. The variance is frequently denoted

$\Sigma\{(x - \mu_1)^2\}$, v or σ^2.

Further, the standard deviation of distribution is

$$\sigma = \sqrt{\mu_2} \tag{7.3}$$

For a traffic distribution, the variance signifies also the concentration around the mean.

The ratio $\mu_2 : \mu_1$, i.e. V:M is frequently used to describe the character of a traffic distribution.

$$\theta = \frac{V}{M} = 1$$

is frequently called "pure chance traffic".
A traffic , for which

$$\theta = \frac{V}{M} < 1$$

is often called smooth traffic, and finally , if

$$\theta = \frac{V}{M} > 1$$

the traffic is said to be rough , or degenerated.

We will in the following learn that $\theta < 1$ for carried traffic, and that $\theta > 1$ applies for overflow traffic. $\theta = 1$ applies only for a poison traffic (infinite number of sources, no congestion).

Mean and Variance for Overflow Traffic

Consider a full availability group for sequential hunting with N sources and $n + n_1$ circuits, where

$$n < N < n + n_1$$

(This means that if $N = \infty$, also $n_1 = \infty$.)

The divided full availability group is used to describe the character of the traffic rejected from the first part of the group (n). This rejected traffic, or overflowing traffic, will be carried by the second part (n_1).

If we denote the state of the group by (p,q) we have the following limits for p and q

$$0 \leq p \leq n$$

$$0 \leq q \leq n_1$$

$$0 \leq p + q \leq n + n_1 \geq N$$

The state probabilities [p q] can be determined by equations of state. As a rule no simple expressions are obtained. The mean and variance of the overflow traffic are defined as

$$M = \sum_{p=0}^{n_1} \sum_{q=0}^{n_2} q\,[p\ q] \qquad (7.4)$$

$$V = \sum_{p=0}^{n_1} \sum_{q=0}^{n_2} (q-M)^2\,[p\ q] \qquad (7.5)$$

The most common case is overflow from an Erlang distributed group. We then have

$$M = AE_n(A) \tag{7.6}$$

$$V = M\left(1 - M + \frac{A}{n + 1 - A + M}\right) \tag{7.7}$$

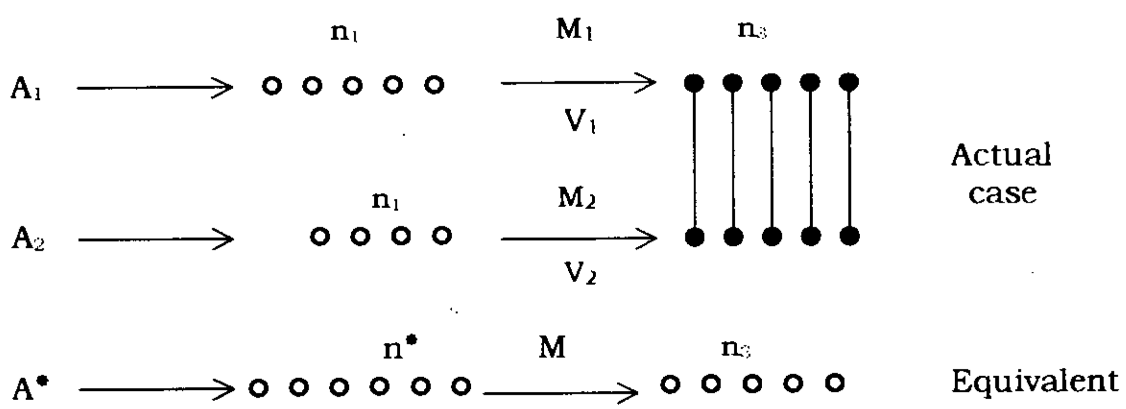
$$\theta = \frac{V}{M} = 1 - M + \frac{A}{n + 1 - A + M} \tag{7.8}$$

This expression has been deduced by Riordan. It is used in the Wilkinson's method for alternative routing calculation.

7.2.8 WILKINSON'S METHOD

For calculating the required number of circuits in alternating routing schemes almost all administrations and manufacturers use today Wilkinson's method, or further developed applications, based on this method.

The method is an equivalence method, where an equivalent full availability group is defined by the mean and variance of its overflow traffic. This mean and variance should equal the sums of the means and variances of the overflow traffic offered to the secondary group.



The values M_1, M_2, V_1 and V_2 are calculated from (7.6) and (7.7). An equivalent full availability group is sought which satisfies the condition.

$$M = M_1 + M_2$$
$$V = V_1 + V_2 \qquad (7.9)$$

The equivalent group is then defined by its two parameters A* and n*, where

$$A^* E_{n^*}(A^*) = M$$
$$M\left(1 - M + \frac{A^*}{n^* + 1 - A^* + M}\right) = V \qquad (7.10)$$

Since the numerical values for M and V are given, (7.10) implies that A* and n* have to be found by trial and error. The solution of (7.10) therefore gives some numerical problems, which are overcome with suitable graphs and algorithms for the calculations. The precision is further improved by using non-integer values for n*. Since the Erlang formula, $E_n(A)$, is only defined for whole numbers of circuits, n, this implies that a suitable convention has to be introduced for the calculation of the formula for non-integer values.

The congestion for the actual case is then estimated as

$$E = \frac{A^*.E_{n^*+n3}(A^*)}{A_1 + A_2} \qquad (7.11)$$

This formula provides an estimate of the total congestion. It does not specify how much of the individual traffics, A_1 and A_2, that are rejected. Different methods exist however for estimating the congestion for these traffics. It is however heuristically found that the losses in the secondary group are proportional to the value of V:M. A more degenerated traffic will namely experience more congestion than a less degenerated one, where the degree of degeneration is expressed by the ratio V:M.

7.3 ALGORITHM

The optimization algorithm described here is designed to optimize successive configurations. The algorithm requires the planner to specify the minimum and maximum number of exchanges to serve the area under study. The optimization will then be carried out for each number of exchanges between the specified minimum and maximum (both extremes included).

The algorithm starts by considering the configuration corresponding to the minimum number of exchanges. Locations for these exchanges have been specified, either tentatively or firmly.

The first act of this first phase is an "initialization process" whereby a feasible solution is found. This should be a configuration which satisfies all the conditions of the particular problem under study and which satisfies the specified demand, but which is not the economic optimum. However, the initialization step should be such that the configuration obtained is not too far removed from the optimum.

The algorithm then enters into an iterative process consisting of two main steps: relocation and reassignment. The relocation steps keep the service area boundaries constant, while relocating exchanges to decrease the network cost. This process ends when the minimum has been reached. The reassignment step reassigns the subscribers (moves the service area boundaries) while keeping the exchange locations constant to decrease the network cost. This process also ends when the minimum is achieved.

After these two steps the configuration obtained is compared with that of previous iterations. If no changes exist, then the minimum cost configuration has been reached. If changes exist a further iteration is carried out.

a) Input data of telephone demand is calculated out.

- Whole area under study is divided into small grid of unit area of size 500m×500m.
- Telephone demand per unit area is calculated out which is the input data.

b) The minimum number of exchanges to serve the area under study is specified.

c) Boundary area of each exchange is assessed approximately for these minimum number of exchanges considered initially.

d) Keeping the boundary of exchange temporarily constant the optimum location of exchange is obtained.

e) Keeping the location of the exchange temporarily constant optimum boundary area of each exchange is obtained.

f) Steps d and e are repeated till we get the optimum location and boundary area of each exchange.

g) Traffic metrix is obtained from the demand input.

h) The circuit metrix is calculated according to the traffic metrix.

i) With these direct circuit total cost of the network is calculated.

j) Increamental cost metrix is obtained.

k) The cost ratio metrix is calculated out.

l) The high usage Junction metrix is found out.

m) The metrix of mean value of the traffic rejected from the high usage routes is calculated out.

n) The variance of the rejected traffic from the high usage routes is calculated.

o) According to Wilkinson's formula used in teletraffic engineering equivalent traffic is calculated on the basis of the data obtained in mean and variance of traffic.

p) According to Wilkinson's formula equivalent number of high usage circuits are calculated.

q) On the basis of the above data number of tandem circuits are calculated.

r) Network cost is calculated.

s) Network cost with only the tandem circuit is calculated.

t) Number of exchanges to serve the area under study is increased by one and step from C to S is repeated. Network cost for different alternative is calculated. On the basis of the above data optimum number of the exchanges to serve the area under study is obtained.

u) Optimum Complex point of Erlang for direct rout is calculated.

v) Considering only tandem circuits where Erlang is less than the optimum complex point of Erlang and only direct circuits above this optimum Erlang point, the tandem circuits, tandem size and direct circuits are calculated.

w) Network cost is calculated.

x) From the network cost for different alternatives optimum network solution can be obtained.

7.4 MODELLING

A model, in this context, is the mathematical representation of a real-life problem: modelling is thus the process by which a problem is quantitatively represented by means of mathematical expressions. In particular the problem of finding the optimum dimensions of a network can be expressed as follows:

a) Given:

- a set of input data, (for instance, subscriber distribution, traffic per subscriber, cost of the telephone equipment, etc.);

- the laws which express the behaviour of the network elements (for instance, technical characteristics of the telephone equipment, traffic rules, etc.);

- the constraints imposed on this solution (for instance, grade of service required, equipment in the existing network, etc.);

- the optimization criterion, that is, overall objective (most frequently, to minimize the cost of the network);

b) the problem is: to produce a set of output data which determines the network dimensions as well as the utilization of the elements of the network (for instance, the number of cables required for a given route and the number of pairs and PCM systems to be used in these cables);

c) the modelling objective is: to represent quantitatively each of the items listed above. Figure 7.1 is a schematic representation of the items involved in the definition of the model.

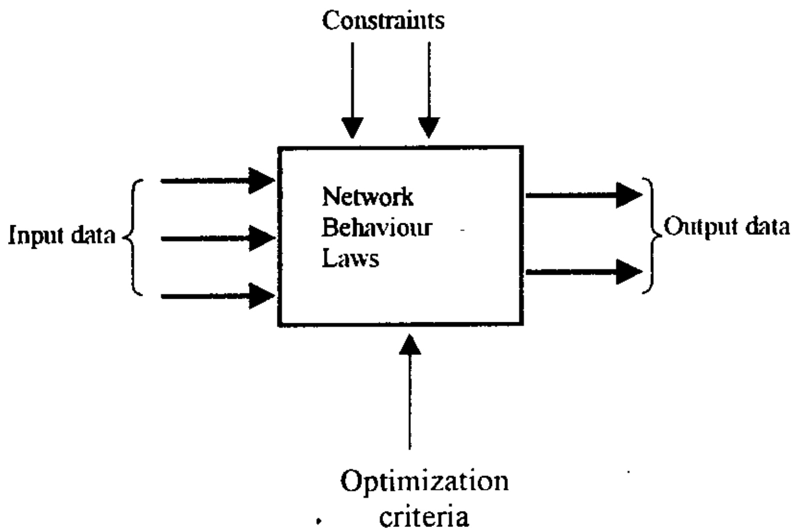


Figure 7.1 Main items in a model

The use of models for representing real life problems is not confined to network dimensioning and optimization; the interest in this use takes its roots from the following facts:

- The problem is contemplated globally and relationships between different parts of the problem are thus taken into account;

- The scope and validity of the solutions based on the model are systematically stated;

- Factors such as "engineering judgment" or "past experience" are inhibited, within more restricting and well-defined boundaries.

