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STATE CRIMINAL JUSTICE TELECOMMUNICATIONS (STACOM)

NETWORK DESIGN AND PERFORMANCE ANALYSIS TECHNIQUES

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FOREWORD

The State Criminal Justice Telecommunications, (STACOM), Project consists of two major study tasks. The first entails a study of criminal justice telecommunication system user requirements and system traffic requirements through the year 1985. The second investigates least cost network alternatives to meet these specified traffic requirements.

Major documentation of the STACOM Project is organized in four volumes as follows:

Title	Document No.
State Criminal Justice Telecommunications (STACOM) Final Report - Volume I: Executive Summary	77-53 Vol. I
State Criminal Justice Telecommunications (STACOM) Final Report - Volume II: Requirements Analysis and Design of Ohio Criminal Justice Telecommunications Network	77-53 Vol. II
State Criminal Justice Telecommunications (STACOM) Final Report - Volume III: Requirements Analysis and Design of Texas Criminal Justice Telecommunications Network	77-53 Vol. III
State Criminal Justice Telecommunications (STACOM) Final Report - Volume IV: Network Design Software Users Guide	77-53 Vol. IV

The above material is also organized in an additional four volumes which provide a slightly different reader orientation as follows:

Title	Document No.
State Criminal Justice Telecommunications (STACOM) Functional Requirements - State of Ohio	5030-43
State Criminal Justice Telecommunications (STACOM) Functional Requirements - State of Texas	5030-61
State Criminal Justice Telecommunications (STACOM) User Requirements Analysis	5030-80
State Criminal Justice Telecommunications (STACOM) Network Design and Performance Analysis Techniques	5030-99

This document, No. 5030-99, entitled, "State Criminal Justice Telecommunications Network Design and Performance Techniques," describes methodologies employed in the analysis, design, and performance measurement of alternative communication network configurations. It then illustrates the application of these methodologies through the design of a set of network options for the states of Ohio and Texas that meet STACOM Functional Requirements.

This document presents the results of one phase of research carried out jointly by the Jet Propulsion Laboratory, California Institute of Technology, and the States of Texas and Ohio. The project is sponsored by the Law Enforcement Assistance Administration, Department of Justice, through the National Aeronautics and Space Administration (Contract NAS7-100).

GLOSSARY OF ABBREVIATIONS AND ACRONYMS

APB	All points bulletin
BCII	Ohio Bureau of Criminal Identification and Investigation
BMV	Ohio Bureau of Motor Vehicles
BPP	Texas Boards of Pardons and Paroles
bps	bits per second
CCH	Computerized Criminal Histories
CDS	Comprehensive Data System
CJIS	Criminal Justice Information System
CLEAR	Hamilton County, Ohio (Cincinnati) County Law Enforcement Applied Regionally
COG	Council of Governments
CRT	Cathode ray tube
DEA	United States Drug Enforcement Agency
DHS	Ohio Department of Highway Safety
DPS	Texas Department of Public Safety
FINDER	Calspan Technology Products, Inc., registered trademark for Fingerprint Detector Readers
FBI	Federal Bureau of Investigation
HIGH SPEED LINE	A communication line with capacity of 1200 Baud or greater
ICR	Identification and Criminal Records Division of Texas Department of Public Safety
LEAA	Law Enforcement Assistance Administration
LEADS	Ohio Law Enforcement Automated Data System
LIDR	Texas License Identification and Driver Registration
LOW SPEED LINE	A communication line with less than 1200 Baud capacity
MDT	Mobile Digital Terminal
MPL	Multi-Schedule Private Line Tariff
MVD	Texas Motor Vehicle Division
NALECOM	National Law Enforcement Telecommunications
NCIC	National Crime Information Center
NCJISS	National Criminal Justice Information and Statistics Service
NILECJ	National Institute of Law Enforcement and Criminal Justice
NLETS	National Law Enforcement Telecommunications System
NORIS	Lucas County, Ohio (Toledo) Northwest Ohio Regional Information System
OBSCIS	Offender Based State Corrections Information System
OBTS	Offender Based Transaction Statistics
OCCA	Omnibus Crime Control Act of 1968
OCH	Ohio Criminal History
ODRC	Ohio Department of Rehabilitation and Corrections
OSP	Ohio State Police

PD	Police Department
RCC	Regional Computing Center
RCIC	Regional Crime Information Center
RSC	Regional Switching Center
SEARCH	System for Electronic Analysis and Retrieval of Criminal Histories
SGI	Search Group, Inc.
SIFTER	System for Identification of Fingerprints by Technical Search of Encoded Records
SJIS	State Judicial Information System
SO	Sheriff Office
SPA	State Planning Agency
STACOM	State Criminal Justice Communications
TCIC	Texas Crime Information Center
TDC	Texas Department of Corrections
THP	Texas Highway Patrol
TJC	Texas Judicial Council
TLETS	Texas Law Enforcement Telecommunications System
TYC	Texas Youth Council
UCR	Uniform Crime Reports

CONTENTS

SECTION I

SUMMARY

SECTION I

STUDY SUMMARY AND CONCLUSIONS

1.1 OBJECTIVES OF NETWORK DESIGN

The State Criminal Justice Communications, (STACOM), network design and performance measurement study was performed to support the primary STACOM project objective of providing states with the tools needed for designing and evaluating intrastate communications networks. The STACOM project goals are:

(1) Develop and document techniques for intrastate traffic measurement, analysis of measured data, and prediction of traffic growth.

(2) Develop and document techniques for intrastate network design, performance analysis, modeling and simulation.

(3) Illustrate applications of network design and analysis techniques on typical existing network configurations and new or improved configurations.

(4) Develop and illustrate a methodology for establishing priorities for cost effective expenditures to improve capabilities in deficient areas.

The STACOM network design objective is to produce the second, third, and fourth components of the STACOM Project goals listed above.

1.2 SUMMARY OF GENERAL METHODOLOGY

Six major activities were carried out in the network design phase of the study. These activities are summarized in the following paragraphs:

1.2.1 Definition of Analysis and Modeling Techniques

A task was undertaken to define and develop specific analysis and modeling tools for general use in intrastate systems. The principal tool developed is the STACOM Network Topology Program. This program, written in FORTRAN V and implemented on a UNIVAC 1108 computer under the EXEC-8 operating system, enables a user to find least cost multidropped statewide networks as a function of traffic level demands and other functional performance requirements.

The major inputs to the program are:

(1) Traffic levels at each system termination on the network

(2) Desired response time at network system terminations

(3) Line tariff structures

(4) Locations of system terminations using Bell System Vertical-Horizontal (V-H), coordinates

(5) The number of desired regional switching center, (RSC), facilities. RSCs serve system terminations in their defined regions and are interconnected to form total networks.

Principal outputs of the topology program are:

(1) Line capacities and layouts servicing system terminations

(2) Fixed and annual recurring costs for lines, modems, service terminals, etc. RSCs are priced separately.

(3) Line performance characteristics such as line utilizations and mean response times

A second major analysis technique enables network designers to determine the reliability and availability of network configurations produced by the topology program.

Finally, a network response time model used in the topology program, is also useful in understanding present and future performance requirements for switching and/or data base computers in the network. This is true because the response time model involves a queueing analysis which includes queueing times encountered at computer facilities.

Descriptions of these design and analysis tools are presented in more detail in Section 2 of this report.

1.2.2 Network Functional Design Requirements

At the completion of state system surveys, and after sufficient interaction with state planning personnel, and prior to any specific network design activity, a document was produced specifying Network Functional Design Requirements. This document provides network performance criteria which are to be met in subsequent designs. The Functional Requirements specify what the network must do, and do not address at this level the specifics of how requirements are to be met.

The network Functional Requirements for Ohio and Texas are presented in Sections 5 and 11 respectively.

1.2.3 Analysis of Existing Networks

This task employed developed design and analysis tools to determine the extent to which existing statewide networks conform to State Network Functional Requirements. Areas of discrepancy are noted and discussed. Results for Ohio and Texas are summarized later in this Section. A detailed discussion is presented in Sections 6 and 12.

1.2.4 Generation of New or Improved Networks

After specific studies of interest were identified with state personnel, STACOM design and analysis techniques were employed to study statewide network configuration alternatives, (options), and additional cost impact studies of interest.

In the State of Ohio, four basic network options were considered for the LEADS system. These involved determining cost and performance measures under the Multi-Schedule Private Line, (MPL), tariff for LEADS configurations employing from zero to three RSCs in addition to the switcher/data base facility in Columbus. The four options were:

Option 1 - switcher/data base located in Columbus (one region).

Option 2 - switcher/data base located in Columbus plus an RSC in Cleveland (two regions).

Option 3 - switcher/data base located in Columbus plus RSCs located in Cleveland and Cincinnati, (three regions).

Option 4 - switcher/data base located in Columbus plus RSCs located in Cleveland, Cincinnati and Toledo, (four regions).

Four more network options were studied in Ohio involving the possible integration of BMV and New Data Networks with the LEADS Network. These options were:

Option 5 - costs for maintaining separate LEADS and BMV networks.

Option 6 - costs for integrating the LEADS and BMV networks into a single network.

Option 7 - costs for maintaining separate LEADS and New Data networks.

Option 8 - costs for integrating the LEADS and New Data networks into a single network.

Two additional network performance studies carried out in Ohio included consideration of LEADS network cost increases as terminal response time requirements are reduced, and an inquiry into the impact on network cost and performance due to adding digitized classified fingerprints as a traffic type to the LEADS system.

In the State of Texas, three basic network options were considered for the TLETS Network. These involved the study of cost and performance measures for one, two and three region networks as follows:

Option 1 - a single switcher located in Austin (one region).

Option 2 - a switcher located in Austin and a second RSC located either in Dallas, or Midland or Lubbock, or Amarillo (two regions).

Option 3 - a switcher located in Austin, and a second RSC located in Dallas with a third RSC located either in Houston, or San Antonio, or Midland, or Lubbock, or Amarillo.

Two additional options were studied involving the possible integration of New Data types in Texas with the TLETS system as follows:

Option 4 - costs of maintaining separate TLETS and New Data networks.

Option 5 - costs of integrating the TLETS and New Data networks into a single network.

Three additional network studies in Texas considered, (1) network cost increases as terminal mean response time requirements were reduced, (2) the impact of network cost and performance due to adding digitized classified fingerprints as a data type to the TLETS system, and (3) the relative difference in network costs between maintaining and abandoning TLETS Network line service oriented toward the existing regional Councils of Government (COGs).

1.2.5 Software Documentation

A final task carried out was the documentation of the STACOM Network Topology Program in the form of a users guide. This document, No. 77-53, Vol. IV, is entitled, "State Criminal Justice Telecommunications (STACOM) Final Report - Volume IV: Network Design Software Users' Guide."

1.3 SUMMARY OF STUDY RESULTS

The study results itemized below are discussed in more detail in Section 8 for Ohio and in Section 9 for Texas in this report. The following summary lists the principal findings of interest for each of the studies carried out in each state.

1.3.1 Ohio Study Outcome

- The least cost LEADS Network is a single region configuration with a switcher/data base facility located in Columbus. The line savings due to the use of one, two or three additional regional switchers do not offset increased costs for regional switcher hardware, sites, personnel, interregion lines and increased engineering costs.

- The STACOM optimized single region LEADS network is less costly than continuation of the present LEADS system over a period of eight years by approximately $2,850,000. This cost differential considers user terminal and line costs only. Columbus switcher/data base costs are not included. The new network also meets all STACOM/OHIO Functional Requirements.

- Response time goals listed in the STACOM/OHIO Functional Requirements are not met in the existing system on low speed lines, and on high speed lines during periods of network peak loading.

- There are no meaningful network cost savings to be realized through the integration of the LEADS and BMV systems if the integrated network is priced with the MPL interstate tariff. A meaningful cost savings can be realized if the integrated network is priced under an intrastate tariff.

- There are no significant cost savings to be realized through the integration of New Data Types into the LEADS network over maintaining separate networks.

- Digitized classified fingerprint data can be added to the LEADS network as specified in this report without compromising performance of the STACOM/OHIO LEADS System.

- LEADS network response time requirements for the STACOM/OHIO single region case can be reduced from 9 to 7 seconds before additional costs are incurred. Reduction to 6 seconds increases annual line costs approximately 2%. Reduction to 5 seconds increases annual line costs approximately 13%.

- The mean service time per transaction in the Columbus switcher/data base computer should be immediately reduced to 470 ms. In 1981 the required mean service time per transaction is 425 ms and in 1985 340 ms is required in order to meet functional requirements for traffic growth. A 4 x 4 processor (4 central processing units) configuration is called for in 1981.

1.3.2 Texas Study Outcome

- The existing TLETS network does not meet STACOM/TEXAS response time Functional Requirements on low speed lines, and on high speed lines at times of network peak traffic loading.

- The existing TLETS network does not meet STACOM/TEXAS system availability Functional Requirements. The

STACOM/ TEXAS networks recommended in this study assume the Austin TCIC/LIDR Data Base computer is upgraded to exhibit an availability of 0.9814 and in multiple region cases, switchers are upgraded to provide an availability of 0.997.

- The least cost STACOM/TEXAS TLETS Network is a single region configuration with regional switcher and data base computers located in Austin. Savings for this configuration over continuation of a three region configuration for a period of eight years is estimated at $2,700,000. The line savings realized through the employment of regional switchers (including regional switchers in Dallas and San Antonio, (as in the present system) do not offset the increased costs of regional switcher facilities.

- An eight-year cost savings of approximately $850,000 can be realized through the integration of New Data Type traffic into the TLETS System.

- TLETS network response time requirements for the STACOM/TEXAS single region case can be reduced from 9 to 7 seconds before additional costs are incurred. Reduction to 6 seconds increases annual line costs approximately 3%. Reduction to 5 seconds increases annual line costs approximately 10%.

- Digitized classified fingerprint data can be added to the TLETS network as specified in this report without compromising performance of the STACOM/TEXAS TLETS System.

- There are no meaningful cost savings to be realized by abandoning C.O.G. oriented line service in Texas. Cost is not a factor in a management decision regarding the continuation of this service.

- Existing lines to the TCIC/LIDR Data Base from the Austin switcher should immediately be upgraded to 4800 Baud.

- Existing lines to the MVD Data Base from the Austin switcher should immediately be upgraded to 4800 Baud.

- The mean service time per transaction in the Austin switcher should be immediately reduced to 130 ms. In 1981, the mean service time per transaction should be 100 ms. This will be sufficient through 1985.