Modelling in network optimization presents some peculiarities which can be summarized as follows:

- a large number of variables play a role in the problem;
- relationship between variables are generally complex;
- there are no generally accepted methods for representing some variables and even optimization criteria (for instance, cost of equipment would depend on its design).

For these reasons network optimization is a complex problem whose solution is a compromise between:

a) the desired precision and generality of application, which calls for vast and detailed models; and

b) the complexity of use of the model (the amount of information required and the difficulties in manipulating it) which calls for simplified models.

To find the right compromise is generally not an easy task. However, the effort expended is always justified, because the penalty paid if the model is not adequately defined or selected may be high, effectively due to the wrong problem being solved. The two basic criteria to follow in network planning modelling are:

- selection of the variables playing a significant role in the optimization, disregarding those variables without impact on the optimum solution or those have the same impact for all practical solutions;

- modelling of the variables according to the particular circumstances of the problem.

7.4.1 MODEL CONSIDERED FOR LOCAL NETWORK.

The problem to be solved is how to extend a given network, over a certain period of time, for specified demands regarding subscriber and traffic development, using certain types of exchange and transmission equipment, observing specifications concerning quality of service, in the most economic way.

Real telecommunication networks are rather complex, and it would be very difficult to use mathematical methods for finding exact solutions to the various planning tasks involved. Also, it is essential to find methods to deal with any kind of network, rather than with a particular one. To make this possible, one has to make a model network, an abstraction of the real network, expressing the relations between the various entities in mathematical terms.

In designing a model, the question arises how close to reality such a model should be. Simpler models will usually lead to simpler, and therefore faster, but also to a certain loss of accuracy in the results. A reasonable compromise has thus to be found between accuracy of results, and speed of calculation. It should also be remembered, that for different types of networks the impact of the complexity of the model on the accuracy of the results can vary considerably.

For all sorts of equipment this task is relatively simple. The cost structure of any particular part of an exchange or transmission system, and the technical properties of the same are available from administration or manufacturer. The structure and properties of the various types of equipment are, more over, independent of the network under investigation, although the actual values for costs involved may vary considerably from one network to another.

A model area is taken for the study of local network. The area is considered to be 40 kilometer by 30 Kilometer urban area. Initially it is considered that there is no existing network in this model area. We have every freedom to choose any location and a boundary for an exchange. The problem is to obtain optimum number of telephone exchanges to serve the area, their optimum location and optimum boundary area of each exchange. For this densely populated areas, a rectangular grid is placed over a map of the area under consideration, and the forecasts then define the number of subscribers in each grid element. Within grid element, the subscribers are then assumed to be evenly distributed.

The size of the grid element should be chosen according to local conditions, typically ranging from 100 to 500 meter. In this model it is considered 500 meter by 500 meter unit area. So 40 Km by 30 Km area has 80 X 60 cells of unit areas in the whole area.

For larger network it is obviously impractical to define the location of every subscriber individually. Although the locations of the existing subscribers are known, the forecasts, being made for the entire population of a city, or for subsets of that population, would be meaningless for defining the location of individual subscribers.

Instead of a grid, forecasts can be defined for arbitrary polygons i.e areas enclosed by a sequence of straight lines. These areas correspond usually to blocks of houses, cabinet areas, industrial complexes, etc. Again, the subscribers are assumed to be evenly distributed within each such area.

Demand per unit area i.e. the grid is calculated usually from the demand forecasted value. For this model random value is assumed for each grid which is from minimum 10 to maximum 20.

Initially it is assumed that the minimum number of exchanges to serve the area under study are four. And the telephone demand per unit area is obtained which is the input data. The boundary area of each exchange is assumed approximately for these minimum number of exchanges considered initially.

Initial approximate location of each exchange is given as input value.

Keeping the boundary of exchange temporarily constant the optimum location of exchange is found out.

Using the model described above, the optimum location (x^*, y^*) of an exchange within a defined area is given by the condition:

$$\min C = \min \sum (n_i / x_i - x^* / + n_i / y_i - y^* /)$$

Where

i denotes any square of the grid.

$\sum$ includes the entire area under study

n_i is the number of subscribers in the square (x_i, y_i)

$/ x_i - x^*/$ and $/y_i - y^*/$ are the distances from the square (x_i, y_i) to square (x^*, y^*) along the x and y axes respectively.

The optimum location (x^*, y^*) satisfies the condition that the difference between the total number of subscribers to the left and to the right of x^* is minimum, and similarly above y^*. This condition provides an easy method for finding the optimum location.

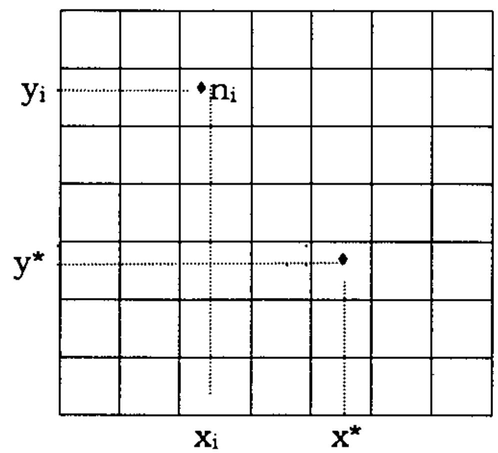


Figure 7.2 Optimum location.

Keeping the location of the exchange temporarily constant optimum boundary area of each exchange is found out.

The cost of connecting a subscriber to an exchange can be represented

$D_E \,.\, C_s(D_E) + C_f$

Where

D_E is distance subscriber – exchange,

C_s is distance – dependent transmission media cost,

C_f is distance - independent transmission media cost,

The cost of a circuit exchange to exchange can be represented as

$D_{EF} \,.C_c(D_E) + C_d$

where

D_{EF} is distance from exchange E to exchange F,

C_c is distance - dependent transmission media cost,

C_d is distance - independent transmission media cost,

When using different transmission system, the choice is made on the number of circuits between E and F. In this case a separate optimization is carried out.

Additional parameter of a transmission system is the capacity, i.e. the maximum number of circuits which could be carried over.

Exchange cost consists of two components:

- cost of exchange equipment
- cost of building

Both components are assumed to be a function of the subscribers, incoming and outgoing circuits.

For a given exchange E, we denote the exchange equipment cost with Ca(E) and the building cost with Cb(E).

Thus, the total network cost function, C, could be expressed as

$$C = \sum_{E=1}^{NEX} \sum_{(i,j) \in E} sub(i,j).[C_s(D_E).\ D_E + C_f] + [\sum_{E=1}^{NEX} [C_a(E) + C_b(E)] +$$

$$+ \sum_{E=1}^{NEX} \sum_{F=1}^{NEX} N_{EF}.[C_c(D_{EF}).\ D_{EF} + C_d]$$

where

NEX is the exchanges,

N_{EF} is the number of circuits from exchange E to exchange F.

Boundary optimization, i.e. finding exchange area boundaries in such a way that total network costs are minimized , is based on the following assumptions.

- exchange locations are fixed (temporally);
- the junction network cost of any subscriber, of a given traffic zone, K, belonging to a given exchange, E, is known (it will have been calculated in the previous iteration) : C_J (K,E)

- the average cost, per subscriber, of exchange and building, is known for any given exchange, E : $C_b(E)$

- the cost of connecting a subscriber to any exchange can be calculated from
  - the distance subscriber to exchange, D_E
  - the transmission plan
  - the available transmission media costs,

and can be written as D_E Cs $(D_E) + C_F$

The cost of connecting a subscriber at location (x,y), belonging to traffic zone K, to an exchange E at (X_E ,Y_E) can thus be expressed as

$$C(E) = C_j(K,E) + C_b(E) + D_E.\ C_s\ (D_E) + C_f \tag{7.12}$$

where $D_E = D(x,y,X_E,Y_E)$

We now have 2 possibilities of finding the optimal exchange boundaries, depending on one more assumption, i.e. whether a grid element can be split between exchanges or not.

- **The grid element can not be split**

In this case the entire grid element in question will be assigned to one exchange. The decision to which exchange, E, a given subscriber grid element should belong can be made simply by comparison. E should be chosen so that C(E) is minimised.

Simplified methods for boundary optimization

If no information about the distribution of the subscriber by exchanges and the junction network is available (when initial boundaries are defined) or we want to speed up the calculations (when tentative exchanges are investigated), a suitable method is to disregard the influence of exchange, building and junction network costs, i.e. to disregard the first two terms in [7.12].

So, we obtain

$$C(E) = C_E.C_s(D_E) + C_f \qquad (7.13)$$

Moreover, we can disregard the different transmission media costs in the subscriber network, i.e. to make a purely geographical division into exchange areas. In this case the boundaries will be placed equidistant to the adjacent exchanges.

Then, if subscriber distribution on grid is used and the grid element cannot be split, the boundary lines are rounded to the nearest grid element.

Besides, we have to treat fixed exchange boundaries, i.e. predefined exchange areas which cannot be changed and have to be excluded from the optimization process.

Then entering into an iterative process consists of two main steps: relocation and reassignment. The relocation step keeps the service area boundaries constant, while relocating exchanges to decrease the network cost. This process ends when the minimum has been reached. The reassignment step reassigns the subscribers (moves the service area boundaries) while keeping the exchange locations constant to decrease the network cost. The process also ends when the minimum is achieved.

Now optimum location and boundary area of four exchanges are obtained. As the location of the exchanges are known the distance matrix is obtained from these data.

From the demand per unit area and the boundary area of the exchange, the capacity of each exchange is calculated.

From the capacity of exchanges and assumed inter exchange traffic affinity traffic matrix is calculated. Using Erlang first formula inter exchange junction circuit matrix is obtained. Cost of junction network is calculated by multiplying the number of inter exchange junction circuits, corresponding distance and per unit cost of cable. Here cost per kilometer per circuit is considered as 200$ and 1$ = 50 Taka approximately.

Cost of subscriber network is calculated by multiplying the grid distance with the number of subscribers in that grid and finally adding the value for each grid under each exchange boundary area.

Cost for exchanges is calculated separately for the capacity of each exchange and other establishment for the exchange. This way total network is calculated for four exchanges.

Similarly model areas studied for six number of exchanges, eight number of exchanges, nine number of exchanges, ten number of exchanges, eleven number of exchanges, twelve number of exchanges, thirteen number of exchanges and sixteen number of exchanges. The result of the cost of different networks are plotted in a graph and from the graph optimum number of exchanges to serve the area under study is obtained as well as the optimum location and boundary area of each exchange is achieved.

SAMPLE RESULTS

Table 7.1. Exchange Locations

Sl.No.	Exchange Number	Exchange Location Cell (i)	(j)
01	0	14	14
02	1	44	14
03	2	14	40
04	3	44	41
05	4	15	57
06	5	44	66

Table 7.2. Distance Matrix of 6 Exchange Local Network.

		Exchange Number					
		0	1	2	3	4	5
Exchange Number	0	0	30	26	57	54	82
	1	30	0	56	27	82	52
	2	26	56	0	31	28	56
	3	57	27	31	0	55	25
	4	54	82	28	55	0	30
	5	82	52	56	25	30	0

Table 7.3. Traffic Matrix of 6 Exchange Local Network.

		Exchange Number					
		0	1	2	3	4	5
Exchange Number	0	0	155	148	151	148	152
	1	168	0	166	170	166	171
	2	147	162	0	149	145	150
	3	151	167	149	0	149	154
	4	147	162	145	149	0	150
	5	152	166	150	154	151	0

Table 7.4. Circuit Matrix of 6 Exchange Local Network.

		Exchange Number					
		0	1	2	3	4	5
Exchange Number	0	0	159	152	155	152	156
	1	172	0	170	174	170	175
	2	151	166	0	153	149	154
	3	155	171	153	0	153	158
	4	151	166	149	153	0	154
	5	156	170	154	158	155	0

Table 7.5 a. Network information.

Sl.No.	Exchange Number	Total Subs:	Number of Cells.	Cable Length.	Incoming Traffic.	Outgoing Traffic
1	0	15323	783	214419	766	766
2	1	16871	867	248229	843	843
3	2	15123	783	211820	756	756
4	3	15475	793	216552	773	773
5	4	15131	781	211817	756	756
6	5	15572	793	220175	778	778

Tabble 7.5.b Network Cost in Taka.

Sl. No.	Number of Exchange	Cost of Local Cable	Cost of Exchange	Cost of Junction Cable	Total Network Cost
01	4	16,80,00,000	2,88,00,000	1,36,34,400	21,04,34,400
02	5	15,47,98,000	2,94,50,000	2,47,36,200	20,89,84,200
03	6	13,60,80,000	3,16,80,000	3,59,74,000	20,37,34,000
04	7	12,67,00,000	3,74,01,000	3,75,41,000	20,16,42,000
05	8	12,00,00,000	5,72,00,000	3,72,24,000	21,19,44,000
06	9	11,20,80,000	10,58,94,000	3,84,24,000	25,63,98,000

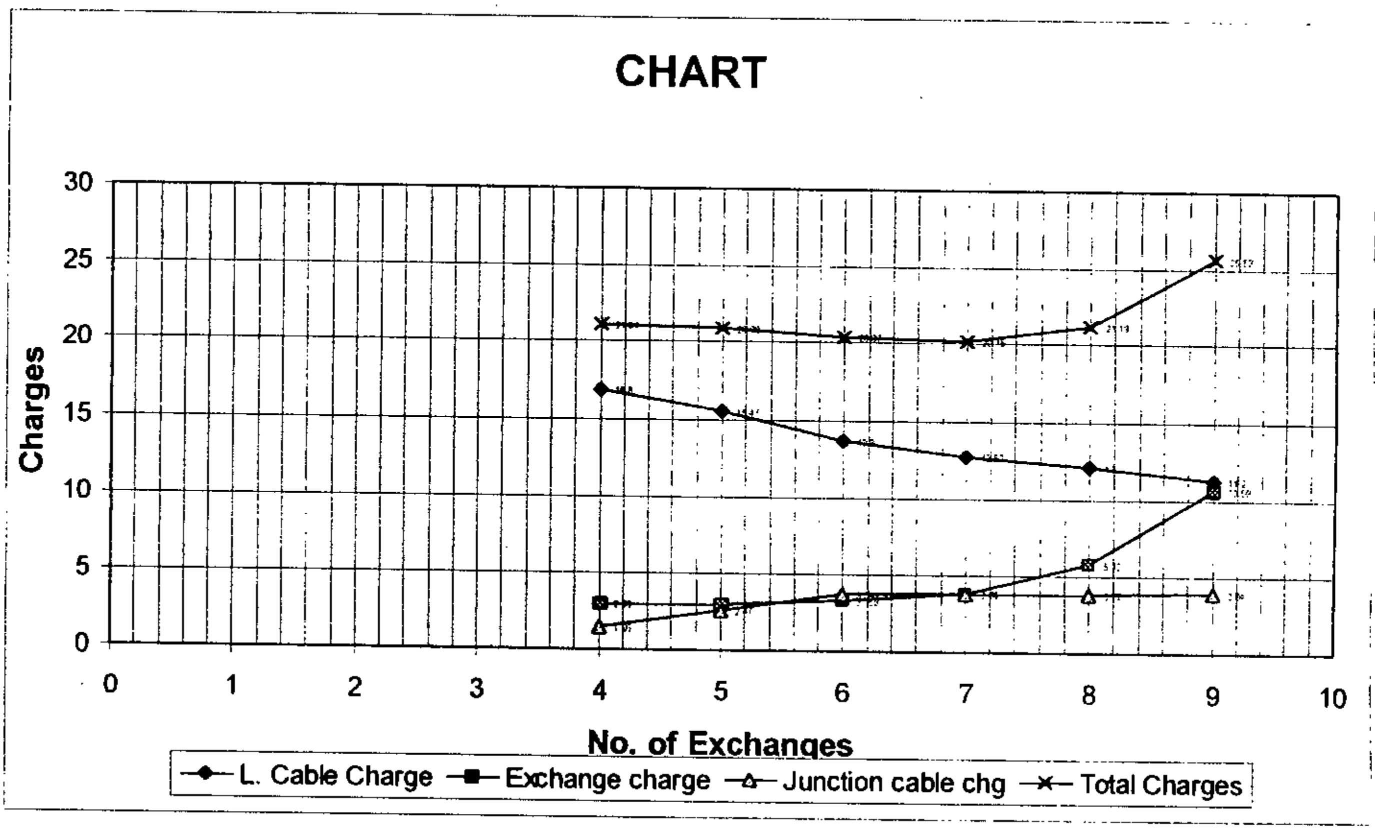


Figure- 7.3 Graph for optimum number of Exchange

Population of many small city gradually increases and ultimately become a highly populated big city. During the time of changing this small city into a densely populated big city telephone demand also increases with its population and socio-economic activities. Most of the cases to satisfy this demand specially with the urgency and immediate requirement of the demand local network has to develop inefficiently scatteredly and without proper planning. Because we do not have any study for good planning methods, enough data and efficient planning tools to increase the network quickly nor the pressing demand allow us to wait for taking a project where foreign expert may help us. When a network become big at that time optimization and dimensioning of total network is no more possible because to change existing network according to optimized planning is costly. Only we can optimize the further expansion but not the existing network. For example if it is required to change the location of an existing exchange for optimization of network then it is require to develop new subscriber network for this exchange because existing one with its old location cannot be used any more. So the modification of existing network is costly. So it is required to have a study for good planning method, enough data and efficient planning tools for future expansion of network of a developing city efficiently and quickly to meet the demand.

Different aspect of this problem and the existing telephone system have been studied throughly in this research work and by using the optimization and dimensioning a planning method has been developed. To execute this method quickly and efficiently and to handle many parameters it is computerized. In first phase for telecommunication system study a model area has been taken. Calculations, method for the calculations and the results have been described in details in the study of the model area in Art 7.4.1. From the results of this study it is seen that different number of exchanges are considered to serve the area under study and optimum location and boundary area of each exchange has been achieved. Finally from all sets of the results the optimum numbers of exchanges to serve the area have been achieved as well as the optimum locations and boundary area of each exchange for the optimum number of exchanges are obtained.

Let us study the different parameters like subscriber demand, traffic demand, exchange cost, junction network cost, and subscriber network cost etc. in respect to the result and the graph of this study.

(a) Subscriber demand

The subscriber demand directly defines the subscriber network required for any particular configuration. Since the contribution of the subscriber network cost to the total network cost is high (typically from 40%to 60%), and since the subscriber network cost significantly changes with the number of exchanges, the subscriber demand needs to be considered very accurately. In addition, the subscriber demand has a direct influence on the optimizing of exchange locations and exchange area boundaries. The conclusion from the above is that subscriber demand should be considered at the level of subscriber density distribution throughout the urban area under study.

For a given area, the influence of the variation in subscriber demand on the optimum number of exchanges is such that this number increases as the subscriber density increases, but much less than proportionally. Figure 7.3 will help to explain this. If the subscriber density is double that used in the figure, the subscriber network cost will approximately double for any particular number of exchanges. However, the increase in the junction network and the exchange costs will be less than double due to the non-proportionality of both costs to the subscriber density, (junction network efficiency will be higher and the start-up cost of the exchanges remains unchanged). The conclusion is that the "minimum" point of the network cost curve will be displaced to the right, but by much less than the position corresponding to double the number of exchanges.

(b) Traffic demand

For a given configuration, the traffic demand has a direct impact on the number of junctions required to interconnect the exchanges: it thus influences both the junction network cost and the exchange cost (which depends upon the number of junction terminations). The influence of the traffic demand on the optimum number of exchanges is such that the number slightly decreases as the traffic demand increases. Within the limits of practical variations, the number of exchanges would remain unchanged. This can be explained using Figure 7.3. An increase in the traffic demand significantly increases the junction network cost and slightly increases the exchange cost, where the subscriber network cost remains unchanged: the result is a slight displacement to the left of the minimum point on the network cost curve.

Traffic demand influences the optimum location of the exchanges as well as the optimum boundaries of the service areas. The influence is generally not large, although it may be important in particular cases. The optimum location depends on: the junction network and the subscriber network (land cost is disregarded in this discussion) and the latter is more important than the former. The optimum service area boundaries depend on the junction network, the switching cost of the exchanges and the subscriber network; here again, the last item is more important than the others.

(c) Exchange cost

Costs associated with an exchange are those of the switching equipment, the building, the power supply and the land. The switching equipment cost is a function of the number of lines, junction terminations and traffic demand. The function has a start-up (or initial) cost, but the particular shape depends upon the type of switching equipment. Buildings, power supply and land costs also depends on the switching equipment, as the space occupied and power consumption vary with different types. Building and power supply costs are a function of the number of lines. Land costs depends on the number of lines for a given type of building construction. The cost functions corresponding to building, power supply and land each have a significant start-up cost. The influence of the exchange costs on the optimum configuration of the network is strong because:

(a) they represent a high proportion of the total cost of the network (30% to 50%);

(b) they change significantly with the number of exchanges.

The marginal switching cost per junction termination is relatively higher in crossbar exchanges and lower in digital exchanges. It should be noted that when all the exchanges have the same cost function, the marginal cost per line or per unit of traffic switched has no influence on the optimum number of exchanges. If this is not the case, the influence exists but is negligible in practice. The exchange costs have no influence on the optimum location of the exchanges, except where there is a cost variation associated with the geographical location of the exchanges (for example, different land costs in different parts of the urban area);

(d) Junction network cost

The junction network cost of any given configuration is a function of the location of the exchanges, the number of junctions between any pair of exchanges and the cost function defining the transmission media. The number of junction is, in turn, a function of the traffic flows between the exchanges and the required traffic grade of service. The function that defines the cost of the transmission media (cables, conduits, transmission systems, etc.) is a function of the length and the number of junctions, and it takes into account the transmission and signalling requirements.

The influence of the junction network in the definition of the optimum configuration though generally not very large is such that the number of exchanges tends to decrease as the junction network cost increases. It is to be noted that junction network itself is also the subject of an optimization process. An almost unlimited number of solutions for the junction network can therefore exists, each satisfying a given grade of service requirement for a predefined traffic matrix between the exchanges.

(e) Subscriber network cost

The subscriber network cost for a given configuration is a function of the physical location of the subscribers, the transmission/signalling requirements and the cost of the elements of the network (cables, conduits, etc.). The subscriber network; like the junction network, is subject to optimization, to select the most appropriate configuration, from an almost unlimited number of alternatives, which satisfies all the technical / service requirements.