- The mean service time per transaction in the Austin TCIC/LIDR Data Base computer should be immediately reduced to 250 ms. From 1981 to 1985 the mean service time per transaction required is 200 ms.

SECTION II

NETWORK ANALYSIS AND DESIGN TOOLS

SECTION II

NETWORK ANALYSIS AND DESIGN TOOLS

This section describes the principal network and analysis design tools developed and utilized during the STACOM Project.

Section 2.1 discusses the Network Topology Program. Section 2.2 develops the approach to network reliability and availability analysis. Sample calculations are presented for the Ohio LEADS and Texas TLETS systems. Section 2.3 derives the approach to network queueing analysis that leads to the development of network response time analysis techniques. Sample calculations are included for both Ohio and Texas.

2.1 THE STACOM NETWORK TOPOLOGY PROGRAM

Two types of analysis are involved in designing a communication network. The first is concerned with arriving at acceptable line loadings; the second involves the achievement of optimal (least cost) line configurations. The STACOM program has been developed to accomplish both types of analysis.

Before describing the STACOM program itself, we will examine a state criminal justice information system and its communication network as an example of a typical communication network. We will then discuss the goal of the STACOM program.

2.1.1 State Criminal Justice Information System

An information system is usually developed to provide a systematic exchange of information between a group of organizations. The information system is used to accept (as inputs), store (in files or a data base) and display (as outputs) strings of symbols that are grouped in various ways. While an information system may exist without a digital computer, we will consider only systems which contain digital computers as integral parts.

Information systems can be classified in various ways for various purposes. If classification is by type of service rendered, the type of information system which serves a criminal justice community in a state can be considered as an information storage and retrieval system. This type of information system is the subject of our interest. For example, the state of Ohio has an information system with data base located at Columbus. The data base contains records on wanted persons, stolen vehicles and stolen license plates. Also included in the same computer are files of the Bureau of Motor Vehicles (BMV) which contain records on all licensed drivers and motor vehicles in that state.

2.1.2 State Digital Communication Network

For a given state information system, storage and retrieval of data to/from the data base can be accomplished in various ways for different user requirements. In general, the users of a state criminal justice information system are geographically distant from the central data base computer. Since fast turn-around time is a necessity for this particular user community, direct in-line access to the central data base by each criminal justice agency constitutes the most important user's requirements. In addition, it is required to quickly move message data from one agency to another at a different location. All of these goals require a data communication network. Because the computer deals only with digital data, only digital data communication networks are considered here.

A digital communication network consists mainly of a set of nodes connected by a set of links. The nodes may be computers, terminals or some type of communication control units in various locations, while the links are the communication channels providing a data path between the nodes. These channels are usually private or switched lines leased from a common carrier. A simple example of a network is given in Figure 2-1, where the links between modems are the communication lines leased from a common carrier. The communication control unit in city E is used to multiplex or concentrate several lower speed terminals onto a high-speed line. The line which connects cities C, D, and others is called multidrop line which connects several terminals to the data base computer.

2.1.3 A STACOM Communication Network

For the purposes of the STACOM study, a communication network is defined as a set of system terminations connected by a set of links. Each system termination consists of one or more physical terminals or computers located at the same city.

2.1.4 Communication Network Configurations

The communication network for an information system with a central data base computer will be one of three basic network configurations: the star, the multidrop, or distributed connection. These three types are shown in Figure 2-2.

As shown in the figure, the star network consists of four direct connections, one for each system termination. Each connection is called a central link. The multidrop network has one line with two system terminations and two central links. In the distributed network shown, more than one path exists between each individual system termination and the central data base.

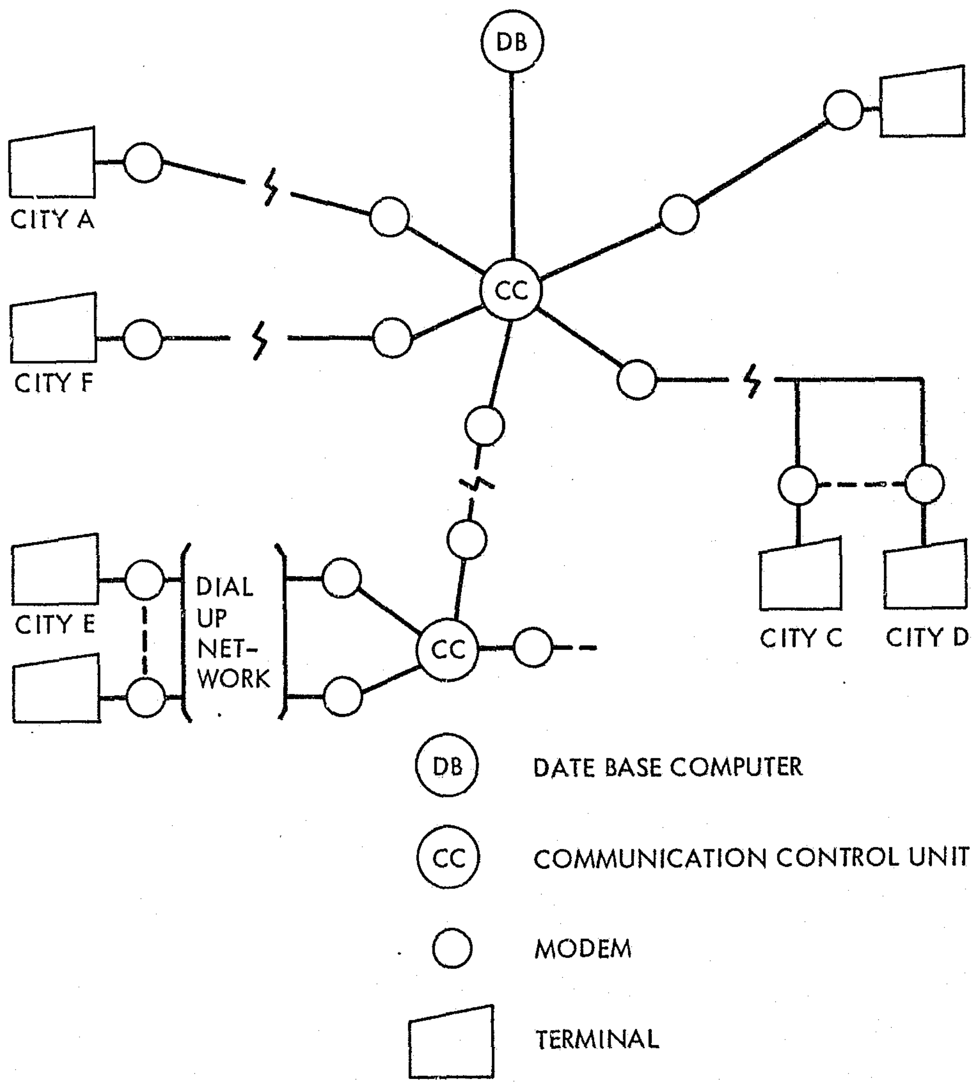


Figure 2-1. Example of a Digital Communication Network

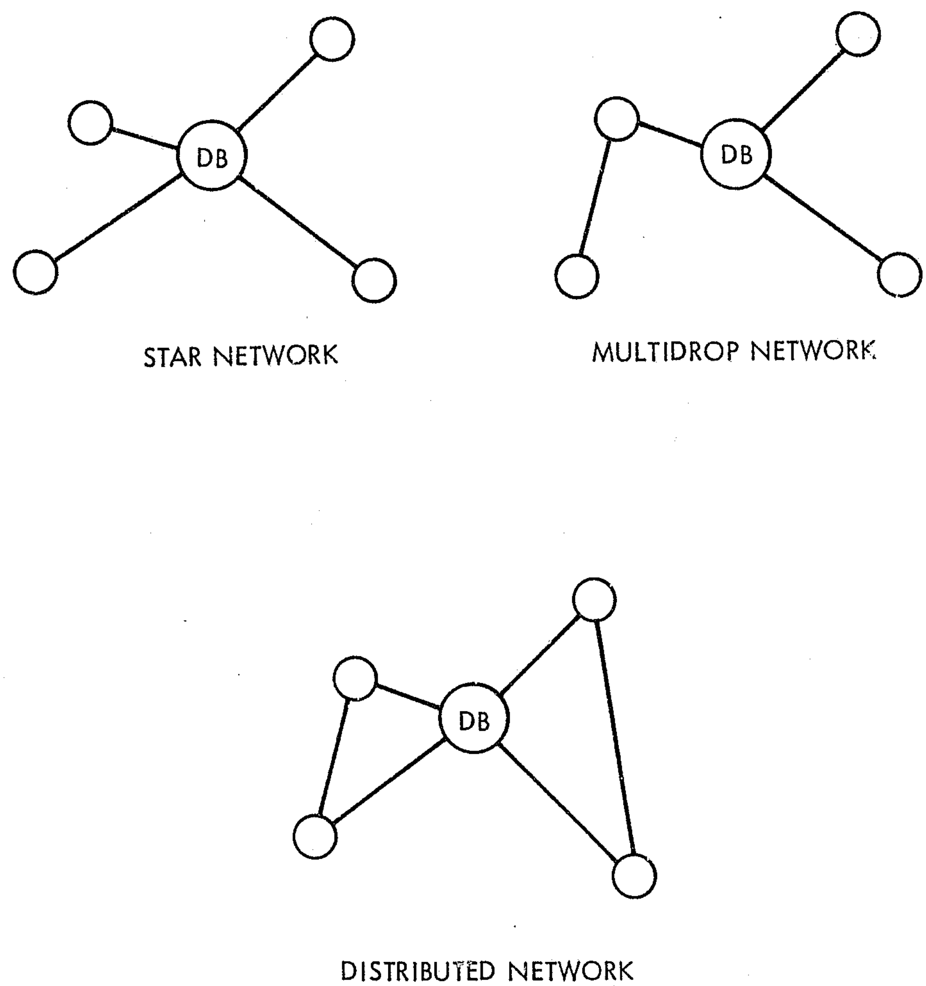


Figure 2-2. Basic Communication Network Configurations

2.1.5 Network Optimization

Given a communication network, the operating costs for the various types of lines or common carrier facilities required are governed by tariffs based upon location, circuit length and type of line. Experience suggests that the operating cost of a network can often be substantially reduced by an initial investment in a configuration analysis. In other words, some efforts in network optimization generally provide cost-saving.

There are two ways of constructing a communication network in a geometrical sense. One can divide a communication system into several regions, construct a minimum cost regional communication network for each region, and then build an inter-regional network connecting all of the regional centers to the central data base center. Each regional center is responsible for switching messages issued from and returned to each system termination in the region. Alternatively, one can consider the whole system as a region which is entirely made up of system terminations, and perform optimization for that region.

2.1.6 The STACOM Program and its Purposes

One of the objectives in the STACOM study is to design minimum cost and effective communication networks which will satisfy the predicted future traffic load for both selected model states, Ohio and Texas. In order to achieve this objective, the STACOM program was developed and utilized for the analysis and synthesis of alternative network topologies. It is also the project's goal that the final product be a portable software package which can be used as a network design tool by any user.

In network design, two major problems are the selection of a cost-effective line configuration for given traffic, and the design of a least cost network to arrive at lower operating costs.

The goal of the STACOM program is to provide a user with a systematic method for solving both problems. In other words, the main purpose of the STACOM program is to provide the network designer with a tool which he can use for line selection and for obtaining least-cost line connections.

2.1.7 Functions Performed by the STACOM Program

The STACOM program is a software tool which has been developed for the purpose of designing least cost networks in order to achieve lower operating costs. It utilizes a modified Esau-Williams technique to search for those direct links between system terminations and a regional switching center (RSC) which may be eliminated in order to reduce operating costs without impairing system performance below that specified. The RSC either provides a switching capability or is a data base center or both.

Inputs for the STACOM program contain data such as traffic, terminal locations, and functional requirements. The network may be divided into any number of desired regions in any given program run. Each region has an RSC which serves terminals in its region. RSCs are finally interconnected to form the complete network. Upon receipt of a complete set of input data, the program first performs formations of regions and, if needed, selection of RSCs. The program then builds a regional network in which only system terminations in the region are connected. The program then optimizes the regional network for each region requested by the user.

The formation of regions is performed by the program on the basis of attempting to arrive at near equal amounts of traffic for all regions. After finding the farthest unassigned system termination from the system centroid (a geographical center), the program starts formation of the first region by selecting unassigned system terminations close to this system termination until the total amount of traffic for that region is greater than a certain percentage (90% in this implementation) of the average regional traffic. The average regional traffic is simply the total network traffic divided by the number of desired regions. The same process is repeated by the program in forming the rest of the regions.

The selection of an RSC is based on the minimal traffic-distance product sum. In the selection process, each system termination is chosen as a trial RSC and the sum of traffic-distance products is then calculated. The location of the system termination which provides the minimal sum is then selected as the RSC. The location of the RSC for a given region may also be specified by the user. The optimization process consists of two basic steps, i.e., searching for lines whose elimination yields the best cost saving, and updating of the network. The two steps are repeated until no further saving is possible.

Before performing network optimization, the STACOM program constructs an initial star network in which each system termination is directly connected to the regional center. It then starts the optimization process. At the termination of this process, a multidrop network is generally developed. In a multidrop network, some lines have more than one system termination; these are called multidrop lines.

When needed, the STACOM program will continue to form an interregion network, which consists of a set of regional centers and has a direct link between any two region centers. The program then performs optimization on the network.

The process for interregional network optimization involves the same two steps: searching and updating. However, the searching step is primarily for finding an alternate route to divert traffic between two regional switching centers with the best saving.

Based on the data provided, a successful run of the STACOM program generates a regional printer output and, if requested, a CalComp plot. The printer output contains data such as initial regional network and optimized network, assignments of system terminations, etc. The CalComp plot shows the geographical connections of the optimized network in which multidrop line actually connects all of the system terminations.

Figure 2-3 gives examples of regional star networks and initial inter-regional network; Figure 2-4 gives examples of optimized regional networks and inter-regional network obtained from Figure 2-3.

2.1.8 Main Features

As described in Paragraph 2.1, the STACOM program has been developed for the purpose of performing analysis and synthesis of alternative network topologies. The following is a list of features which characterize the STACOM program:

(1) The Esau-Williams routine has been modified, tested, and utilized for determining near optimal (least cost), network topology.

(2) A tree type structure is used as the storage structure in the program.

(3) The program execution has been made flexible; for example, constraint on response time for a multidrop line is an input parameter.

(4) A response-time algorithm has been implemented in the program.

(5) A CalComp plotting routine has been included for drawing resulting multidropped networks.