The problem of finding the optimum configuration has been stated assuming that the subscriber demand will be totally served. There is also an implicit assumption in the statement: there is no limitation on the capital which will be required to put the optimum network in service. However, the case may exist in which the capital available is not enough to satisfy the demand entirely. In this case the definition of the optimization task needs to be restated in order to establish a criterion which is able to separate the demand to be served from the total demand. This new definition calls for a new parameter of the income per subscriber in service, which is used as a selection criterion for the demand to be served. The problem can be stated in the following terms: with a fixed and restricted available capital what is the configuration which maximizes the total income.

7.4.2 MODEL CONSIDERED FOR JUNCTION NETWORK.

A model area is taken for this study. In this area eight existing exchanges are working. We consider that there are pending demand for each exchange and also this demand is increasing day by day. In this circumstances network will have to be expanded and new exchanges are to be added to satisfy the additional demand. We consider the location and boundary area of the new exchange at the same location and same boundary area of the existing exchanges.

Because even if the new location is optimum but new land is not available in urban area as well as these new exchanges are serving the same local area network of the existing exchanges. As we have considered the location and boundary of existing exchanges for the new exchanges so the location and boundary area of the new exchanges are known. On the basis of this distance matrix is obtained and shown in table 7.6.

Table 7.6. Distance Matrix of 8 Exchange Junction Network..

	1A	2B	3C	4D	5E	6F	7G	8H
1A	0	8	16	10	12.8	18.87	19.1	23.6
2B	8	0	8	12.8	10	12.8	19.92	19.92
3C	16	8	0	18.87	12.8	10	23.6	19.1
4D	10	12.8	18.87	0	8	16	9.22	16.64
5E	12.8	10	12.8	8	0	8	10.82	10.82
6F	18.87	12.8	10	16	8	0	16.64	9.22
7G	19.1	19.92	23.6	9.22	10.82	16.64	0	12
8H	23.6	19.92	19.1	16.64	10.82	9.22	12	0

If we considered the execution period for the expansion of the existing network as three years then we shall calculate the demand of each exchange as the present pending demand and the forecasted demand of the execution period of three years. Let us consider the total demand of each new exchange after three years is equal to the present capacity of the existing exchange. The name and capacity of each exchange are shown in table 7.7.

Table 7.7. New Exchange Capacity.

Sl. No.	Name of the Exchange	Capacity of the Exchange
01	1A	6,700
02	2B	6,840
03	3C	5,200
04	4D	5,400
05	5E	12,160
06	6F	8,480
07	7G	8,600
08	8H	3,400

Total traffic of each exchange can be obtained by taking (0.10) as average traffic per subscriber. From the above data traffic matrix is obtained by considering the present affinity of the existing traffic same as the affinity of the traffic of the new exchanges and shown in table 7.8.

Table 7.8. Traffic Matrix of 8 Exchange Junction Network.

	1A	2B	3C	4D	5E	6F	7G	8H
1A	0	17	9	10	51	27	30	8
2B	20	0	8	13	50	25	29	10
3C	10	9	0	12	37	16	9	4
4D	11	13	14	0	26	12	15	16
5E	51	52	32	22	0	52	46	15
6F	24	34	14	11	50	0	45	12
7G	34	29	8	13	52	42	0	15
8H	9	8	10	14	12	10	13	0

We consider that the Junction network for these new exchanges will be only direct route and no tandem exchange is used for Junction. We can use the Erlang's first formula to find out the number of direct Junction circuits. According to this formula, the probability of congestion, i.e. the average proportion of the traffic which will meet congestion, will be equal to:

$$E\ (n,A) = \frac{\dfrac{A^n}{N!}}{1 + A + \dfrac{A^2}{2!} + \ldots + \dfrac{A^n}{N!}}$$

$$= \frac{\dfrac{A^n}{N!}}{\sum_{i=0}^{n} \dfrac{A^i}{i!}}$$

E = degree of congestion

N = number of circuits

A = traffic offered

Erlang's first formula – conditions

In order to be able to use Erlang's first formula the following four conditions must be fulfilled.

1. Loss system, i.e. a call which failed because of congestion is disconnected and there is no attempt to call again.

   Note: This is not completely realistic-the subscriber often immediately makes a new attempt to call.
2. Full accessibility, i.e. any free inlet can reach any free outlet.
3. Pure chance (random) traffic, i.e. the time between two calls will be random. This type of random course of events may be described by a negative exponential function.
4. A large number of call sources, i.e. regardless of whether few or many calls are in progress, the traffic interest is approximately

constant (same average value). In the mathematical model this is equivalent to an infinite number of call sources.

The grade of service is considered 5% for the network design of this study. The traffic matrix is known so the circuit matrix is calculated out using the above mensioned formula and shown in table 7.9.

Table 7.9. Circuit Matrix for Direct Route of 8 Exchange Junction Network.

	1A	2B	3C	4D	5E	6F	7G	8H
1A	0	22	14	15	57	33	36	13
2B	26	0	13	18	56	31	35	15
3C	15	14	0	17	43	21	14	8
4D	16	18	19	0	32	17	20	21
5E	57	58	38	28	0	58	52	20
6F	30	40	19	16	56	0	51	17
7G	40	35	13	18	58	48	0	20
8H	14	13	15	19	17	15	18	0

Now we consider the case of Junction circuits as tandem circuits and as well as direct routes. The class of circuits to be used between two exchanges i.e. tandem(T), high uses(H) or direct(D) circuits, is predominantly determined by the offered traffic, A, between the exchanges and the cost ratio between the incremental cost for direct and tandem circuits.

Table 7.10. Incremental cost matrix.

	1A	2B	3C	4D	5E	6F	7G	8H	Mtj
1A	X	1600	3200	2000	2560	3774	3820	4720	2560
2B	1600	X	1600	2560	2000	2560	3984	3984	2000
3C	3200	1600	X	3774	2560	2000	4720	3820	2560
4D	2000	2560	3774	X	1600	3200	1844	3328	1600
5E	2560	2000	2560	1600	X	1600	2164	2164	1
6F	3774	2560	2000	3200	1600	X	3328	1844	1600
7G	3820	3984	4720	1844	2164	3328	X	2400	2164
8H	4720	3984	3820	3328	2164	1844	2400	X	2164
Mij	2560	2000	2560	1600	1	1600	2164	2164	1

$$\text{Cost ratio } \varepsilon = \frac{B_{ij}}{B_{it} + Bt_j}$$

Where

B_{ij} = incremental cost for direct circuit from exchange i to exchange j;

B_{it} = incremental cost for circuit from exchange i to tandem t;

B_{tj} = incremental cost for circuit from tandem t to exchange j.

Incremental cost between exchanges and tandem exchange can be obtained from distance matrix. Here per Kilometer per channel cost is considered to be 200$. This is shown in table 7.10.

By using cost ratio formula and incremental cost matrix cost ratio matrix is obtained and shown in table 7.11.

Table 7.11. Cost Ratio Matrix.

	1A	2B	3C	4D	5E	6F	7G	8H
1A	X	.351	.625	.481	1	.907	.809	999
2B	.351	X	.351	.711	1	.711	.957	.957
3C	.625	.351	X	.907	1	.481	.999	.809
4D	.481	.711	.907	X	999	1	.490	.884
5E	1	1	1	999	X	999	1	1
6F	.907	.711	.481	1	.999	X	.884	.490
7G	809	.957	.999	.490	1	.884	X	.555
8H	999	.957	.809	.884	1	.490	.555	X

The network of minimum cost offered for a given quantity of traffic between two exchange i and j is equivalent to finding the number of circuits n to allocate to the high usage route i – j. The traffic carried by the (n+1)th circuit (equal to the efficiency of the group of n+1 circuits in the direct route) when multiplied by the cost of establishing this (n+1)th circuit in the high usage route, should be equal to the cost of a circuit in the final route multiplied by the efficiency of this circuit. This is known as Moe's principle [7].

The minimum network cost is calculated by solving the equation.

$$A \cdot [\, E(A, n) - E(A, n+1)] = \eta . \varepsilon$$

Where

A is the traffic offered to the direct or high usage route

N is the number of circuits (the unknown)

E is the Erlang function

η is the efficiency of final routes

The expression $A \times [\, E(A,n) - E(A,n+1)]$ represents the traffic carried by the (n+1)th circuit in the high usage route, when a quantity of traffic A is offered to the route.

Equation can be written as:

$$F(n,A) = A[\, E(n,A) - E(n+1,A)] = \eta . \varepsilon$$

Where:

F(n,A) = the " improvement" function, i.e. the increase of the traffic carried by high usage junction on an increase in the number of high usage junctions from n to n+1.

η = the efficiency of incremental trunks.

ε = cost ratio.

However, this formula has the disadvantage of giving too many high usage circuits if the cost ratio is high and/or the traffic is small.

A better approximation is obtained by the formula

$F(n.A) = \varepsilon.[\ 1-0.3(1-\varepsilon^2)]$

which is fitted to the result of extensive calculations on a computer.

High usage Junction matrix is obtained by using the traffic matrix and Moe's formula which is shown in table 7.12.

Table 7.12. High Usage Circuit Matrix of 8 Exchange Junction Network.

	1A	2B	3C	4D	5E	6F	7G	8H
1A	0	22	9	12	46	22	26	2
2B	25	0	11	12	45	24	24	4
3C	10	12	0	6	32	19	3	1
4D	13	12	8	0	21	6	18	10
5E	46	47	27	17	0	47	41	9
6F	19	34	17	5	45	0	40	14
7G	30	24	2	15	47	37	0	17
8H	3	2	7	8	6	12	14	0

With the aid of Wilkinson's equivalent random theory the number of circuits on high usage and tandem routes carrying overflow traffic from said routes can be determined, but the method is rather time consuming.

Table 7.13. Matrix for mean value.

	1A	2B	3C	4D	5E	6F	7G	8H	Mit
1A	X	0.813	2.019	1.197	8.641	7.146	6.619	6.244	32.678
2B	1.004	X	0.650	3.086	8.586	4.200	7.290	6.467	31.283
3C	2.146	0.748	X	6.673	7.823	1.377	6.358	3.200	28.324
4D	1.304	3.086	6.866	X	7.072	6.673	1.293	7.049	33.343
5E	8.641	8.695	7.497	6.764	X	8.695	8.362	6.959	55.612
6F	6.921	4.254	1.206	6.572	8.586	X	8.305	1.407	37.251
7G	6.894	7.290	6.244	1.506	8.695	8.130	X	1.697	40.455
8H	6.358	6.244	4.090	6.866	6.673	1.197	1.966	X	33.394
Mtj	33.267	31.129	28.573	32.665	56.076	37.417	40.192	33.022	0000

The mean value M and the variance V for the overflow traffic from each high usage route should first be calculated according to formulas 7.14 and 7.15.

$$M = A.\ E_N(A)\ .\ .\ \ .\ .\ .\ . \qquad 7.14.$$

Where

A = The traffic offered

E = The Erlang function

N = The number of circuits

M = Mean of overflow traffic from a route

Table 7.14. Variance Matrix.

	1A	2B	3C	4D	5E	6F	7G	8H	Vit
1A	X	2.180	3.962	2.616	28.942	17.412	17.685	7.414	80.213
2B	2.864	X	1.346	6.562	28.478	11.563	18.414	8.741	77.967
3C	4.362	1.606	X	10.006	22.331	3.578	8.087	3.627	53.597
4D	2.936	6.562	11.223	X	16.907	10.006	3.285	12.405	63.324
5E	28.942	29.406	19.898	14.857	X	29.406	26.609	11.818	160.936
6F	15.889	13.684	2.995	9.380	28.478	X	26.139	3.259	99.823
7G	19.560	18.414	7.414	3.583	29.406	24.772	X	4.237	107.335
8H	8.087	7.414	6.926	11.223	10.006	2.616	4.545	X	50.818
Vtj	82.641	79.266	53.765	58.227	164.547	99.303	104.765	51.500	0

$$V = M.\left(1 - M + \frac{A}{1 + N + M - A}\right) \qquad 7.15$$

Where

A = The traffic offered

V = Variance of overflow traffic from a route

N = The number of circuits

M = Mean of overflow traffic from a route

The sum of these mean values is denominated Ms and of the variances Vs. Ms and Vs can be characterised in a more convenient way i.e. as overflow traffic from one fictitious group of circuits with equivalent number of circuits = n_e and equivalent traffic offered = A_e Erl. Ms and Vs are then used to determine n_e and A_e in accordance with the formulas 7.16 and 7.17.

$$Ms = Ae.\ E_{n_e}(Ae) \qquad 7.16.$$

$$Vs = Ms\left(1 - Ms + \frac{Ae}{1 + n_e + Ms - Ae}\right) \qquad 7.17.$$

Where

Ms = Sum of the mean values of overflow traffic from a route

Ae = Wilkinson's equivalent traffic

n_e = Wilkinson's equivalent circuit

E = The Erlang function

Vs = Sum of the variance of overflow traffic from a route

Instead of using this method an approximate formula 7.18, can be used and there by making it possible to solve the problem much quicker and with sufficient accuracy.

$$Ae = Vs + 3 \cdot \frac{Vs}{Ms} \cdot \left(\frac{Vs}{Ms} - 1\right) \qquad 7.18.$$

Where

Ae = Equivalent traffic

Vs = Equivalent variance

Ms = Sum of the mean values of overflow traffic from a route

From the above formula Wilkinson's equivalent Erlang Ae can be obtained.

Table 7.15.a. Equivalent Erlang Matrix (it).

	T1
1A	90.925
2B	89.125
3C	58.662
4D	68.447
5E	177.379
6F	113.327
7G	120.494
8H	53.200

Table 7.15.b. Equivalent Erlang Matrix (tj).

	1A	2B	3C	4D	5E	6F	7G	8H
T1	93.701	91.078	58.743	62.412	181.576	112.471	117.329	54.118

When A_e has been determined n_e can be calculated in accordance with the exact formula 7.19 which can be derived from formula 7.17.

Table 7.16.a. Equivalent Circuit Matrix (it).

	T1
1A	59.911
2B	59.562
3C	31.345
4D	36.103
5E	123.852
6F	77.987
7G	81.900
8H	20.374

Table 7.16.b Equivalent circuit matrix (tj).

	1A	2B	3C	4D	5E	6F	7G	8H
T1	62.131	61.736	31.164	30.613	127.631	76.930	78.944	21.707

$$n_e = \frac{Ae}{1 - \cfrac{1}{Ms + \cfrac{Vs}{Ms}}} - Ms - 1 \qquad 7.19.$$

Where

A_e = Equivalent traffic

Vs = Equivalent variance

Ms = Sum of the mean values of overflow traffic from a route

N_e = Equivalent circuit

From the above formula and the equivalent Erlang matrix Wilkinson's equivalent circuit matrix can be obtained.

If we consider the total congestion for the final route following equation can be used.

$E_0 \times M_{it} = A_{it} \times E\,(n_{it} + m_{it}, A_{it})$

$E_0 \times M_{tj} = A_{tj} \times E\,(n_{tj} + m_{tj}, A_{tj})$

Where

E_0 = Total congestion

M_{it} = Sum of the mean of overflow traffic for incoming tandem Circuit

A_{it} = Equivalent traffic for incoming tandem circuit

n_{it} = Equivalent circuit for incoming tandem circuit

m_{it} = Incoming tandem circuit

M_{tj} = Sum of the mean of overflow traffic for outgoing tandem Circuit

A_{tj} = Equivalent traffic for outgoing tandem circuit

n_{tj} = Equivalent circuit for outgoing tandem circuit

m_{tj} = Outgoing tandem circuit

Using the above formula, Wilkinson's equivalent Erlang matrix and Wilkinson's equivalent circuit matrix tandem circuits are calculated and shown in table 7.17.a. and 7.17.b.

Table 7.17.a. Incoming Tandem Circuits.

	1A
1A	53
2B	52
3C	45
4D	51
5E	15
6F	61
7G	64
8H	49

Table 7.17.b. Outgoing Tandem Circuits.

	1A	2B	3C	4D	5E	6F	7G	8H
T1	54	53	45	50	10	61	64	50

Now existing network for the study area is considered. Name of the exchanges and their capacity is shown in the table 7.18.

Table 7.18. Existing Exchange Capacity.

Sl.No.	Name of the Exchange	Capacity of the Exchange
01	1A1	6,700
02	2B1	6,840
03	3C1	5,200
04	4D1	5,400
05	5E1	12,160
06	6F1	8,480
07	7G1	8,600
08	8H1	3,400

Considering the existing exchanges and new exchanges simultenously new distance matrix is obtain and shown in table 7.19.

Table 7.19. Distance matrix of 16 Exchange Junction Network.

	1A	2B	3C	4D	5E	6F	7G	8H	1A1	2B1	3C1	4D1	5E1	6F1	7G1	8H1
1A	0	8	16	10	12.8	18.87	19.1	23.6	0	8	16	10	12.8	18.87	19.1	23.6
2B	8	0	8	12.8	10	12.8	19.92	19.92	8	0	8	12.8	10	12.8	19.92	19.92
3C	16	8	0	18.87	12.8	10	23.6	19.1	16	8	0	18.87	12.8	10	23.6	19.1
4D	10	12.8	18.87	0	8	16	9.22	16.64	10	12.8	18.87	0	8	16	9.22	16.64
5E	12.8	10	12.8	8	0	8	10.82	10.82	12.8	10	12.8	8	0	8	10.82	10.82
6F	18.87	12.8	10	16	8	0	16.64	9.22	18.87	12.8	10	16	8	0	16.64	9.22
7G	19.1	19.92	23.6	9.22	10.82	16.64	0	12	19.1	19.92	23.6	9.22	10.82	16.64	0	12
8H	23.6	19.92	19.1	16.64	10.82	9.22	12	0	23.6	19.92	19.1	16.64	10.82	9.22	12	0
1A1	0	8	16	10	12.8	18.87	19.1	23.6	0	8	16	10	12.8	18.87	19.1	23.6
2B1	8	0	8	12.8	10	12.8	19.92	19.92	8	0	8	12.8	10	12.8	19.92	19.92
3C1	16	8	0	18.87	12.8	10	23.6	19.1	16	8	0	18.87	12.8	10	23.6	19.1
4D1	10	12.8	18.87	0	8	16	9.22	16.64	10	12.8	18.87	0	8	16	9.22	16.64
5E1	12.8	10	12.8	8	0	8	10.82	10.82	12.8	10	12.8	8	0	8	10.82	10.82
6F1	18.87	12.8	10	16	8	0	16.64	9.22	18.87	12.8	10	16	8	0	16.64	9.22
7G1	19.1	19.92	23.6	9.22	10.82	16.64	0	12	19.1	19.92	23.6	9.22	10.82	16.64	0	12
8H1	23.6	19.92	19.1	16.64	10.82	9.22	12	0	23.6	19.92	19.1	16.64	10.82	9.22	12	0

Traffic matrix of existing exchanges are known. Traffic matrix of new exchanges are already calculated in table 7.8. So the traffic matrix of the total area is calculated out from above data and shown in table 7.20.

For the first case we consider that there is no tandem exchange and all Junction circuits are connected directly between each other. By using the Erlang formula circuit matrix is calculated out and shown in table 7.21.

From the distance matrix and circuit matrix of the network the total Junction circuit length is 61,032.51 kilometers. If the cost per kilometer per channel is 200$ then total cost of the Junction network considering only direct route is 61,03,25,100 Taka. Here 1$ ≈ 50 Tk.

We can consider the tandem circuit and high usage route for Junction Network.

By using the formula of cost ratio and the increamental cost matrix cost ratio matrix is obtained. This matrix is shown in table 7.22. High usage Junction circuit matrix is calculated and shown in table 7.23.

Mean value matrix of rejected traffic from the high usage route is calculated out and shown in table 7.24.

Variance matrix of rejected traffic from the high usage route is calculated and is shown in table 7.25.

Table 7.20. Traffic Matrix of 16 Exchange Junction Network.

	1A	2B	3C	4D	5E	6F	7G	8H	1A1	2B1	3C1	4D1	5E1	6F1	7G1	8H1
1A	0	17	9	10	51	27	30	8	0	17	9	10	51	27	30	8
2B	20	0	8	13	50	25	29	10	20	0	8	13	50	25	29	10
3C	10	9	0	12	37	16	9	4	10	9	0	12	37	16	9	4
4D	11	13	14	0	26	12	15	16	11	13	14	0	26	12	15	16
5E	51	52	32	22	0	52	46	15	51	52	32	22	0	52	46	15
6F	24	34	14	11	50	0	45	12	24	34	14	11	50	0	45	12
7G	34	29	8	13	52	42	0	15	34	29	8	13	52	42	0	15
8H	9	8	10	14	12	10	13	0	9	8	10	14	12	10	13	0
1A1	0	17	9	10	51	27	30	8	0	17	9	10	51	27	30	8
2B1	20	0	8	13	50	25	29	10	20	0	8	13	50	25	29	10
3C1	10	9	0	12	37	16	9	4	10	9	0	12	37	16	9	4
4D1	11	13	14	0	26	12	15	16	11	13	14	0	26	12	15	16
5E1	51	52	32	22	0	52	46	15	51	52	32	22	0	52	46	15
6F1	24	34	14	11	50	0	45	12	24	34	14	11	50	0	45	12
7G1	34	29	8	13	52	42	0	15	34	29	8	13	52	42	0	15
8H1	9	8	10	14	12	10	13	0	9	8	10	14	12	10	13	0

Table 7.21. Direct Route Matrix of 16 Exchange Junction Network.

	1A	2B	3C	4D	5E	6F	7G	8H	1A1	2B1	3C1	4D1	5E1	6F1	7G1	8H1
1A	0	22	14	15	57	33	36	13	0	22	14	15	57	33	36	13
2B	26	0	13	18	56	31	35	15	26	0	13	18	56	31	35	15
3C	15	14	0	17	43	21	14	8	15	14	0	17	43	21	14	8
4D	16	18	19	0	32	17	20	21	16	18	19	0	32	17	20	21
5E	57	58	38	28	0	58	52	20	57	58	38	28	0	58	52	20
6F	30	40	19	16	56	0	51	17	30	40	19	16	56	0	51	17
7G	40	35	13	18	58	48	0	20	40	35	13	18	58	48	0	20
8H	14	13	15	19	17	15	18	0	14	13	15	19	17	15	18	0
1A1	0	22	14	15	57	33	36	13	0	22	14	15	57	33	36	13
2B1	26	0	13	18	56	31	35	15	26	0	13	18	56	31	35	15
3C1	15	14	0	17	43	21	14	8	15	14	0	17	43	21	14	8
4D1	16	18	19	0	32	17	20	21	16	18	19	0	32	17	20	21
5E1	57	58	38	28	0	58	52	20	57	58	38	28	0	58	52	20
6F1	30	40	19	16	56	0	51	17	30	40	19	16	56	0	51	17
7G1	40	35	13	18	58	48	0	20	40	35	13	18	58	48	0	20
8H1	14	13	15	19	17	15	18	0	14	13	15	19	17	15	18	0

Table 7.22. Cost ratio matrix of 16 Exchange Junction Network.