In the rest of this subsection, these main features are discussed in detail.

2.1.8.1 Structure

2.1.8.1.1 Storage. Since a multidrop network can be viewed as a tree composed of sub-trees, it was determined that a tree-type data structure would be appropriate and convenient for representing a multidrop network.

A tree-type storage structure is therefore needed in the program. This tree-type storage structure is implemented by defining a set of storage cells.

Each system termination (data) is represented internally by a storage cell in the program. Each cell consists of five fields and each field occupies one word (i.e., a 36-bit word for UNIVAC 1108 computers).

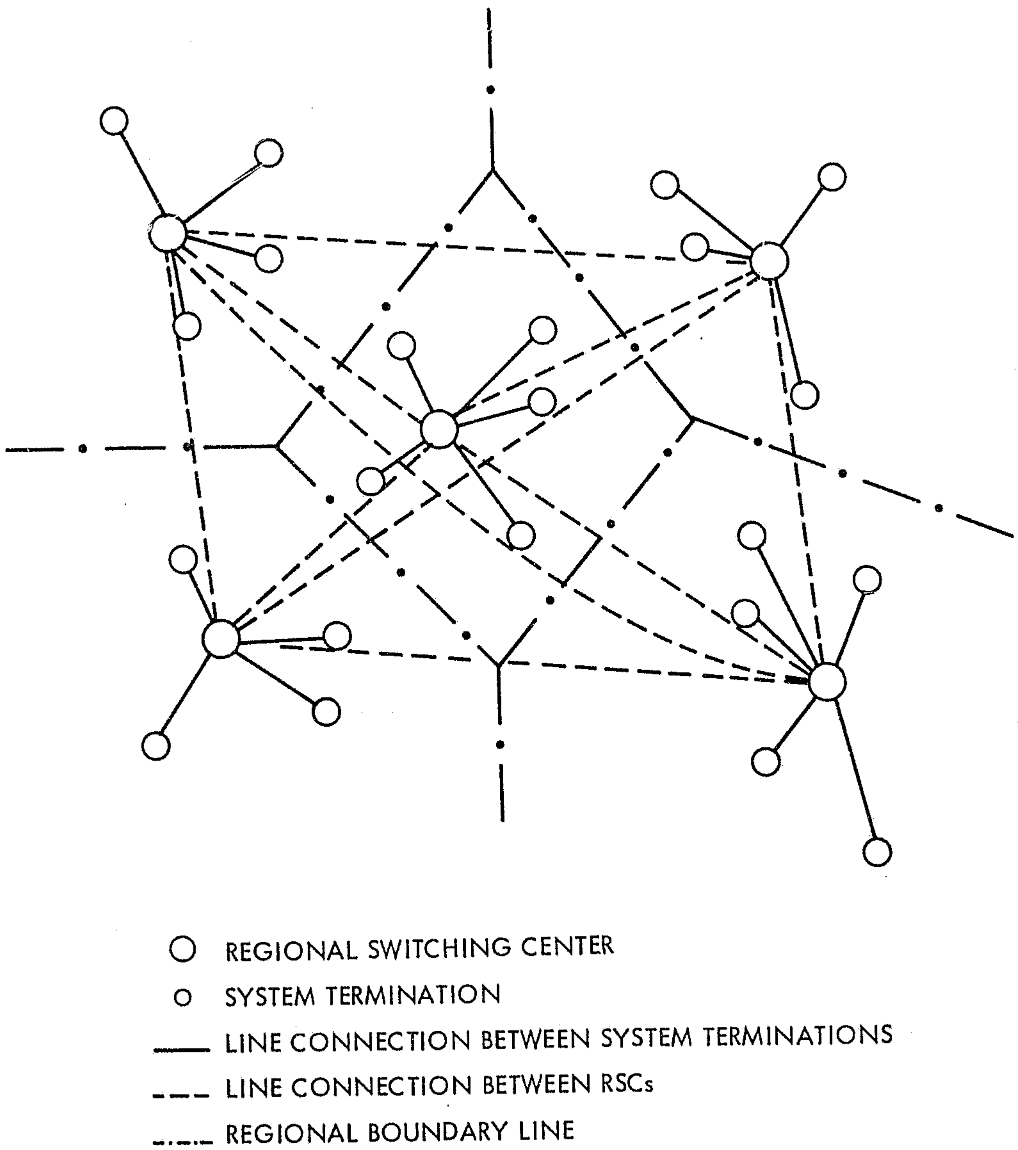


Figure 2-3. Example of Initial Region Network and Initial Interregion Network

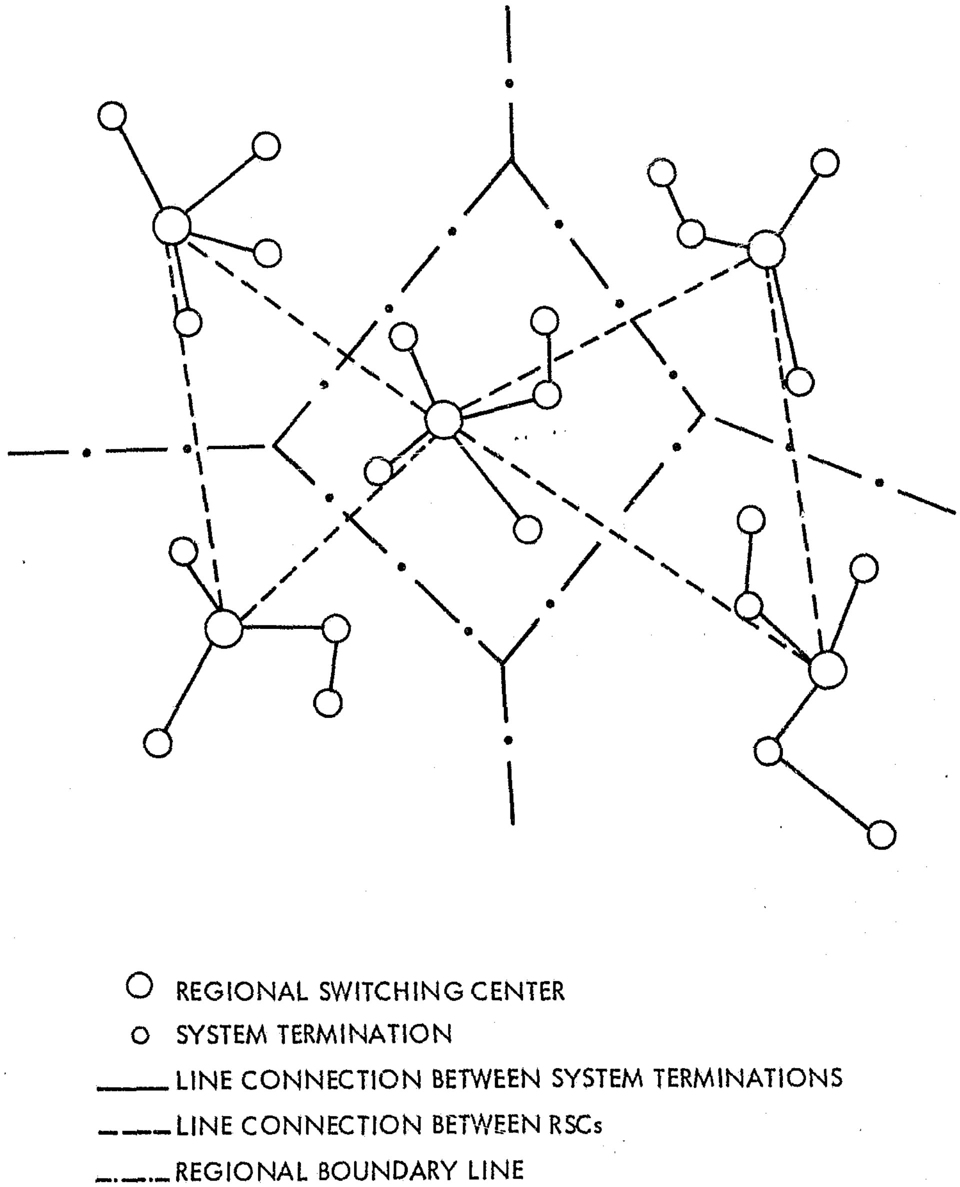


Figure 2-4. Example of Optimized Regional Networks and Optimized Interregion Network

Defining that system termination X as a successor of Y, and Y a predecessor of X if X branches out from Y, and defining X as the root of a tree if it has no predecessor before it, then the basic storage cell for system termination A can be described as follows:

A

I_A

f_1	f_2	f_3	f_4	f_5

Let $c(f_i)$ = content of i-th field in a storage cell I_A, where I_A is an internal index for a system termination A (data), then

$c(f_1)$ = no. of system terminations under A

$c(f_2)$ = a pointer which points to the first successor of A

$c(f_3)$ = a pointer which points to the next system termination whose predecessor is the same as A's

$c(f_4)$ = a pointer which points back to the previous system termination whose predecessor is the same as A's

$c(f_5)$ = a pointer which points to A's predecessor

When there is a "zero" in a field, this indicates there is no one relating to A under that specific relationship. Given a tree as Figure 2-5, A is root of the tree; it has 4 descendents, i.e., B, C, D, and E. Figure 2-6 is the internal representation of that relationship among indice I_A, I_B, I_C, I_D and I_E which are internal cardinal numbers for system terminations A, B, C, D and E.

The first field of storage cell I_A indicates that there are 4 system terminations under I_A; the pointer to I_B says that I_B is its first successor. Since I_A is the root of the tree, the other three fields are left with zeroes.

In the case of I_C, I_D is its next successor of I_A, and its previous successor of I_A is I_B. Its third field has a pointer pointing to I_D, and its fourth field a pointer pointing to I_B.

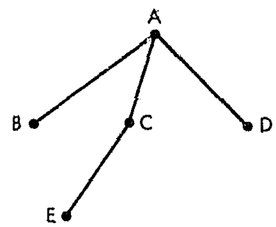
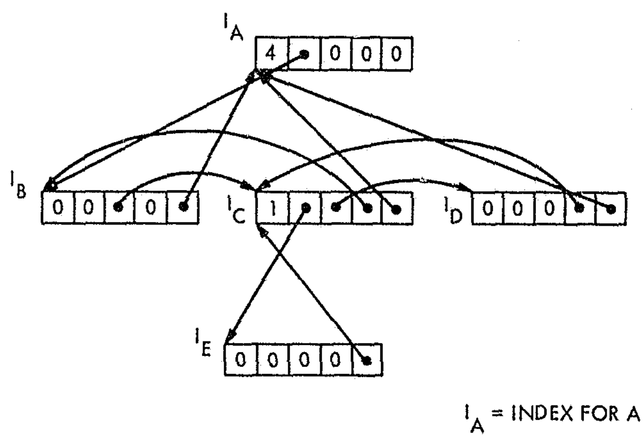


Figure 2-5. A Tree with A as its Root



Fi·ure 2-6. Internal Representation of the Tree in Figure 2.5

2.1.8.1.2 Program. The STACOM program consists of twelve functionally independent routines. Figure 2-7 shows the basic structure of the program. The functional interrelationship is indicated by arrows.

An arrow from routine A to routine B indicates that routine B will be called upon by routine A during its execution. In addition, all of these routines communicate to each other through the COMMON block besides the normal subroutine arguments.

Major functions of these eleven routines are given below:

(1) MAIN Routine
This is the master routine of the STACOM program. In its execution, it reads in all the data required from an input device (card reader or demand terminal) and performs calculations of distances between any two system terminations. It assigns system terminations to

regions, and, if necessary, selects the regional switching center by finding the system termination in the region with the minimal traffic-distance product sum. It calls upon routine RGNNET to build a star network and then performs network-optimization, if required, for each of these regions.

It also performs the construction of an inter-regional network and its optimization by calling subroutine IRNOP.

In addition to these processings, the MAIN routine also prints out distance matrix, traffic matrix, and lists of system terminations by region.

(2) RGNNET Routine

This routine is called upon to act only by the MAIN routine. Its main functions are the formation and optimization of regional star networks. During the formation of a regional star network, each system termination is linked directly to the designated or selected Regional Switching Center (RSC) by assigning the RSC index to the last field of each associated storage cell. Tree relationships are built among system terminations by assigning pointers to the third and fourth fields of each storage cell. The resulting star network is then printed on the printer.

The optimization process utilizes the Esau-Williams algorithm with some modifications. It consists of two steps: searching for a central link (a direct link from a system termination to RSC) with best cost savings under constraints (such as response-time requirement), and subsequent network updating. This network optimization process is executed only upon request. When no further cost improvement is possible, this routine prints a resulting network with data such as number of system terminations and the response time, traffic, cost, etc., associated with each multidrop line. Routine PLOTPT is then called upon to plot the resulting network layout.

(3) IRNOP Routine

This routine is called upon to act by routine MAIN. It forms an interregional network and then performs its optimization. The interregional lines are assumed to be full-duplex lines. During the optimization process, no line between two RSCs can be eliminated if traffic between them cannot be handled through only one intermediate RSC. Also each RSC requires at least two lines to other RSCs.