	1A	**2B**	**3C**	**4D**	**5E**	**6R**	**7G**	**8H**	**1A1**	**2B1**	**3C1**	**4D1**	**5E1**	**6F1**	**7G1**	**8H1**
1A	X	.351	.625	.481	1	.907	.809	.999	X	.351	.625	.481	1	.907	.809	.999
2B	.351	X	.351	.711	1	.711	.957	.957	.351	X	.351	.711	1	.711	.957	.957
3C	.625	.351	X	.907	1	.481	.999	.809	.625	.351	X	.907	1	.481	.999	.809
4D	.481	.711	.907	X	.999	1	.490	.884	.481	.711	.907	X	.999	1	.490	.884
5E	1	1	1	.999	X	.999	1	1	1	1	1	.999	X	.999	1	1
6F	.907	.711	.481	1	.999	X	.884	.490	.907	.711	.481	1	.999	X	.884	.490
7G	.809	.957	.999	.490	1	.884	X	.555	.809	.957	.999	.490	1	.884	X	.555
8H	.999	.957	.809	.884	1	.490	.555	X	.999	.957	.809	.884	1	.490	.555	X
1A1	X	.351	.625	.481	1	.907	.809	.999	X	.351	.625	.481	1	.907	.809	.999
2B1	.351	X	.351	.711	1	.711	.957	.957	.351	X	.351	.711	1	.711	.957	.957
3C1	.625	.351	X	.907	1	.481	.999	.809	.625	.351	X	.907	1	.481	.999	.809
4D1	.481	.711	.907	X	.999	1	.490	.884	.481	.711	.907	X	.999	1	.490	.884
5E1	1	1	1	.999	X	.999	1	1	1	1	1	.999	X	.999	1	1
6F1	.907	.711	.481	1	.999	X	.884	.490	.907	.711	.481	1	.999	X	.884	.490
7G1	.809	.957	.999	.490	1	.884	X	.555	.809	.957	.999	.490	1	.884	X	.555
8H1	.999	.957	.809	.884	1	.490	.555	X	.999	.957	.809	.884	1	.490	.555	X

Table 7.23. High usage circuit matrix of 16 Exchange Junction Network.

	1A	2B	3C	4D	5E	6F	7G	8H	1A1	2B1	3C1	4D1	5E1	6F1	7G1	8H1
1A	0	22	9	12	46	22	26	2	0	22	14	15	57	33	36	13
2B	25	0	11	12	45	24	24	4	26	0	13	18	56	31	35	15
3C	10	12	0	6	32	19	3	1	15	14	0	17	43	21	14	8
4D	13	12	8	0	21	6	18	10	16	18	19	0	32	17	20	21
5E	46	47	27	17	0	47	41	9	57	58	38	28	0	58	52	20
6F	19	34	17	5	45	0	40	14	30	40	19	16	56	0	51	17
7G	30	24	2	15	47	37	0	17	40	35	13	18	58	48	0	20
8H	3	2	7	8	6	12	14	0	14	13	15	19	17	15	18	0
1A1	0	22	14	15	57	33	36	13	0	22	14	15	57	33	36	13
2B1	26	0	13	18	56	31	35	15	26	0	13	18	56	31	35	15
3C1	15	14	0	17	43	21	14	8	15	14	0	17	43	21	14	8
4D1	16	18	19	0	32	17	20	21	16	18	19	0	32	17	20	21
5E1	57	58	38	28	0	58	52	20	57	58	38	28	0	58	52	20
6F1	30	40	19	16	56	0	51	17	30	40	19	16	56	0	51	17
7G1	40	35	13	18	58	48	0	20	40	35	13	18	58	48	0	20
8H1	14	13	15	19	17	15	18	0	14	13	15	19	17	15	18	0

Table 7.24. Matrix for mean value of 16 Exchange Junction Network.

	1A	2B	3C	4D	5E	6F	7G	8H	1A1	2B1	3C1	4D1	5E1	6F1	7G1	8H1
1A	X	0.813	2.019	1.197	8.641	7.146	6.619	6.244	X	0.813	2.019	1.197	8.641	7.146	6.619	6.244
2B	1.004	X	0.650	3.086	8.586	4.200	7.290	6.467	1.004	X	0.650	3.086	8.586	4.200	7.290	6.467
3C	2.146	0.748	X	6.673	7.823	1.377	6.358	3.200	2.146	0.748	X	6.673	7.823	1.377	6.358	3.200
4D	1.304	3.086	6.866	X	7.072	6.673	1.293	7.049	1.304	3.086	6.866	X	7.072	6.673	1.293	7.049
5E	8.641	8.695	7.497	6.764	X	8.695	8.362	6.959	8.641	8.695	7.497	6.764	X	8.695	8.362	6.959
6F	6.921	4.254	1.206	6.572	8.586	X	8.305	1.407	6.921	4.254	1.206	6.572	8.586	X	8.305	1.407
7G	6.894	7.290	6.244	1.506	8.695	8.130	X	1.697	6.894	7.290	6.244	1.506	8.695	8.130	X	1.697
8H	6.358	6.244	4.090	6.866	6.673	1.197	1.966	X	6.358	6.244	4.090	6.866	6.673	1.197	1.966	X
1A1	X	0.813	2.019	1.197	8.641	7.146	6.619	6.244	X	0.813	2.019	1.197	8.641	7.146	6.619	6.244
2B1	1.004	X	0.650	3.086	8.586	4.200	7.290	6.467	1.004	X	0.650	3.086	8.586	4.200	7.290	6.467
3C1	2.146	0.748	X	6.673	7.823	1.377	6.358	3.200	2.146	0.748	X	6.673	7.823	1.377	6.358	3.200
4D1	1.304	3.086	6.866	X	7.072	6.673	1.293	7.049	1.304	3.086	6.866	X	7.072	6.673	1.293	7.049
5E1	8.641	8.695	7.497	6.764	X	8.695	8.362	6.959	8.641	8.695	7.497	6.764	X	8.695	8.362	6.959
6F1	6.921	4.254	1.206	6.572	8.586	X	8.305	1.407	6.921	4.254	1.206	6.572	8.586	X	8.305	1.407
7G1	6.894	7.290	6.244	1.506	8.695	8.130	X	1.697	6.894	7.290	6.244	1.506	8.695	8.130	X	1.697
8H1	6.358	6.244	4.090	6.866	6.673	1.197	1.966	X	6.358	6.244	4.090	6.866	6.673	1.197	1.966	X

Table 7.25. Variance matrix of 16 Exchange Junction Network.

	1A	2B	3C	4D	5E	6F	7G	8H	1A1	2B1	3C1	4D1	5E1	6F1	7G1	8H1
1A	X	2.180	3.962	2.616	28.942	17.412	17.685	7.414	X	2.180	3.962	2.616	28.942	17.412	17.685	7.414
2B	2.864	X	1.346	6.562	28.478	11.563	18.414	8.741	2.864	X	1.346	6.562	28.478	11.563	18.414	8.741
3C	4.362	1.606	X	10.006	22.331	3.578	8.087	3.627	4.362	1.606	X	10.006	22.331	3.578	8.087	3.627
4D	2.936	6.562	11.223	X	16.907	10.006	3.285	12.405	2.936	6.562	11.223	X	16.907	10.006	3.285	12.405
5E	28.942	29.406	19.898	14.857	X	29.406	26.609	11.818	28.942	29.406	19.898	14.857	X	29.406	26.609	11.818
6F	15.889	13.684	2.995	9.380	28.478	X	26.139	3.259	15.889	13.684	2.995	9.380	28.478	X	26.139	3.259
7G	19.560	18.414	7.414	3.583	29.406	24.772	X	4.237	19.560	18.414	7.414	3.583	29.406	24.772	X	4.237
8H	8.087	7.414	6.926	11.223	10.006	2.616	4.545	X	8.087	7.414	6.926	11.223	10.006	2.616	4.545	X
1A1	X	2.180	3.962	2.616	28.942	17.412	17.685	7.414	X	2.180	3.962	2.616	28.942	17.412	17.685	7.414
2B1	2.864	X	1.346	6.562	28.478	11.563	18.414	8.741	2.864	X	1.346	6.562	28.478	11.563	18.414	8.741
3C1	4.362	1.606	X	10.006	22.331	3.578	8.087	3.627	4.362	1.606	X	10.006	22.331	3.578	8.087	3.627
4D1	2.936	6.562	11.223	X	16.907	10.006	3.285	12.405	2.936	6.562	11.223	X	16.907	10.006	3.285	12.405
5E1	28.942	29.406	19.898	14.857	X	29.406	26.609	11.818	28.942	29.406	19.898	14.857	X	29.406	26.609	11.818
6F1	15.889	13.684	2.995	9.380	28.478	X	26.139	3.259	15.889	13.684	2.995	9.380	28.478	X	26.139	3.259
7G1	19.560	18.414	7.414	3.583	29.406	24.772	X	4.237	19.560	18.414	7.414	3.583	29.406	24.772	X	4.237
8H1	8.087	7.414	6.926	11.223	10.006	2.616	4.545	X	8.087	7.414	6.926	11.223	10.006	2.616	4.545	X

Using mean value matrix, variance matrix, Wilkinson's equivalent circuit formula and the formula for total congestion incoming and out going circuits of the tandem for existing exchanges and tandem for new exchanges are calculated. This data is used in the cost calculation of the Network for optimization process. For calculation of incoming and out going circuits of tandem with existing exchanges and new exchanges are considered separately.

Total cable length of high usage inter exchange routes are calculated by multiplying the number of circuits and corresponding distance. Per circuit per kilometer cost is considered 200$. So the cost of high usage inter exchange Junction routes is 44,26,50,000 Taka. Here 1$ = 50 Taka.

Total length of incoming circuit route of tandem T_1 is calculated by multiplying the number incoming circuits and corresponding route distance. Which is multiplied by 200$ (for per kilometer per circuit cost is considered as 200$). So total cost is 7,22,00,000 Taka. Here 1$ = 50 Taka.

Similarly the cost for outgoing route from tandem T_1 to existing exchanges is 3,57,30,800 Taka. Cost for outgoing routes from tandem T_1 to new exchanges is 3,57,30,800 Taka. Cost for outgoing routes from tandem T_2 to new exchanges is 3,57,30,800 Taka.

Tandem size is calculated from the incoming and outgoing circuits of the tandem. The size of T_1 is obtained as 1444 and the cost for the tandem is calculated as 1,08,30,000 Taka. Here per circuit cost is considered as 150$ and 1$ = 50 Taka.

Similarly the cost for expansion of existing tandem T_2 is calculated as 27,00,000 Taka. So the total Network cost is 63,55,72,40 Taka.

Now let us consider that there is no direct route for inter exchange Junction. All exchanges are connected to each other by tandem exchange. From the traffic matrix incoming traffic of tandem T_1 for each exchange is calculated. Corresponding incoming circuits of tandem T_1 is calculated by using Erlang's first formula. By multiplying the number of circuits of each route with corresponding distance the cost of incoming route is calculated as previous. This cost is 21,84,55,000 Taka.

Similarly outgoing traffic and corresponding circuits are calculated for tandem T_1 to existing exchanges, tandem T_1 to new exchanges and tandem T_2 to new exchanges.

In each case cost is calculated as previous. Cost of outgoing trunk route of tandem T_1 to new exchanges, tandem T_1 to existing exchanges and tandem T_2 to new exchanges are 10,25,62,800 Taka 12,19,91,200 Taka and 12,19,91,200 Taka respectively.

Tandem size is calculated from the incoming and outgoing circuits of the tandem. The size of T_1 is obtained as 5475 and the cost for the tandem is calculated as 4,10,62,500 Taka. Here per circuit cost is considered as 150$ and 1$ = 50 Taka.

Similarly the cost for expansion of existing tandem T_2 is calculated as 1,13,40,000 Taka. So the total Network cost is calculated 61,74,02,700 Taka.

Optimum Erlang is obtained by plotting a graph of number of inter exchange route vs Erlang and tandem size vs Erlang is shown in figure 7.4. From this graph it is found that 23 Erlang is a optimum point for network design. Considering this 23 Erlang we changed the traffic matrix and shown in table 7.26.

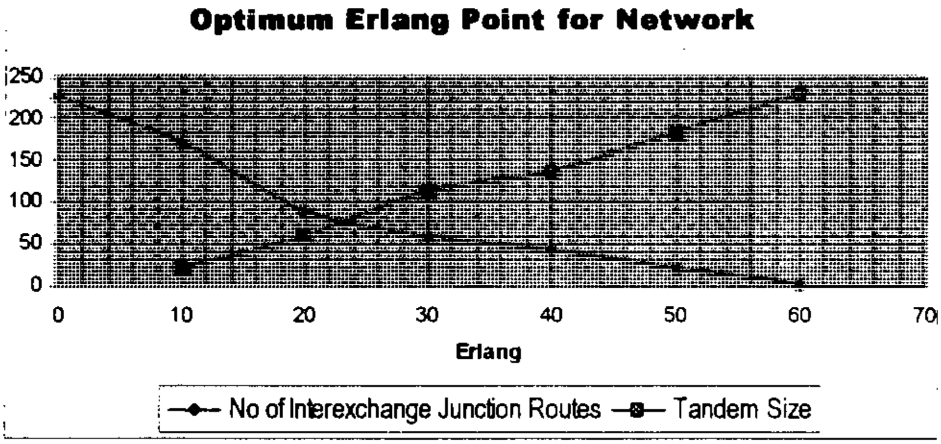


Fig 7.4 Optimum Erlang Point for 08 Exchange Network

Table 7.26. Traffic Matrix Considering 23 Erlang and below.

	1A	2B	3C	4D	5E	6F	7G	8H
1A	0	17	9	10	NC	NC	NC	8
2B	20	0	8	13	NC	NC	NC	10
3C	10	9	0	12	NC	16	9	4
4D	11	13	14	0	NC	12	15	16
5E	NC	NC	NC	22	0	NC	NC	15
6F	NC	NC	14	11	NC	0	NC	12
7G	NC	NC	8	13	NC	NC	0	15
8H	9	8	10	14	12	10	13	0

- Not Considered = NC

Considering the traffic matrix in table 7.26. incoming trunk route cost of tandem T_1 is calculated as previous case. This cost is 8,47,28,000 Taka.

Similarly outgoing traffic and corresponding circuits are calculated for tandem T_1 to existing exchanges, tandem T_1 to new exchanges and tandem T_2 to new exchanges.

In each case cost is calculated as previous. Cost of outgoing trunk route of tandem T_1 to new exchanges, tandem T_1 to existing exchanges and tandem T_2 to new exchanges are 4,54,73,000 Taka 4,54,73,000 Taka and 4,54,73,000 Taka respectively.

Similarly tandem size is calculated from the incoming and outgoing circuits of the tandem. The size of T_1 is obtained as 1820 and the cost for the tandem is calculated as 1,36,50,000 Taka. Here per circuit cost is considered as 150$ and 1$ = 50 Taka.

Similarly the cost for expansion of existing tandem T_2 is calculated as 34,12,500 Taka.

For cost calculation of direct route we consider 24 Erlang and above for inter exchange traffic and traffic matrix is calculated as shown in table 7.27.

Corresponding distance considering only the link 24 Erlang and above traffic matrix is obtained and shown in table 7.27.Corresponding circuit matrix is calculated by using Erlang first formula.

Multiplying the number of circuit with corresponding route distance total cost of direct route is calculated as previous. The cost of direct route is 37,05,06,300 Taka. So the total cost of the Network is 60,80,85,800 Taka.

Table 7.27. Traffic Matrix Considering 24 Erlang and above.

	1A	2B	3C	4D	5E	6F	7G	8H
1A	NC	NC	NC	NC	51	27	30	NC
2B	NC	NC	NC	NC	50	25	29	NC
3C	NC	NC	NC	NC	37	NC	NC	NC
4D	NC	NC	NC	NC	NC	NC	NC	NC
5E	51	52	32	NC	NC	52	46	NC
6F	24	34	NC	NC	50	NC	45	NC
7G	34	29	NC	NC	52	42	NC	NC
8H	NC	NC	NC	NC	NC	NC	NC	NC

- NC= Not Considered

The junction network plays a very important role in a multi exchange urban area. In this study we have considered a model area which is already a multi exchange urban area. Where demand is growing day by day as well as there are pending demands. We are to plan for the expansion to satisfy this growing demand as well as dimension the whole network in such a way that economically it is optimum though in some cases optimum point in respect of complexity is considered. Here cost calculations are considered for four alternatives. They are:

a) In the first case the network is considered such that there is no tandem circuit for inter exchange junction network. Only the direct circuits are considered for inter exchange junction routes.

b) In the second case it is considered that there are direct high usage routes for inter exchange junction network as well as there are alternate tandem junction circuits.

c) In the third case only the tandem circuits are considered for inter exchange junction . No direct circuits are considered for inter exchange junction routes.

d) In this case complexity of circuit management is also considered . That is when the network is expanding more and more at that time if we consider only the direct routes for inter exchange junction then there will be huge number of direct routes in the network. On the other hand if we consider only tandem circuit for inter exchange junction then the tandem network will be huge to control. In that case we can find out the optimum point of Erlang above that inter exchange traffic direct route is considered and below that inter exchange traffic tandem circuit is considered . So in this case the number of direct routes and size of tandem network both are in optimum position to control . This point is found out from the graph of a number inter exchange direct routes vs Erlang and tandem size vs Erlang. For this case study this point is 30 Erlang .So in this case tandem circuit network in considered for below 30 Erlang inter exchange traffic and direct routes are considered for the inter exchange traffic above 30 Erlang.

Total cost of the network is calculated in each alternative. They are:

1) In the first case total cost of the network is 61,03,25,100 Taka.
2) In the 2nd case the total cost of the network is 63,55,72,400 Taka.
3) In the 3rd case total cost of the network is 61,74,02,700 Taka.
4) In the last case total cost of the network in 60,86,85,800 Taka.

From the results of the four alternatives it is seen that if we consider the optimization of the net work economically then the fourth case is the optimum case. And the corresponding network is the optimum network. If we analyse the four alternatives in respect of complexity of network then it is also the fourth case which is the optimum case. So we can consider the fourth case as the optimum case. And corresponding network as the optimum network. The route matrix of the final network is shown in table 7.28. Logical diagram of the optimum network is shown in figure 7.5.

It is to be noted here in telecommunication system that the cost is not always the only deciding factor to choose the network or dimension the network. Some time security plays an important role when it is required , In that view case two is important because in this network every junction has alternate route. If some times it happens that one of the routs is faulty other route can continue the communication though the grade of service is not up to the level. It is to be noted here that though security is good in this case but the network cost is not the least one. So different condition may have to be considered to dimension a network according to requirement but the important thing is that there must have tools to analyse the network properly.

Table 7.28. Route matrix.

	1A	2B	3C	4D	5E	6F	7G	8H	1A1	2B1	3C1	4D1	5E1	6F1	7G1	8H1
1A	T	T	T	T	H	T	T	T	T	T	T	T	H	T	T	T
2B	T	T	T	T	H	T	T	T	T	T	T	T	H	T	T	T
3C	T	T	T	T	H	T	T	T	T	T	T	T	H	T	T	T
4D	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
5E	H	H	H	T	T	H	H	T	H	H	H	T	T	H	H	T
6F	T	H	T	T	H	T	H	T	T	H	T	T	H	T	H	T
7G	H	T	T	T	H	H	T	T	H	T	T	T	H	H	T	T
8H	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
1A1	T	T	T	T	H	T	T	T	T	T	T	T	H	T	T	T
2B1	T	T	T	T	H	T	T	T	T	T	T	T	H	T	T	T
3C1	T	T	T	T	H	T	T	T	T	T	T	T	H	T	T	T
4D1	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
5E1	H	H	H	T	T	H	H	T	H	H	H	T	T	H	H	T
6F1	T	H	T	T	H	T	H	T	T	H	T	T	H	T	H	T
7G1	H	T	T	T	H	H	T	T	H	T	T	T	H	H	T	T
8H1	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T

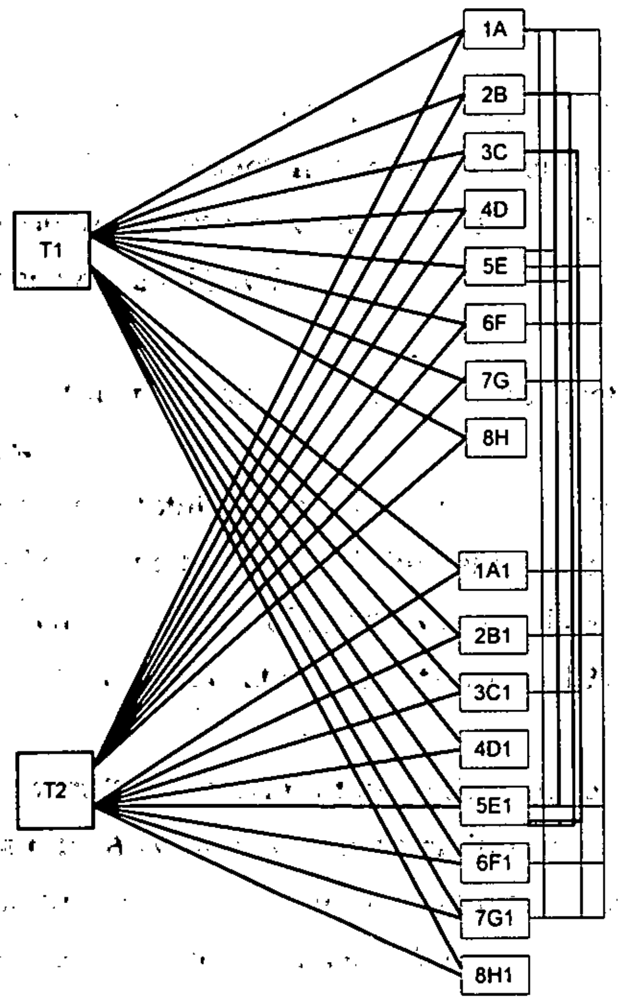


Fig 7.5 Logical diagram of the final network.