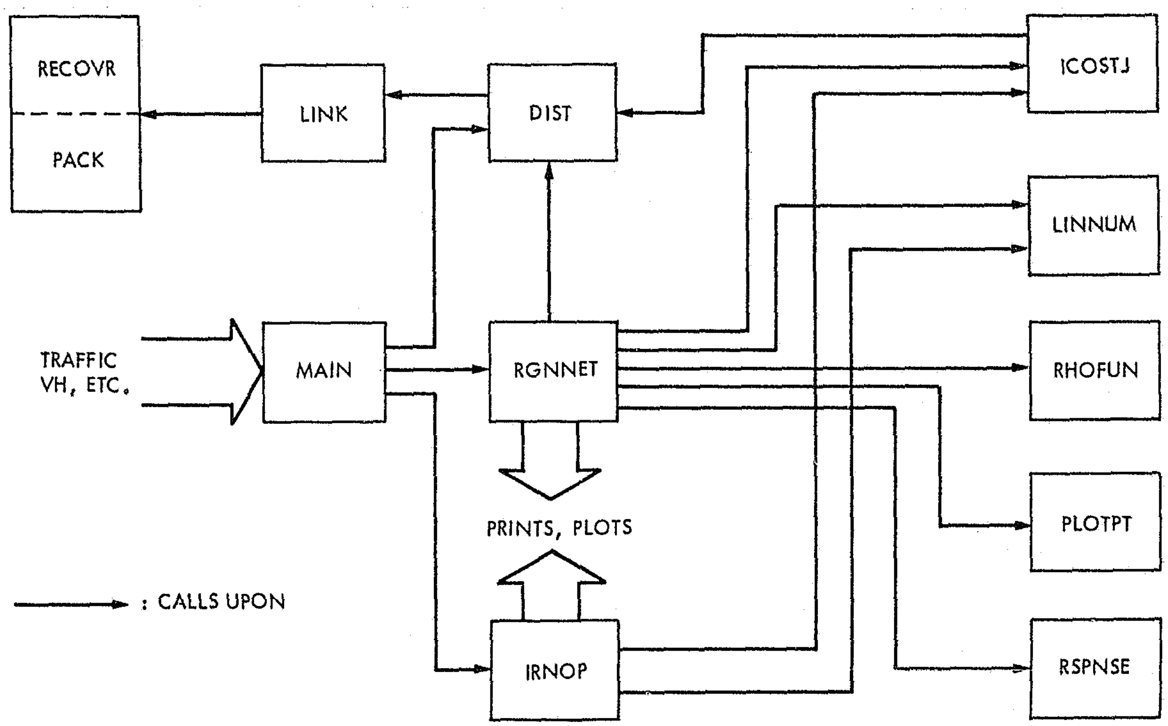


Figure 2-7. STACOM Program Structure

(4) LINNUM Routine
This routine provides an estimated line configuration required to satisfy a given traffic and is mainly called upon by routine RGNNET. During its execution, utilization of selected lines are calculated against the given traffic by calling RHOFUN so that effective line utilization is less than the pre-determined number.

(5) RHOFUN Routine
This routine calculates the line effective utilization for a given traffic and line configuration.

(6) ICOSTJ Routine
Given the line configuration and indices for any two system terminations, this routine calculates the installation costs and annual recurring costs for the line and other chargeable items required. In calculating line costs, it calls upon routine DIST for distance data between two given system terminations. Resulting cost data are arranged by chargeable item type.

(7) DIST Routine
This routine retrieves distance data between any two system terminations by calling routine PACK. When the distance is greater than 510 miles, it retrieves distance data by calling routine RECOVR.

(8) PACK Routine
This routine stores or retrieves distance data between any two system terminations. It is called upon by routine MAIN for distance data depositing, and called upon by routine DIST for its retrieval. For the purpose of saving storage, distance data has been compressed, and each 36-bit word has been divided into four sub-words of 9 bits. Therefore, any distance datum with value equal to or greater than 511 is stored in another specified area; its retrieval calls upon routine RECOVR.

(9) RECOVR Routine
During distance data retrieval in the execution of the DIST routine, if the return value from routine PACK is 511, this routine will be called upon to provide the actual distance data, which is equal to or greater than 511.

(10) LINK Routine
Since the distance between any two system terminations I and J is independent of how I and J are referred to, the routine LINK provides a mechanism for preserving such an independency by mapping I and J into an absolute index.

(11) PLOTPT Routine
This routine provides instructions for plotting a given point on a CalComp plotter. Location of a point is calculated by its associated V-H coordinates.

2.1.9 Response Time Algorithm - RSPNSE Routine

There is a limit on the number of terminals which can be linked together by a multidropped line due to constraints on reliability and response time. However, it would be an oversimplification to just use a particular number as the main constraint in determining how many terminals a multidrop line can have. In reality, the response time of a given multidrop line depends on the amount of traffic, the number of terminals on the line, and very heavily, on the number of transactions to be processed in the data base computer system.

In the STACOM program, a response time algorithm is implemented in such a way that during the network optimization process it is used to accept or reject the addition of a given terminal to a multidrop line. This response time routine calculates the average response time on the given multidrop line, given the number of terminals and amount of peak traffic on the line. Before its inclusion in the STACOM program, the fidelity of this algorithm was evaluated by simulation and found to be acceptable.

2.1.10 Flexibility

At the outset of the STACOM project it was anticipated that the STACOM program would be used for states with varying traffic requirements; it was decided that the resulting program should be as flexible and general as possible. With this in mind, the STACOM program has been implemented with the following features which make it flexible and thereby enhance its capabilities:

(1) Rate Structures, Line Types, and Chargeable Items

Because a state can have more than one rate structure (tariff) applicable at any one time, the STACOM program has been designed to accommodate this.

Under a specific rate structure, any combination of line types with their names, line capacities, and basic cost figures can be prescribed to the program. In addition to the line cost, any number of chargeable items associated with each line type can be prescribed to the program. For example, any combination of cost items such as service terminals, drops, modem and others can be used. Furthermore, under the Multischedule Private Line (MPL) tariffs given by AT&T for interstate communication lines, the monthly line charge between any two terminals is now a function of both the inter-city distance and the traffic densities of both terminal cities.

The STACOM program has been implemented in such a way that it can take line-cost figures based on MPL tariffs or other tariffs.

(2) Region Formation, Switcher Selection, and Network Optimization.

Given a set of system terminations dividing them into regions can be performed in either of the following ways: the user can preassign some or all of the terminations into preselected regions, alternatively the user can let the program perform the region formation by simply providing the system centroid. Following the formation process, the STACOM program will start selecting regional switching centers for regions without a preassigned switching center. The process of regional network formation and its optimization will then follow.

(3) Number of Terminals per Multidrop Line and Average Response Time

It may be desirable to set a limit on the number of terminals on a multidrop line. In its implementation, the STACOM program takes this number from the user's input data as a constraint during its optimization process.

Besides the limit on the number of terminals allowed on a multidrop line, a good network design also requires a constraint on the average terminal response time on a multidrop line. The STACOM program allows a user to specify the limit on a run basis.

2.1.11 Programming Language

The STACOM program is implemented with the FORTRAN V language of UNIVAC systems, compiled with the EXEC-8 FORTRAN Preprocessor and mapped by its MAP processor.

2.1.12 Operating System Requirements

The EXEC-8 operating system of the UNIVAC 1108 computer has been used in the development of the STACOM program. The current edition of the STACOM program can only be executed under the EXEC-8 system. Furthermore, since a CalComp routine is linked with the program, the plotter must be part of the operating system. If such a hardware unit is not included in the system, the STACOM program must be updated to reflect this environment.

In addition, the current STACOM program has been designed with the feature that all the desired output be put into a FORTRAN file designated as 100. Before executing this program, a file with the name 100 must be assigned. Otherwise, regular WRITE unit 6 will be the destination output file, e.g., print output will go to the user's demand terminal when it is run as a demand job.

As an example, the following is a complete list of EXEC-8 control statements which need to be prepared or typed in after the run card for properly executing the STACOM program.

```
@ASG,UP 100
@SYM,P PUNCH$,,G9PLTF
@XQT File.Element
          ⁄
     (data)
          ⁄
@BRKPT 100
@FREE  100
@SYM   100,,T4
```

The @SYM,P command directs the resulting plot card images to a CalComp plotter designated G9PLTF. The last @SYM command directs print output to the slow hardcopy printer designated T4.

2.1.13 Functional Limitations

While the STACOM program has been designed and implemented with the intention that it be applicable as widely as possible, it does have certain limitations. These are due mainly to the limit of program size (sum of I and D bank) allowed under the EXEC-8 system for simplistic programs. The maximum program size allowed is 65k words per program. Although it is more convenient for later use to assign all parameters with maximum values as long as the overall program size is within limits, this results in greater expense in later use of the program due to the higher core-time product. Therefore, it is recommended that all parameters be set at values just high enough for anticipated use.

After setting parameter values, the STACOM program capabilities are then limited to these assigned values. If a run requires that certain parameter value be exceeded, the STACOM program must be recompiled and remapped.

2.2 SYSTEM RELIABILITY AND AVAILABILITY ANALYSIS

While cost may be a major concern in deciding the option for network implementation when several alternatives are available, the factor of system reliability (survival probability) and availability as a function of alternate option does deserve some considerations. The reliability and availability of a system not only depends on how the system is built up, it also depends on how each component of the system behaves as time passes by. In the following sections, we will present assumptions and definitions of terms and equations which are to be used later in calculating system reliabilities and availabilities. The constraints of subsystems to be investigated and results from applying these equations for both Ohio and Texas are then presented.

2.2.1 Assumptions

The true reliability (survival probability) of a given component as a function of age is impossible to describe exactly and simply. However, in many cases, a component's reliability can be practically and usefully represented as a unit with a "bathtub" shape failure rate function as shown in Figure 2-8. In other words, a component can be well described as having a failure rate that is initially decreasing during the infant mortality phase, constant during the so-called "useful life" phase, and, finally, increasing during the so-called "wear-out" phase.

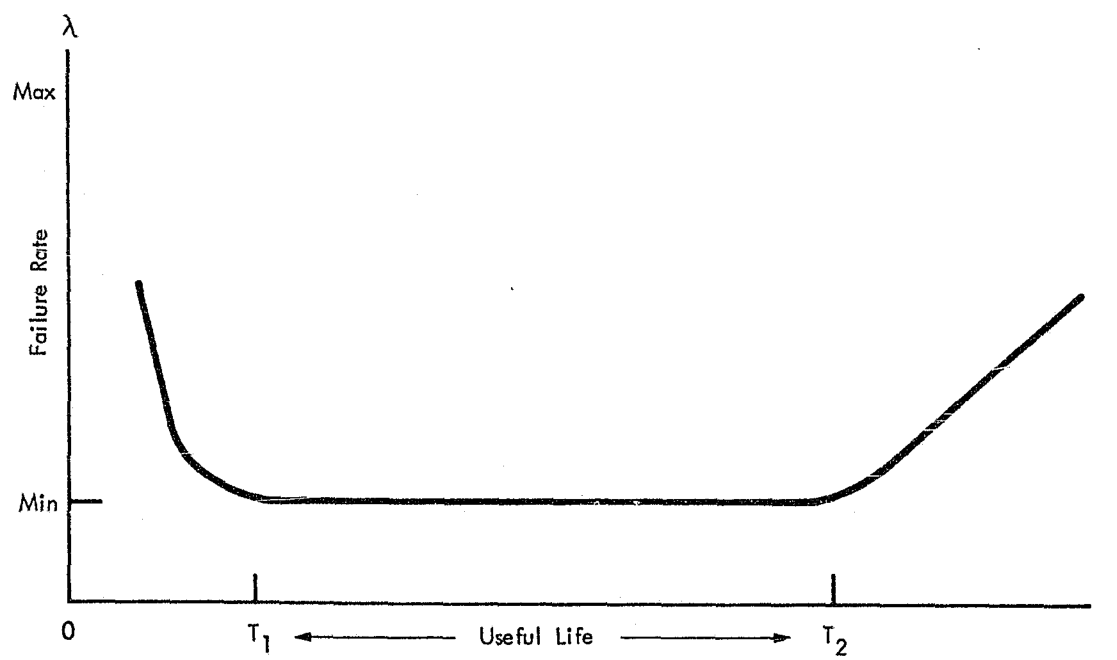


Figure 2-8. "Bathtub" Failure Rate Function

In this study, we assume that all components are to be operated within the constant failure rate phase. Several distribution functions do have such a constant failure rate case. However, in the following discussions, we use the exponential distribution to represent the reliability function for each individual component. An important property of the exponential distribution is that the remaining life of a used component is independent of its initial age (the "memoryless property"). With the exponential distribution it follows that:*

(a) Since a used component is as good as new (statistically), there is no advantage in following a policy of planned replacement of used components known to be still functioning.

(b) The statistical estimation data of mean-life, percentiles, reliability and so on, may be collected on the basis only of the number of hours of observed life and of the number of observed failures; the ages of components under observation are irrelevant.

2.2.2 Definition

For the purpose of convenience in later discussions, we give definitions to the following terms and notations:

(a) λ_i = Failure rate for component i

(b) μ_i = Mean time between failures (MTBF) for component i

(c) ν_i = Mean time to repair (MTTR) for component i

(d) R(t) = Reliability function as a function of time, t

(e) A(t) = Availability function as a function of time, t

(f) A_{av} = The limiting average availability

(g) $\gamma_i = \nu_i/\mu_i$

(h) λ = System failure rate

(i) μ = System MTBF

(j) ν = System MTTR

*See R. Barlow and F. Proschan, Statistical Theory of Reliability and Life Testing Probability Models, Holt, Rinehart and Winston, Inc., 1975.

2.2.3 System Reliability and Availability

Given a system with n (≥ 2) components, it is in general impossible to derive its exact reliability and availability. However, if the statistical interrelationship among its components can be described, we can then relate the system reliability and availability to the reliabilities and availabilities of the components. For the simplest case, if all of the components are statistically independent and each of them has a constant failure rate λ_i, then the overall system reliability R(t) for a series system (a system which functions if and only if each component functions) is

$$R(t) = e^{-\lambda t} \tag{1}$$

where $\lambda = \sum_{i=1}^{n} \lambda i$

n = number of components in the system

If the system has a parallel structure (a system which functions if and only if at least one component functions), its reliability becomes

$$R(t) = 1 - \prod_{i=1}^{n} \left(1 - e^{-\lambda_i t}\right) \tag{2}$$

where π denotes the multiplication operation.

Furthermore, for a series system, its limiting average system availability can be described as

$$\hat{A}_{avg} = \left(1 + \sum_{i=1}^{n} \gamma_i\right)^{-1} \tag{3}$$

and the average of system downtime (MTTR) becomes

$$\nu = \mu \sum_{i=1}^{n} \gamma_i \tag{4}$$

where μ = system MTBF

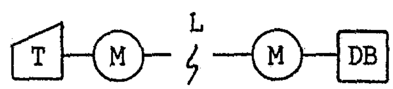
$$= \left(\sum_{i=1}^{n} 1/\mu_i\right)^{-1} = \left(\sum_{i=1}^{n} \lambda_i\right)^{-1} \tag{5}$$

2.2.4 System Reliability and Availability for the Ohio Network

2.2.4.1 Reliability System Structures. The communications network for Ohio currently consists of one central switcher with data bases and may have regional switchers in the future. The regional switchers serve as intermediate message switchers between local terminals and the central switcher. With this in mind, the reliability system structures from an individual user terminal can be described as follows:

Case 1 - One Central Switcher with Data Bases.

Figure 2-9 shows the reliability system structure for the user terminal when its communication with the data bases has to go through the central switcher directly.



where T = user terminal

M = Modem

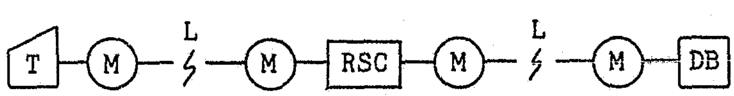
DB = Columbus data base computer, i.e., Univac 1100/42

L = communication line from the user modem to the central switcher modem

Figure 2-9. Ohio Reliability System Structure for Case 1

Case 2 - One Central Switcher with One Regional Switcher

In another configuration, the user terminal communicates with the central switcher with the data bases through the regional switcher. Its reliability system structure can be described as Figure 2-10.



Where RSC = Regional Switching Center

Figure 2-10. Ohio Reliability System Structure for Case 2

2.2.4.2 Empirical Components' Failure Statistics. With reliability system structures obtained, estimation of system availability and reliability is then obtainable by simply applying empirical statistics for system components. Table 2-1 shows failure statistics for all of relevant components as given in Ohio reliability system structures. These data were provided by different sources, as indicated in the table. The statistics for the terminals were provided by vendor Bee-Hive, Inc.; these terminals have capacities of 1200 bps and up. For the switcher computer, the data provided by Action, Inc. was used.

2.2.4.3 System Reliabilities and Availabilities.

Case 1:

The effective failure rate for this system is equal to

$$\lambda_1 = \lambda_T + 2\lambda_M + \lambda_L + \lambda_{DB} + \lambda_{ENV} \text{ (Environment)}$$

$$= 0.02966$$

Its reliability function as a function of time becomes

$$R_1(t) = e^{-\lambda_1 t} = e^{-0.02966\ t}$$

Applying t = 24, $R_1(24)$ becomes 0.491.

In other words a terminal user will expect to have on the average one daily failure, half of the time for an expected 24-hour operation period.

Similarly,

$$\gamma_1 = \gamma_T + 2\gamma_M + \gamma_L + \gamma_{DB} + \gamma_{ENV}$$

$$= 0.012182$$

and its average availability is equal to

$$A_1 = (1 + 0.012182)^{-1} = 0.9880$$

In other words, given a 24-hour operational period, the system will have on the average a sum of 1440 x (1-0.998) = 17.3 minute outages. These results are tabulated in Table 2.2.

Table 2-1. Empirical Components Failure Statistics

Component	i MTBF (hours)	i MTTR (hours)	i=1/ i Failure Rate (x10^{-3})	A_i Average Availability	i= i/ i (x10^{-3})	Source
Terminal	6000 to 1000	4-5	0.167	0.9993 0.9994	0.83	Bee-Hive Inc.
Modem	5000	3	0.2	0.9994	0.6	Ohio Western Union
Line	668.5	1.4	1.496	0.99791	2.1	Ohio Western Union
Columbus Data Base Computer	37.3	0.24	26.81	0.9936	6.43	Ohio DPS
Ohio DB Environment	350.8	0.57	2.85	0.9984	1.62	Ohio DPS
Switcher Computer	1000	3	1	0.997	3.01	*

*STACOM Team Estimate; UNIVAC Data Unavailable

Table 2-2. Ohio System Reliabilities and Availabilities for a 24-hour Operation Period

	System 1	System 2
Reliability	0.491	0.4357
Availability	0.9880	0.9818
Daily Outage	17.3 minutes	26.2 minutes

Case 2:

The effective system failure rate is equal to

$$\lambda_2 = \lambda_T + 4\,\lambda_M + \lambda_{RSC} + 2\lambda_L + \lambda_{DB} + \lambda_{ENV}$$
$$= 0.034619$$

and its reliability function becomes

$$R_2(t) = e^{-\,0.034619\,t}$$

Applying $t = 24$, $R_2(24)$ becomes 0.4357.

In addition, the system availability is obtained by letting

$$\gamma_2 = \gamma_T + 4\gamma_M + 2\gamma_L + \gamma_{RSC} + \gamma_{DB} + \gamma_{ENV}$$
$$= 0.01849$$

and it is equal to

$$A_2 = (1 + 0.01849)^{-1} = 0.9818$$

In other words, given a 24-hour operational period, on the average the system will have a sum of

$$1440 \times (1 - 0.9818)^1 = 26.2 \text{ minute outages}$$

These results are also tabulated in Table 2-2.

2.2.5 System Reliability and Availability for the Texas Network

2.2.5.1 <u>Reliability System Structures</u>. The existing communication network for Texas consists of two central data base computers at Austin, one central switcher at Austin and two regional switching computers at both Dallas and San Antonio.

With this in mind, the reliability system structures for an individual user terminal can be described as follows:

Case 1: User Terminal - Austin Switcher - Austin Data Base Computer

Figure 2-11 shows the reliability system structure for the user terminal when its communication with the central data bases has to go through the Austin switcher only.

Since line L_2 is a very short one and it is an in-house line, its reliability is considered to be 1. This also applies to the following cases.

Case 2: User Terminal - Dallas Switcher - Austin Switcher - Austin Data Base Computer

Figure 2-12 shows the reliability system structure for the user terminal when its communication with the data base has to go through both Dallas and Austin switchers.

Case 3: User Terminal - San Antonio Switcher - Austin Switcher - Austin Data Base Computer

Case 3 is similar to Case 2, with the exception that San Antonio switcher is the local switcher instead of Dallas switcher. It is shown in Figure 2-13.

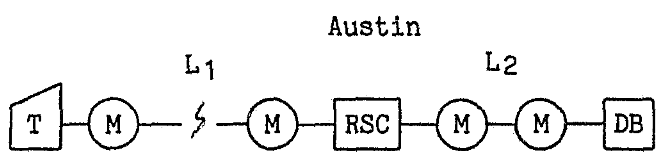


Figure 2-11. Texas Reliability Structure for Case 1

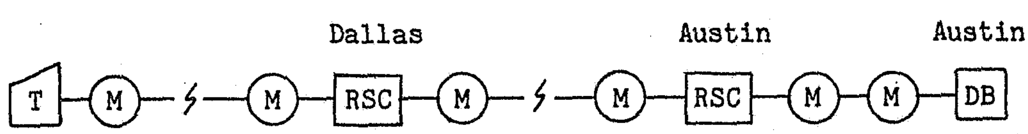


Figure 2-12. Texas Reliability Structure for Case 2

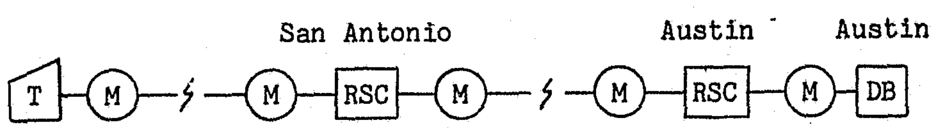


Figure 2-13. Texas Reliability Structure for Case 3

2.2.5.2 Empirical Components' Failure Statistics. Table 2-3 shows failure statistics for all of relevant components as given in Texas reliability system structures. These data are provided by different sources as indicated on the Table.

2.2.5.3 System Reliabilities and Availabilities.

(a) Case 1

The effective system failure rate is equal to

$$\lambda_1 = \lambda_T + 4\lambda_M + \lambda_L + \lambda_{RSC} + \lambda_{DB} + \lambda_{ENV}$$

$$= 0.02786$$

Its reliability function as a function of time becomes

$$R,(t) = e^{-0.02786t}$$

Table 2-3. Empirical/Estimate Components' Failure Statistics

	Component	μ_i MTBF	ν_i MTTR	λ_i Failure Rate ($X10^{-3}$)	A_i Availa-bility	γ_i	Source
1.	Terminal	900	0.667	1.11	0.99926	.074	Int. Comm. Corp.
2.	Modem	5000	3	0.2	0.9994	0.6	Ohio WU
3.	Line	668.5	1.4	1.496	0.099791	2.1	Ohio WU
4.	Data Base Environment	350.8	0.57	2.85	0.9984	1.62	Ohio
5.	Austin S/W	143.9	1.17	6.94	0.9920	8.13	
6.	Dallas S/W	145.0	0.95	6.89	0.9935	6.53	Texas
7.	San Antonio S/W	145.4	0.56	6.88	0.9962	3.86	DPS
8.	Data Base	68.3	4.67	14.64	0.936	68.4	

Applying

$$t = 24,\ R_1(24) = 0.512$$

Since $\lambda_1 = \lambda_T + 4\lambda_M + \lambda_L + \lambda_{RSC} + \lambda_{DB} + \lambda_{ENV}$

$$= 0.0832$$

and its average availability is equal to

$$A_1 = 0.9134$$

Given a 24-hour operation period, the system will have a sum of 110.6 minutes of outage. These results are tabulated in Table 2-4.

(b) Case 2

The effective system failure rate is equal to

$$\lambda_2 = \lambda_1 + 2\lambda_M + \lambda_L + \lambda_{RSC} \text{ at Dallas}$$

$$= 0.03664$$

and its reliability function becomes

$$R_2(t) = e^{-0.03664t}$$

Table 2-4. Texas System Reliabilities and Availabilities for a 24-Hour Operation Period

	System 1	System 2	System 3
1) Reliability	0.512	0.415	0.415
2) Availability	0.9232	0.915	0.917
3) Daily Outage	110.6 minutes	122.5 minutes	119.3 minutes

Applying $t = 24$, $R_2(24) = 0.415$

Since $\gamma_2 = 0.0930$, its average system availability is equal to

$$A_2 = 0.915$$

Given a 24-hour operational period, the system will have a sum of 122.5 minutes of outage. These results are tabulated in Table 2-4.

(c) Case 3

The effective system failure rate is equal to

$$\lambda_3 = \lambda_1 + 2\lambda_M + \lambda_L + \lambda_{RSC} \text{ at San Antonio}$$

$$= 0.03663$$

and its reliability function becomes

$$R_3(t) = e^{-0.03663}$$

Applying $t = 24$, $R_3(24) = 0.415$

Since $\gamma_3 = 0.09036$

its average system availability is equal to

$$A_3 = 0.917$$

Given a 24-hour operation period, the system will have a sum of 119.3 minutes of outage. These results are also tabulated in Table 2-4.

2.3 RESPONSE TIME ALGORITHM

This section describes a network response time algorithm which models mean response time values at network user terminals. Response time is defined as that time interval between the time a network user initiates a request for network service and the time at which a response is completed at the users inquiring terminal.

Section 2.3.1 describes a general approach to network response time modeling. Following this background material, specific models used in Ohio and Texas are discussed in Sections 2.3.2 and 2.3.3.

2.3.1 General Response Time Modeling Approach

2.3.1.1 Approach. Components of the model described in this section can be assembled to mimic response time behavior at any terminal imbedded in any network configuration incorporating terminals, lines, message switching computers and data base computers.

To facilitate discussion, we shall consider the components for a response time model for the general network depicted in Figure 2-14, although the principles of model component development apply to any network configuration.

In the network shown, Regional Switching Computers, (RSCs), service terminals within their defined regions. RSCs from each region are connected to a central RSC which provides a data base for inquiry/response transactions.

The longest response time at a system termination will occur on a multi-dropped line served by a remote RSC. The response time model discussed here treats this condition.

Figure 2-15 presents a simplified drawing of the configuration of interest. The remote RSC services a multidrop of M terminals and receives a single regional traffic load from all other terminals in the region. In our discussion, intraregion lines are half duplex and interregion lines are full duplex. Again, the general approach is not limited to these specific choices.

The central RSC connected to the data base receives traffic from the remote RSC of interest, and from both terminals in its region, and other RSCs in the network.

In this scheme, messages transmitted from multidrop terminals to the data base and back to the appropriate multidrop terminal, encounter a series of queues.

The total time spent in any queue is defined as the time spent waiting for service from a facility plus the time spent by the facility in servicing the transaction. The response time model developed here considers average or mean values for all variables, so that,

$$E(\text{Queue Time}) = E(\text{Wait Time}) + E(\text{Service Time})$$

Facilities in the model consist of transmission lines and computers.

Figure 2-16 shows seven distinct queues encountered by a data base inquiry and response operation from a multidropped terminal. The wait time and service time components of each queue are delineated in the figure. Inquiry input to the data base moves across the top of the figure from left to right. Response output from the data base moves across the bottom of the figure from right to left. Each of the queues, seven in all, are numbered for later easy reference when specific equations are discussed.

Each of the queues is considered to be a single server queue, with the exception of the data base RSC computer which may be treated as a double server queue (dual CPUs) if desired.