Similarly another model area is considered with 10 existing exchanges i.e now we are studing a model area with 10 exchanges instead of 08 exchanges considered in the previous case. As in the previous case all the four alternatives are considered.

Total cost of the network is calculated in each alternative. They are shown below:

1) In the first case total cost of the network is 149,43,28,500 Taka.
2) In the 2nd case the total cost of the network is 129,32,41,000 Taka.
3) In the 3rd case total cost of the network is 128,54,32,500 Taka.
4) In the last case total cost of the network in 127,17,71,000 Taka.

From the result it is seen that as in the previous case the fourth case is the cheapest one. As well as the network in this case is less complex. So this is the optimum network. The graph to findout the optimum Erlang for the fourth alternative is shown in figure 7.6.

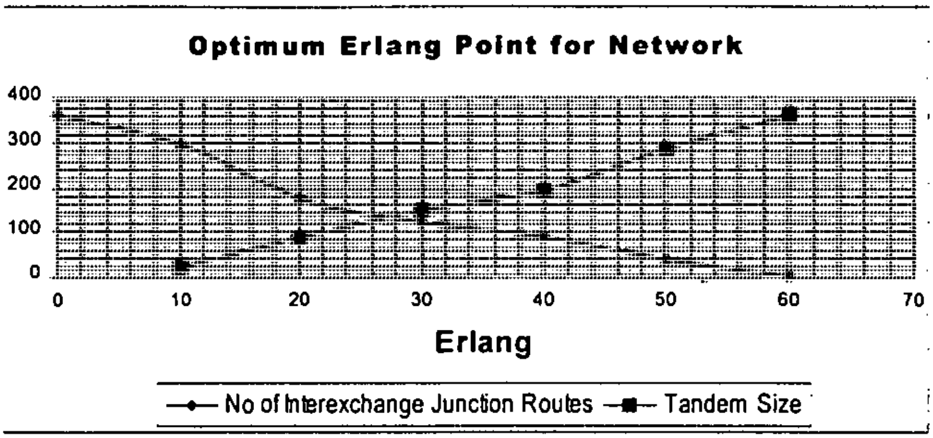


Fig 7.6 Optimum Erlang point for 10 exchange Network

CHAPTER EIGHT

CONCLUSION

8. INTRODUCTION.

For attaining sustained growth in the socio-economic infrastructure of a nation, a well balanced and widely developed telecommunication system is one of the major pre-requisites. Its sphere of activities now-a-days, has stretched to almost every aspects of our life, be it on trade or commerce, agriculture, or industry, education or culture, sports or entertainment, health or social welfare, politics or world peace, environment or disaster management. The wide range of application of telecommunications technology with its phenomenal advancement in recent times, is bringing the people of the world closer and the fast developing 'global information infrastructure' is making the concept of ' global village' into a reality.

So development of telecommunication system deserves the priority and optimization and dimensioning plays a vital role in the development of telecommunication system.

8.1 CONCLUSION

In telecommunications, the geographical location of investment is Particularly important, much more than for other distribution networks such as electricity, gas, etc. This peculiarity is apparent when it is realized that each subscriber has at his disposal an individual pair of wires connecting his telephone to the local exchange. This necessary individualization is the source of the difficulty. Structural options must thus be adopted for the network in relation to the geographical distribution of potential customers: incorrectly located spare capacity will be wasted or will lead to prohibitive operating costs.

Each type of investment is made at a different geographical level:

- transmission: country, region (transit areas);

- switching: all towns (local switching areas);
- distribution: districts (distribution cabinets) rural communities.

The existence of " service areas" at different levels in a hierarchical structure imposes a correlated need for hierarchical telephone demand forecasts at even finer geographical levels: these forecasts will constitute the basis and principal justification for the investment decisions at each level.

Forecasting is not included in this study because main aim of this study was optimization and dimensioning. So the data for traffic demand is obtained not from traffic forcasting but a model area is taken for study and model data is assumed for study.

Two basic types of deviation from the demand forecast may occur:

Volumes of equipments and distribution materilize as forecasted but there is a change in the timing. If the demands appear earlier than expected, extensions must be made before originally planned or demand will not be satisfied. The effect is not too significant from the economic point of view. It the demand appears later than forecasted, part of the equipment is not used or inefficiently used, which means poor use of investments. The worst case is when the demand does not appear during the life of the equipment.

The demand was forecasted in one place and materialized in another. This is one of the worst cases as it is equivalent to having an underestimate in one place and an overestimate in the other at the same time. Depending on particular conditions, rearrangements or removals and reinstallations of equipment will have to occur. Sometimes the basic structure of the network is affected, bringing heavy penalties.

The basic risk associated with over-dimensioning is that the excess equipment will be used either a long time after its provision or never. Under dimensioning has the risk of requiring additional installations and can sometimes be costly. In some cases these installations may cause the network to become more complex. Furthermore, the reaction time between the additional order and its implementation may cause the service to deteriorate.

The normal philosophy of planning is to make a plan to satisfy the future forecast demand based on present day costs and technology. The difficulties in forecasting technological changes reinforce this procedure. However, it is sometimes possible, particularly in short-range planning to have an idea of the trends and to take them into account. In these cases the planner evaluates the consequences that cost trends will have on the studied alternatives. This is normally performed by analyzing the sensitivity of the plan to changes in cost parameters.

In certain circumstances it is technically possible to adopt a transitory solution, using equipment that is easy and cheap to remove and reuse. These solutions can be adopted temporarily pending clarification of demand uncertainties. Once the uncertainty disappears a permanent solution will replace the temporary solution.

When the traffic between two points of a long distance network is very high (more than 100 erlangs), a common practice is to carry final traffic on different physical paths. In the case of a fault on one of these paths, at least part of the traffic can be handled on the other. Another common practice is to limit the maximum number of subscriber lines (in one building, for example) to 60000 or 80000 for reasons of security. In a similar way the maximum number of erlangs handled in a transit exchange in a metroplitan area may be also limited. All these constraints, and others which can similarly be imposed on a network for reasons of security, lead to network structures which differ from the economic optimum.

To optimize the network from the economic point of view considering demand, grade of service under normal conditions, probability of a catastrophic event and deterioration of the service when this catastrophic event occurs. This approach is rather complicated and is not considered here.

If at any time it is found that a direct route is economical, the decision is taken to establish it. The connection between any pair of switching centres always uses a minimum-length path. This is to be taken into account when studying the comvenience of opening a direct route.

It is well known that for a given grade of service the relationship between the traffic to be carried and the necessary number of junctions is not linear. For example, to carry 1.13 E with a GOS of 0.5% circuits are necessary, the efficiency or use of these circuits being 22.6% (1.13÷5%). In a similar way 9 Junctions carry 3.33 E with an efficiency of 37.0% and 66 circuits carry 50.1 E with an efficiency of 75.9%. With a GOS of 1%, 64 circuits carry 50.6 E with 79.0% utilization. This lack of linearity between Junctions and carried traffic plays an important role in functional network optimization, as the tendency is to collect small packets of traffic together to increasethe efficiency of Junctions. In other words, small packets of traffic call for star configurations and large packets of traffic lead to mesh network [7].

When the amount of traffic increases the tendency is to justify more direct connections between exchanges. Two towns with the same number of exchanges and the same topology but with different amounts of traffic, may have rather different optimumjunction networks.

In urban areas, Junction networks generally present only one hierarchical level and consequently a maximum of only two transit exchanges are involved in a call. This is in contrast to long distance networks where two or three hierarchical levels are normally found.

To diminish the switching cost and to increase the flexibility, the combination of local and transit functions in the same switch is a practice being introduced with SPC systems, particularly with digital technology. This does not create any particular difficulty for 'Junction network optimization.

The most common restrictions are caused by the switching equipment. In a local area the local exchanges have been installed at different times, using technology which at that time appeared perfectly adequate. In old equipment the lack of some of the capability of modern equipment sometimes imposes severe constraints on the Junction network.

The most common, and significant restrictions are:

- a limitation in the number of outgoing routes;
- an inability to perform alternative routing;
- a signalling system in that some cases may prevent the establishment of some routes;
- limitation in the number of incoming and outgoing junctors which the equipment can accommodate;
- a lack of full accessibility, or the parameters defining the accessibility when this is limited.

The first three limitation have imposed strong constraints in the past, particularly with step-by-step switching systems. All, and in particular the first, have had more effect on the definition of network structures of many metropolitan areas than have any economic implications.

Other sets of restrictions arise from limitations on the extension of existing equipment, building space and location, etc. Finally, security requirements may influence the solutions chosen. For instance, protection against overloads may limit the efficiency of Junction circuits and protective measures against sabotage or disaster may influence the decision as to whether to split the transit function between two transits or to concentrate it on one.

The growing need of using cordless systems in outdoors environments, carries out an added complexity to existing one when planning these systems in indoors environments. Taking into account the extension of the areas under study, that most of times make very expensive in-situ measurements, it is necessary to have available new Planning Methodologies for these applications [16].

The incorporation of interactivity to distribution networks, or inversely, the provision of distribution services over interactive networks give place to new network design and planning issues, which impose nowadays important constraints to the deployment of evolutionary access architectures [20].

The purpose of telecommunications network planning is to provide an optimum compromise among the traffic demands of telecommunications services, the network modernization objectives, the quality performance and the economic aspects, by taking into account the existing networks, the equipment available and the fundamental technical and other constraints [33].

8.2 SCOPE OF FUTURE RESEARCH

In this age of Information Technology (IT) telecommunication system plays a very important role in data communications. Data communication is not dependent on data network only now a days. But public switched telephone network (PSTN) takes a big fraction of the load of data communication. Dial up connection service facilities in data communication is based on public switched telephone network. Anybody who has a telephone line can connect to a data network like internet network or public switched data network (PSPDN) just by replacing the telephone set with a personal computer through a modem.

So further research on this telephone system optimization and dimensioning is very much required for infrastructure development of Information Technology.

In this study and research of telecommunication system most of the input datas are assumed, as the collection of real life datas are very complicated and complex job as well time consuming. In telecommunication system planning forecasting is used for obtaining data. It is an important area for further research to consider forecasting in collecting input data for optimization and dimensioning of telephone system.

Hierarchy of switching in telecommunication network is very important. Whenever a telecommunication network increases it needs transit exchanges for routing its traffic to different parts of the network. When the network increases more and more at that time 2^{nd} level transit exchanges are needed over the first level transit exchanges for routing the traffic. In this research work only one level hierarchy is consider but further research work can be done considering more that one level higherarchy.

Reliability and security of a big telecommunication network is very important. For reliability and security of a network different alternating routes may be considered. It is an important area for further research to consider the alternating route in the network.

Now a days open market economy is encouraged all over the world. And privatization plays important role in the telecommunication sector.

Now a days privatization is encouraged all over the world. Specially in telecommunication sector privatization is very much encouraged. In Bangladesh many private companies are coming up as an operator in telecommunication sector. But a very important problem arises for the operators in interconnecting and sharing the networks with each other. As the number of operators are increasing and the traffic of each network in increasing, the problem become more complicated. It is an important area for further research of telephone network to consider the interconnection problem between different telephone operators.

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