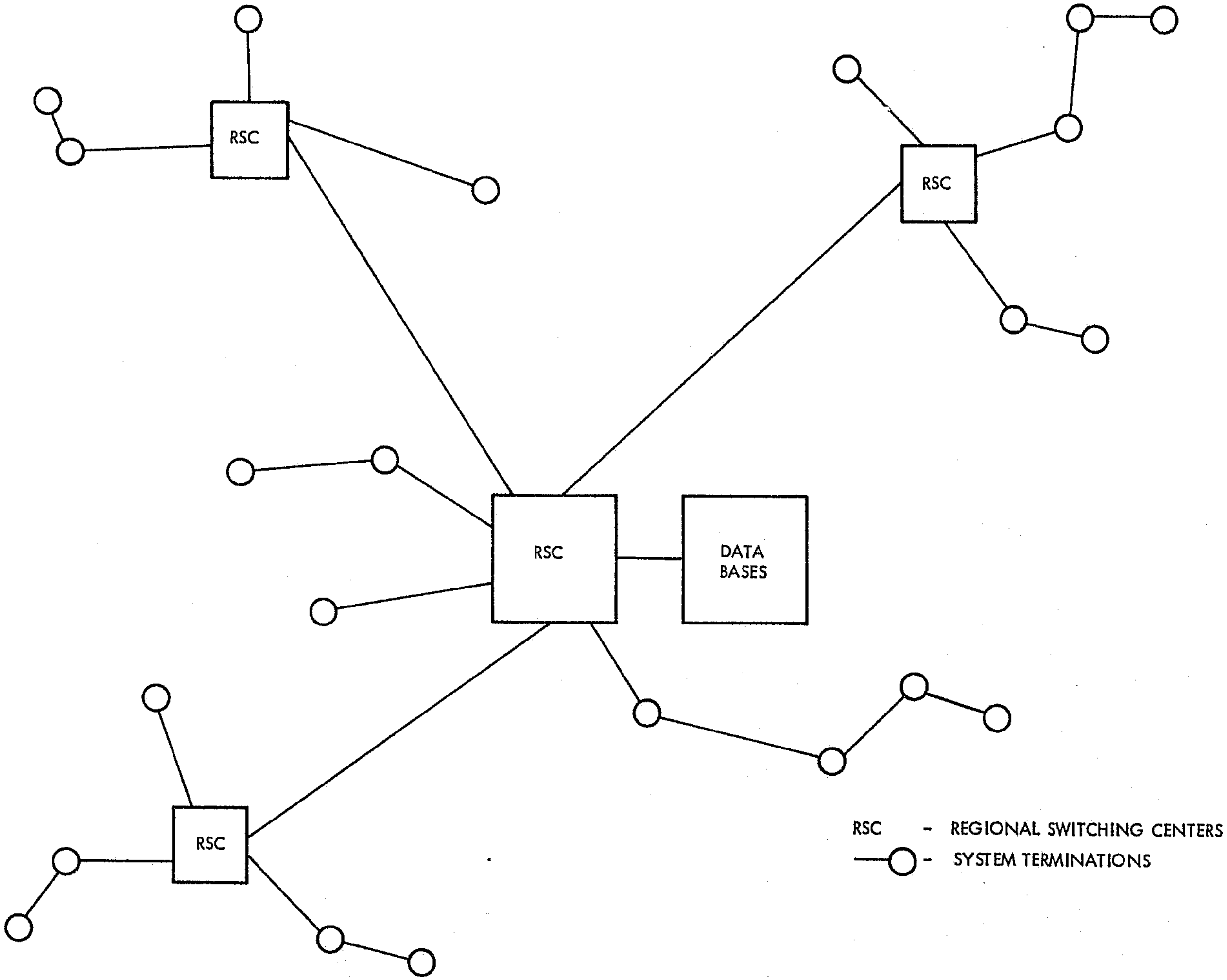


Figure 2-14. A General Network

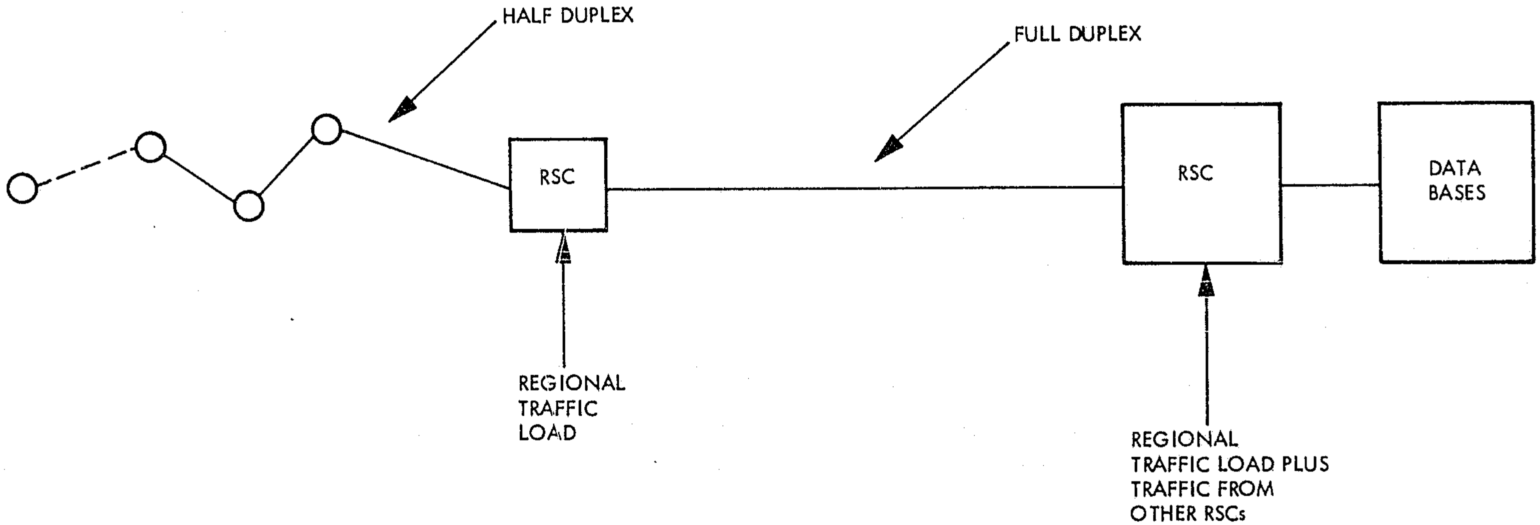


Figure 2-15. Simplified Configuration for Response Time Analysis

5030-99

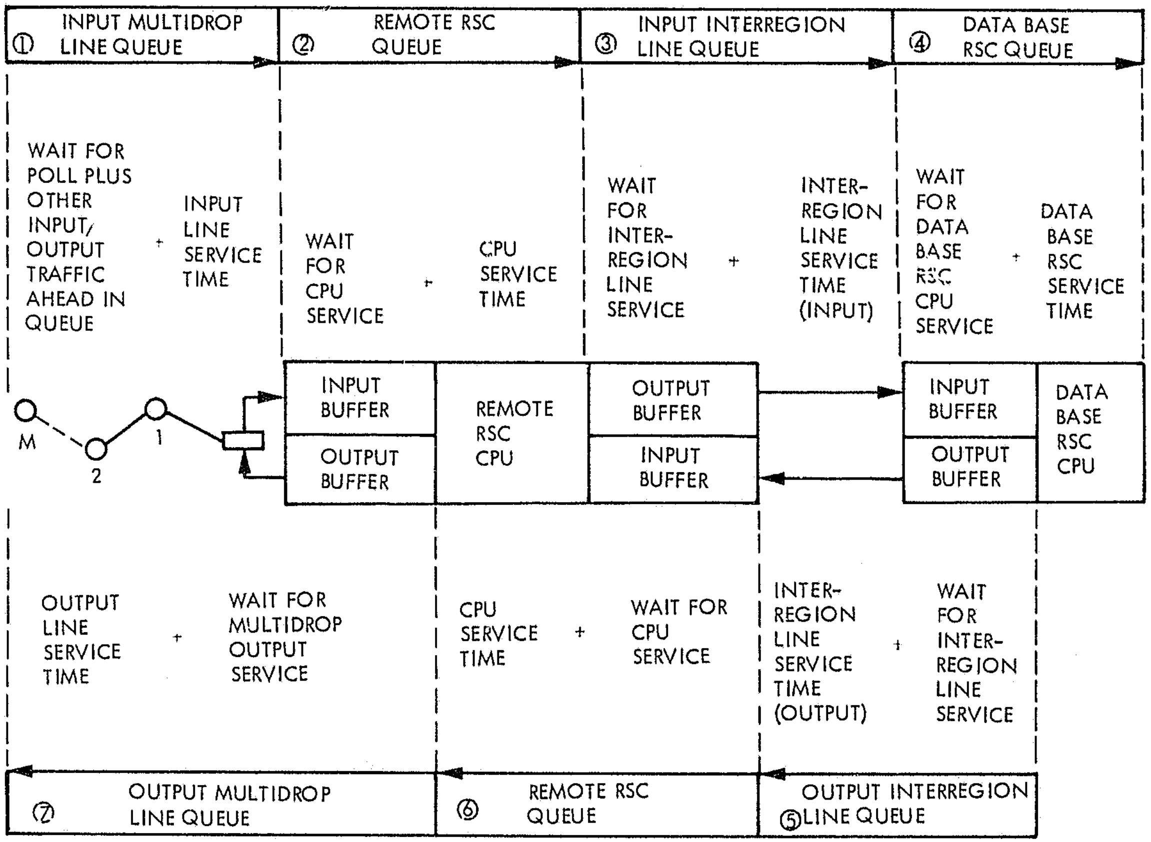


Figure 2-16. System Message Queues

5030-99

2.3.1.2 General Equations. We shall now develop a set of general equations for a response time model. In this model, response time is defined as that time from initiation of a request for network service at a terminal to the time that a response is completed at the requesting terminal. We wish to develop equations for the queues outlined in Figure 2-16 for a network capable of handling three types of message priorities. In addition, for purposes of this discussion, output from the computer onto the multidrop line is given priority over input messages to the computer from the multidrop line.

Thus, there are really 4 types of priorities to deal with. Consider the three message priority types as being

Priority 1 = Message type A
Priority 2 = Message type B
Priority 3 = Message type C

Then, on the multidrop, the model will need to handle the following four priority types

Priority 1 = Output of Message type A
Priority 2 = Output of Message type B
Priority 3 = Output of Message type C
Priority 4 = Input of all Message types

This approach is necessary since messages cannot be prioritized until they reach a computer, at which point, message types can be examined and appropriate priorities assigned to each. It is assumed here that it is not desirable to allow network users to assign priorities to messages.

On interregion full duplex lines, output does not interfere with input so that the model need deal with input and output of the three priority types, messages A, B, and C only.

The following assumptions are made for model development:

(1) Traffic arrival patterns at facilities are Poisson.

(2) Inter-arrival times of messages are exponentially distributed.

(3) Output messages from the computer to the multidrop line have priority over input messages from the terminals to the computer.

(4) Message dispatching is first in, first out, (FIFO).

(5) No messages leave queues without first being serviced.

(6) Polling is cyclic on the multidrop with equal weighting for each terminal.

(7) Message handling is on a non pre-emptive basis, that is, messages are not interrupted once they are placed on a transmission line.

(8) When dual CPU's are considered, they are assumed to be evenly loaded.

(9) Users on the multidrop line do not hold the line for more than one message before polling is resumed.

Under conditions of the above assumptions, the mean waiting time, E(tw), in a single server queue is

$$E(tw) = \frac{\rho E(ts)}{1 - \rho} \qquad (1)$$

where E(ts) = mean service time (sec)

and $\rho = E(n) \times E(ts)$

where E(n) = average number of transaction arrivals per second

The mean queue time is therefore

$$E(tq) = E(tw) + E(ts)$$

or

$$E(tq) = \frac{\rho E(ts)}{1 - \rho} + E(ts)$$

or simplified

$$E(tq) = \frac{E(ts)}{1 - \rho} \qquad (2)$$

The term, ρ, is a measure of facility utilization and is equal to the fraction of time that a facility is in use serving transactions. The term, ρ, takes on values betwen 0 and 1. When $\rho = 1$ it means that the facility is 100% utilized. We shall see that ρ values should generally not exceed 0.700.

For dual server queues, such as computers with twin processors where an incoming transaction is serviced by the first processor which is not busy, the waiting time for service, E(tw), is given by

$$E(tw) = \frac{\rho 2}{1 + \rho} \; \frac{E(ts)}{1 - \rho} \qquad (3)$$

and in this case the traffic value, E(n), should be halved in calculating ρ; that is

$$\rho = \frac{E(n)}{2} E(ts)$$

Before presenting specific equations for the queues outlined in Figure 2-16, we shall consider the general equations for waiting times when it is desired to handle messages of different priority types.

The ability to prioritize messages can be an important network feature when there is a mixture of long and short messages on the network, that is, when there is a wide range of average message lengths for different message types. For example, in the law enforcement environment, when long message types such as digital fingerprint data, Computerized Criminal History data, digital facsimile data or long administrative messages are included in a network along with shorter inquiry/response messages related to officer safety, it may be expedient to transmit the latter message types with a higher priority over the network to insure shorter response times for these more important message types.

The response time model is capable of handling up to four message priority levels. The mean wait time components of mean queue times for the four priority levels are given below. Priority 1 is the highest priority.

Mean wait time, Priority 1,

$$E(tw1) = \frac{\rho E(ts)}{1 - \rho 1} \qquad (4)$$

Mean wait time, Priority 2,

$$E(tw2) = \frac{\rho E(ts)}{(1 - \rho_1)(1 - \rho_1 - \rho_2)} \qquad (5)$$

Mean wait time, Priority 3,

$$E(tw3) = \frac{\rho E(ts)}{(1 - \rho_1 - \rho_2)(1 - \rho_1 - \rho_2 - \rho_3)} \qquad (6)$$

Mean wait time, Priority 4,

$$E(tw4) = \frac{\rho E(ts)}{(1 - \rho_1 - \rho_2 - \rho_3)(1 - \rho)} \qquad (7)$$

In the above equations

ρ_i = facility utilization due to priority i message type where i = 1, 2, 3, 4

and $\rho_i = E(n_i) \times E(ts_i)$

where $E(n_i)$ = arrivals per second of priority i type messages

and $E(ts_i)$ = service time for priority i type messages

so that the total facility utilization

$$\rho = \rho_1 + \rho_2 + \rho_3 + \rho_4$$

and the total message arrivals per second

$$E(n) = E(n_1) + E(n_2) + E(n_3) + E(n_4)$$

Finally, in the model, there are two types of service times to be calculated. One is service time for message transmission over communication line facilities and the other is service time for message switching and data base acquisition by computer facilities.

For the four priority types, service times for messages on communication lines are given by

$$E(tsi) = \frac{(Lmi + OH) \times Bc}{C} + MPSE \qquad (8)$$

where i = 1, 2, 3, 4,

and Lmi = average message length of a priority i type message in characters

OH = number of overhead characters that accompany a message on the network

Bc = number of bits per character

C = line capacity in Bauds

MPSE = time spent for pauses in transmission due to modem line turnaround time or other factors

The unsubscripted service time term, E(ts), (which appears with the unsubscripted ρ term in the numerators of equations 4 thru 7), is calculated similarly, but uses the overall network average message length, Lm, in place of Lmi,

$$Lm = P_1(Lm1) + P_2(Lm2) + P_3(Lm3) + P_4(Lm4)$$

where P_i = the percentage of priority i type messages on the network
$i = 1, 2, 3, 4$

The mean service time for a negative poll on the multidrop network is given by

$$E(tPOLL) = \frac{POH \times Bc}{C_m} + PPSE \qquad (9)$$

where POH = number of polling characters including overhead characters

Bc = number of bits per character

C_m = line capacity in Bauds

PPSE = total line pauses during a negative poll due to modem turnarounds, etc. There are two line turnarounds for a negative poll on a half duplex line.

Note that communication line service times do not include terms accounting for line transmission delays as a function of distance. These contributions to total response time are negligible and are not included in the model.

Mean service times for computers are estimated from data supplied by computer system vendors. Of interest is the average time required to process a transaction. For an RSC the time is that required to perform message switching. For a remote single server RSC, the mean queue time E(tqRC), is

$$E(tqRC) = \frac{E(tsRC)}{1-\rho_{RC}} \qquad (10)$$

where E(tsRC) = mean service time for switching per transaction in a regional computer

ρ_{RC} = facility utilization for a regional computer

and ρ_{RC} = E(nRC) E(tsRC)

where E(nRC) total transaction arrivals per second at the regional RSC

For an RSC connected to a data base, we shall assume that the computer is a dual processor so that it behaves as a dual server queue. In this case, the mean queue time for the data base switcher computer, E(tqCD), is

$$E(tqCD) = \frac{\rho^2_{CD}}{1 + \rho_{CD}} \frac{E(tsCD)}{1 - \rho_{CD}} + E(tsCD) \qquad (11)$$

where E(tsCD) = mean service time for switching plus data base access per transaction

ρ_{CD} = facility utilization for an RSC with data base

and $$\rho_{CD} = \frac{E(nCD)}{2} E(tsCD)$$

where E(nCD) = total transaction arrival rate per second at the data base RSC

Mean service times for computers are hardware and software configuration dependent, which necessitates vendor consultation in each case. Generally, computer mean service times will range from 100 ms to 700 ms.

In arriving at values for computer mean service times, it is important to visualize the computer facility as a single large queue, despite the fact that the operating system may involve many queues in reality. One approach, for example, may consider the mean number of program steps executed per transaction and the mean number of disc accesses per transaction. Typical numbers may be:

ITEM	SPEED	TIME
150,000 instructions per transaction	@ 1 microsecond mean instruction execution time	0.150
6 disc accesses per transaction	@ 47.5 milliseconds per access	0.282
	MEAN COMPUTER SERVICE TIME =	0.432 sec

Ideally, vendors or system users may have actual measurements available from operating statistics.

2.3.1.3 Inputs/Outputs. The general model requires the input data listed in Table 2-5. Table 2-6 describes the terms calculated by the model. Figure 2-17 clarifies where various terms apply in the model.

Once the calculated values are found, it is a simple matter to sum up the desired components of the seven queues involved, (outlined in

Figure 2-16), to arrive at desired values for response times by priority type. It is also possible to use the model for simpler network configurations which may or may not involve message prioritization. The following two examples will clarify model use.

Table 2-5. Model Inputs

Item	Symbol	Meaning and Units
1	Cm	Line capacity of the multidrop (Baud)
2	CR	Line capacity of interregion line (Baud)
3	OH	Overhead characters in line protocol (CH)
4	MPSEM	Total line turn-around time on multidrop (sec)
5	MPSER	Total line turn-around time on interregion line (sec)
6	M	Number of terminals on multidrop
7	U_C	Units per character (bits)
8	L_1	Priority one output average message length (CH)
9	L_2	Priority two output average message length (CH)
10	L_3	Priority three output average message length (CH)
11	L_4	Input average message length (CH)
12	L_5	Priority one input average message length (CH)
13	L_6	Priority two input average message length (CH)
14	L_7	Priority three input average message length (CH)
15	Lm	Overall system average message length (CH)
16	E(nm1)	Mean arrival rate of priority one output messages to multidrop (msg/sec)
17	E(nm2)	Mean arrival rate of priority two output messages to multidrop (msg/sec)
18	E(nm3)	Mean arrival rate of Priority 3 output messages to multidrop (msg/sec)

Table 2-5. Model Inputs (Continuation 1)

Item	Symbol	Meaning and Units
19	E(nm4)	Mean arrival rate of all input messages from multidrop (msg/sec)
20	E(nRI1)	Mean arrival rate of Priority 1 input messages on interregion line (msg/sec)
21	E(nRI2)	Mean arrival rate of Priority 2 input messages on interregion line (msg/sec)
22	E(nRI3)	Mean arrival rate of Priority 3 input messages on interregion line (msg/sec)
23	E(nRO1)	Mean arrival rate of Priority 1 output messages on interregion line (msg/sec)
24	E(nRO2)	Mean arrival rate of Priority 2 output messages on interregion line (msg/sec)
25	E(nRO3)	Mean arrival rate of Priority 3 output messages on interregion line (msg/sec)
26	E(nCR)	Mean number of transactions/sec at RSC (trans/sec)
27	E(nCD)	Mean number of transactions/sec at the RSC with a data base (trans/sec)
28	E(tsCR)	Mean service time per transaction for the RSC computer (sec/trans)
29	E(tsCD)	Mean service time per transaction for the RSC data base computer (sec/trans)

Table 2-6. Calculated Values

Item	Symbol	Meaning and Units
1	E(tsmi) i = 1-7	Mean service time for messages on the multidrop line (sec/msg)
2	E(tsm)	Mean service time for messages on the multidrop using overall average message length (Lm) (sec/msg)
3	E(twmi) i = 1-4	Mean wait time for service on the multidrop line (sec/msg)
4	ρmi i = 1-4	Mean utilization of multidrop line for each priority type
5	ρm	Total mean utilization of multidrop line for all messages
6	E(tqCR)	Mean queue time of RSC (sec/msg)
7	E(tsRIi) i = 1-3	Mean service time for input messages on interregion line (sec/msg)
8	E(tsROi) i = 1-3	Mean service time for output messages on interregion line (sec/msg)
9	E(tsRI)	Overall mean service time for input messages on interregion line (sec/msg)
10	E(tsRO)	Overall mean service time for output messages on interregion line (sec/msg)
11	ρRIi i = 1-3	Mean utilization of interregion line for input messages for each priority type
12	ρROi i = 1-3	Mean utilization of interregion line for output messages for each priority type
13	ρRI	Total mean utilization of interregion line for all input messages
14	ρRO	Total mean utilization of interregion line for all output messages
15	E(twRIi) i = 1-3	Mean wait time for input service on inter-regional line (sec/msg)
16	E(twROi) i = 1-3	Mean wait time for output service on inter-regional line (sec/msg)
17	E(tqCD)	Mean queue time of RSC with data base (sec/msg)

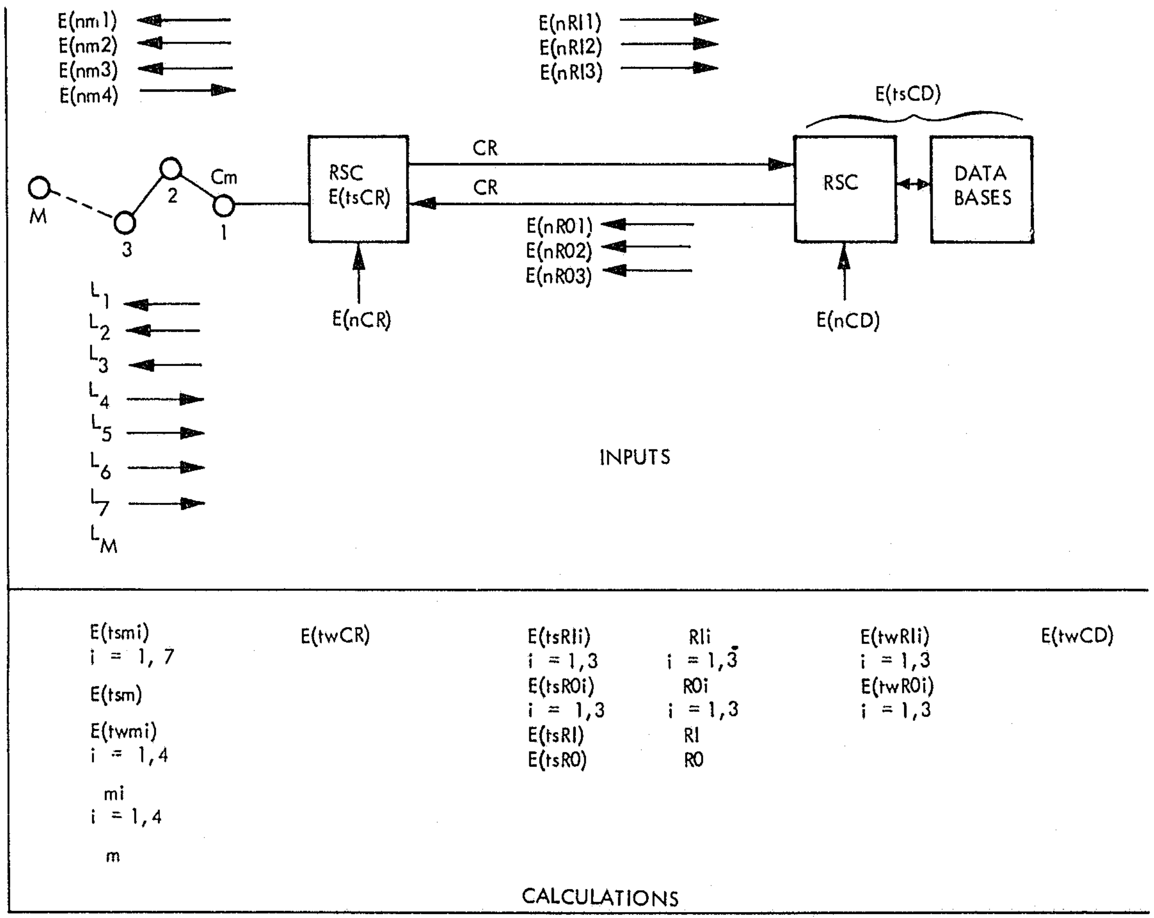


Figure 2-17. Model Inputs and Calculated Values

EXAMPLE 1

Suppose we wished to find response times for the network shown in Figure 2-17 under the following conditions:

- There are three priority type messages on the network, A, B, and C, with A being the higher priority
- Output of messages to the multidrop line has priority over input messages from the line multidrop
- Inquiry messages flow from the multidrop line through an RSC, over interregion lines to a data base RSC and response messages flow back

The equations for response time are presented below. There are three equations shown.

E(trA) = mean response time for a priority A message

E(trB) = mean response time for a priority B message

E(trC) = mean response time for a priority C message

Each equation is comprised of the appropriate wait and service time components calculated by the model. The equation for E(trA) is presented in more detail. The equations for E(trB) and E(trC) are of similiar construction, however, the wait times in queues are longer since they are of lower priority and the line service times are different since average message lengths are different. These differences are evident in the use of different subscripts. Note that the wait time for line service for an input message on the multidrop line is the same in all equations since input from the multidrop is visualized as priority 4 on the multidrop line, that is, input waits for all output onto the multidrop.

Term	Explanation (See Table 2-6)	Queue No. (See Figure 2-3)
E(trA)	Response time of priority A messages	Not applicable
$= \left[\frac{M-1}{2}\right]$ E(tpoll)	Mean waiting time for poll at a terminal	1
+ E(twm4)	Mean waiting time for other input messages on multidrop that may be polled before terminal of interest.	1
+ E(tsm5)	Mean service time for Priority A input message on multidrop line	1
+ E(tqCR)	Mean queue time at RSC	2

Term	Explanation (See Table 2-6)	Queue No. (See Figure 2-3)
+ E(twRI1)	Mean waiting time for Priority A message for interregion line service	3
+ E(tsRI1)	Mean service time for Priority A message on interregion line	3
+ E(tqCD)	Mean queue time at RSC with data base	4
+ E(twRO1)	Mean waiting time for Priority A message for interregion line service	5
+ E(tsRO1)	Mean service time for Priority A message on interregion line	5
+ E(tqCR)	Mean queue time at RSC	6
+ E(twm1)	Mean wait time for output service of Priority A message onto multidrop line	7
+ E(tsm1)	Mean service time for output message of Priority A on multidrop line	7

$$E(trB) = \left[\frac{M-1}{2}\right] E(tpoll) + E(twm4) + E(tsm6) + E(tqCR)$$

$$+ E(twRI2) + E(tsRI2) + E(tqCD)$$
$$+ E(twRO2) + E(tsRO2) + E(tqCR)$$
$$+ E(twm2) + E(tsm2)$$

and

$$E(trC) = \left[\frac{M-1}{2}\right] E(tpoll) + E(twm4) + E(tsm7) + E(tqCR)$$

$$+ E(twRI3) + E(tsRI3) + E(tqCD)$$
$$+ E(twRO3) + E(tsRO3) + E(tqCD)$$
$$+ E(twm3) + E(tms3)$$

EXAMPLE 2

Suppose we wish to deal with the simpler network configuration shown in Figure 2-18. As before, the longest response time in this network will occur on one of the multidropped lines. Therefore, consider the simplification of Figure 2-19 where we consider one such line. Consider, also, the following characteristics of interest.

- There is no prioritization of messages.

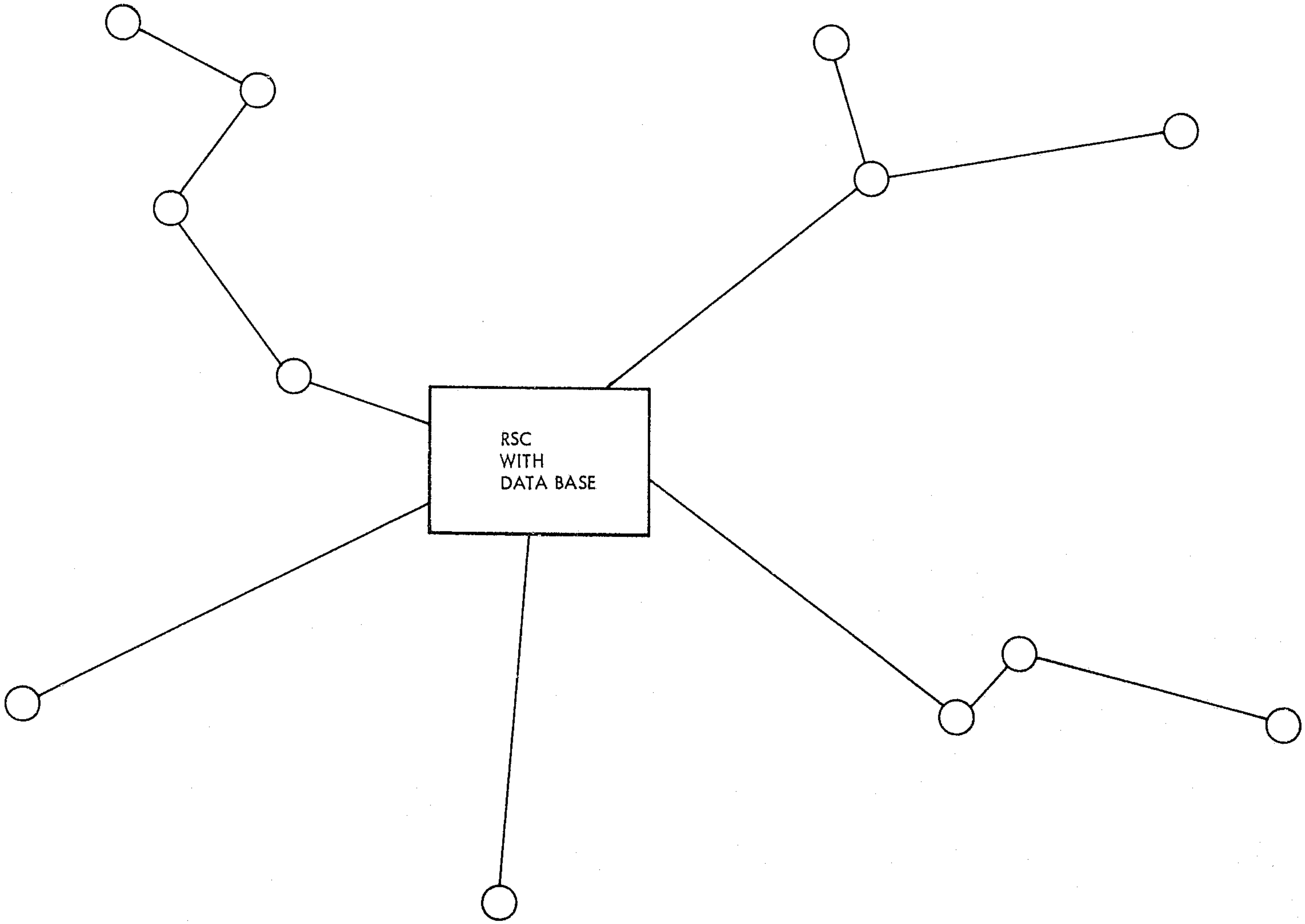


Figure 2-18. A Simpler Network

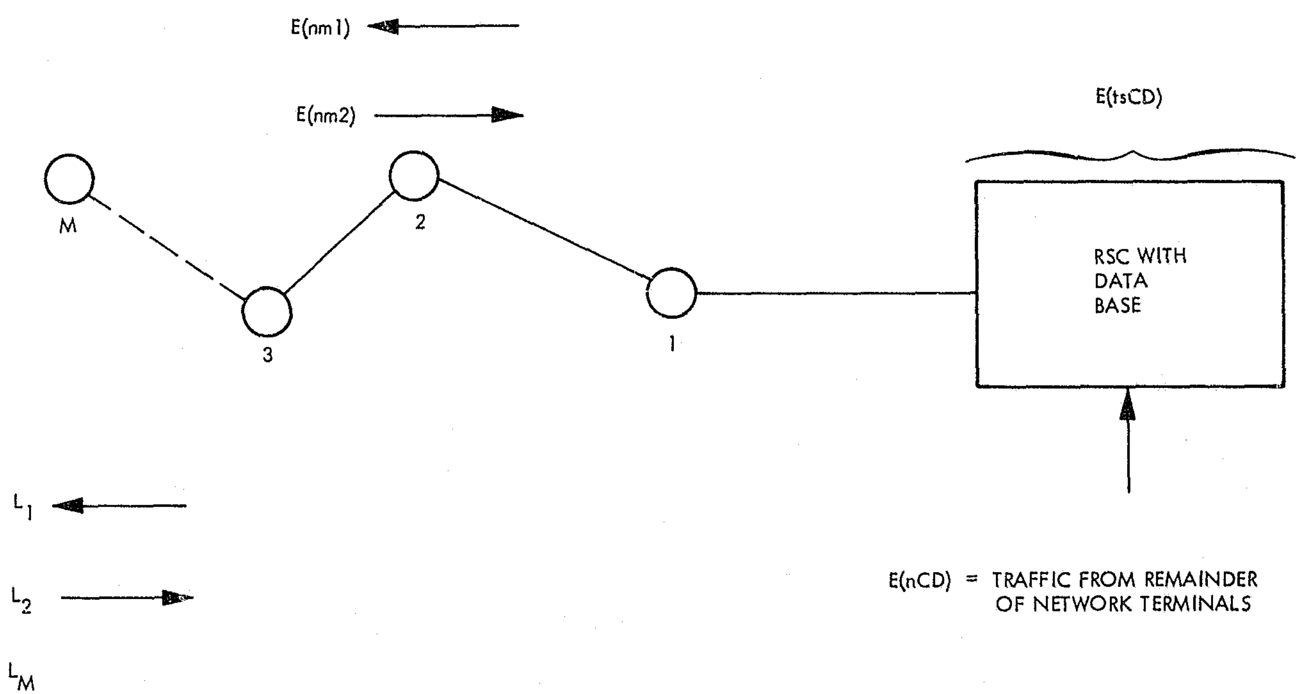


Figure 2-19. Network Inputs for Example 2

- Output of messages to the multidrop has priority over input messages from the multidrop

- A single RSC with data base is used in the network

Under these conditions, the response time, E(tr), for messages is given by

$$E(tr) = \left[\frac{M - 1}{2}\right] E(tpoll) + E(twm2) + E(tsm2)$$

$$+ E(tqCD) + E(twm1) + E(tsm1)$$

In this equation, output is given priority one and input is given priority two.

2.3.1.4 Model Validation. The reader will note that simplifications have been introduced into the model. For example, mean queue time at computers is calculated without regard to average message lengths of transactions. This assumes that the mean number of software operations carried out per transaction (hence, mean time), as well as time for disc accesses, is fairly insensitive to the lengths of messages which are being handled. These and other simplifying assumptions are best tested by comparing model outputs with simulation. This exercise was performed with a GPSS program that simulated a network with the characteristics of Example 2 of the section entitled Model Inputs/Outputs, but with two priority message types, A and B, instead of no prioritization. Results are shown in Figure 2-20. These results show the model to be sufficiently close to simulation results to be of meaningful value as a design tool. Values used in these specific tests are shown in Table 2-7. Values in Table 2-7 for E(nCD), E(nm1), E(nm2), and E(nm3) correspond to a total network transaction level of 90,720 transactions per day. The curves of Figure 2-20 were generated by increasing, (or decreasing), these values proportionately to generate x coordinate values.

The equations for response times in this model were

$$E(trA) = \left[\frac{M - 1}{2}\right] E(tpoll) + E(twm3) + E(tsm5) + E(tqCD)$$

$$+ E(twm1) + E(tsm1)$$

and

$$E(trB) = \left[\frac{M - 1}{2}\right] E(tpoll) + E(twm3) + E(tsm6) + E(tqCD)$$

$$+ E(twm2) + E(tsm2)$$

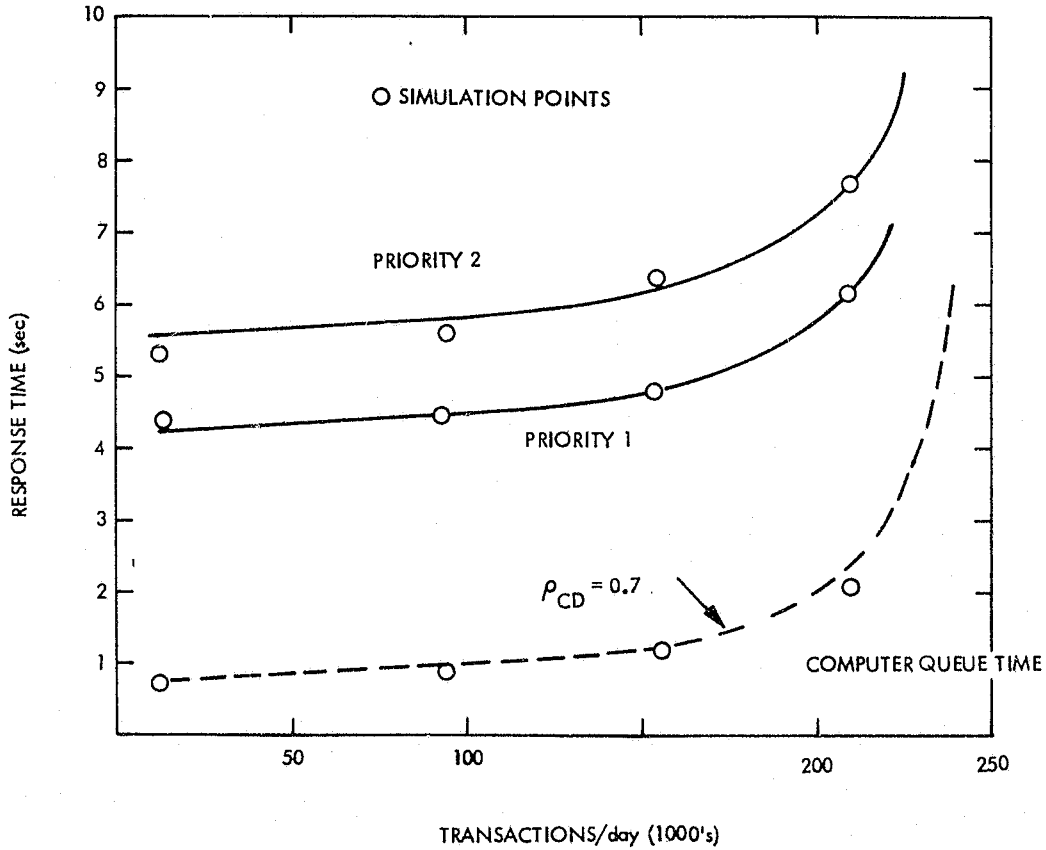


Figure 2-20. Response Time Model vs. Simulation

Table 2-7. Model Validation Input Values

Term	Value
Cm	2400 Baud
OH	13 characters
POH	10 characters
MPSEM	0.150 sec
PPSEM	0.150 sec
M	10 terminals
Uc	10 bits
L5	18 characters
L6	250 characters
L1	170 characters (output Priority 1)
L2	250 characters (output Priority 2)
L3	39 characters (input)
LM	108 characters
E(tsCD)	0.700 seconds
E(nm1)*	0.046
E(nm2)*	0.0042
E(nm3)*	0.0502
E(nCD)**	0.525

*Values for multidrop traffic used at E(nCD) = .525 (see text)

**E(nCD) = .525 for evenly loaded dual processors total computer transaction load = 2 x .525 = 1.05 transactions/sec or 90,720 transactions/day

The dotted line in Figure 2-20 represents the time spent in queue in the computer (see Equation 11). Note that the overall life of the system in terms of ability to handle throughput is limited by the computer performance. In the system shown, the computer utilization, ρ_{CD}, reaches 0.700 at approximately 173,000 transactions per day. At this point, excessive queues can develop in the computer with small variations in throughput demand. Consequently, designers should be well into planning an upgrade when mean computer utilization hovers near 0.700. The model can be used to find the new required computer mean service time to handle throughput demand for any number of years in the future. Mean service times may be reduced in any number of ways, the most typical being use of fixed head discs, improving communications software, obtaining faster core, and implementing multiple processing units.

2.3.2 The Ohio Response Time Model

The existing Ohio LEADS System consists of a single regional message switcher and data base computer located in Columbus. The computer facility employs a Univac 1100/42 dual processor, so that for the single region case, with output from the computer given priority over input from the multidrop, the following equation is applicable:

$$E(tr) = \left[\frac{M-1}{2}\right] E(tpoll) + E(tWM2) + E(tSM2) \qquad (12)$$

$$+ E(tQCD) + E(tWM1) + E(tSM1)$$

The meaning of these terms are described in Table 2-6 of Section 2.3.1.3. The value for E(tQCD) is calculated using the expression for a dual server data base computer presented in equation (11) of Section 2.3.1.2.

For multiple region cases, where inquiries pass from multi-dropped terminals, through a regional switcher, over interregional lines to the data base computer and back over the same path to the terminal on the multidrop, the following equation is applicable:

$$E(tr) = \left[\frac{M-1}{2}\right] E(tpoll) + E(tWM2) + E(tSM2) \qquad (13)$$

$$+ E(tQCR) + E(tWRI1) + E(tSRI1)$$

$$+ E(tQCD) + E(tWRO1) + E(tSRO1)$$

$$+ E(tWM1) + E(tWM1)$$

See Table 2-6, Section 2.3.1.3 for term descriptions.

Equation 12 is used to analyze the performance of the existing 150 and 2400 Baud lines in Ohio. This analysis is presented in Section V. Both equations 12 and 13 are used as a basis for calculating network response times in the Topology Program for the generation of new or improved networks reported on in Section VI.

Sample Calculation --

By way of example, consider the response time on a 2400 Baud line with 10 multidropped terminals into the Columbus switcher and data base computer. For this example equation 12 is appropriate. The numerical values required for input to the model are listed in Table 2-8.

The components of equation 12 are then evaluated as follows:

$$\left[\frac{M-1}{2}\right] E(tpoll) = \left[\frac{M-1}{2}\right] \frac{POH \times U_c}{C_m} + PPSEM = 0.34 \text{ sec}$$

$$E(tWM2) = \frac{\rho_m \, E(tSM2)}{(1-\rho_{m1})\,(1-\rho_{m1}-m2)} \qquad = 0.009 \text{ sec}$$

$$E(tSM2) = \frac{(L_2 + OH)\,U_c}{C_m} + MPSEM \qquad = 0.29 \text{ sec}$$

$$E(tQCD) = \frac{E(tSCD)}{1 - \rho_m 2} \qquad = 1.197 \text{ sec}$$

Table 2-8. Input Values for Sample Calculation

Term	Meaning	Value
Cm	Line Capacity of multidrop	2400 Baud
OH	Message overhead	13 char
POH	Polling overhead	18 char
MPSEM	Total line turn around time per message	0.008 sec
PPSEM	Total line turn around time per poll	0.016 sec
M	Number of multidropped terminals	10
Uc	Units per character	8 bits/char
L1	Average message length of messages from the computer onto the multidrop	155 char
L2	Average message length of messages from the multidrop into the computer	71 char
Lm	Overall average message length	121 char
E(nM1)	Rate of message flow from the computer onto the multidrop	0.024/sec
E(nM2)	Rate of message flow from the multidrop into the computer	0.016/sec
E(nCD)	Total arrival rate of transactions at the computer	1.04/sec
E(tSCD)	Mean service time of the computer	0.650 sec

CONTINUED

1 OF 4

$$E(tWM1) = \frac{\rho_m \; E(tSM1)}{1 - \rho_{m1}} \qquad = \quad 0.008 \text{ sec}$$

$$E(tSM1) = \frac{(L_1 + OH) \; U_c}{C_m} + MPSEM \qquad = \quad 0.57 \text{ sec}$$

Thus, the total response time, E(tr), in this sample calculation becomes:

$$E(tr) = 2.41 \text{ sec}$$

2.3.3 The Texas Response Time Model

The response time model for the State of Texas requires the development of further terms to handle the queueing analysis of data base terms.

The present system in Texas employs three regional switchers - one in Garland, one in Austin and one in San Antonio. Each switcher serves terminals in its general region. The Garland and San Antonio switchers are connected through communication lines to the Austin switcher. The Austin switcher, in turn, is connected to state data bases. Response time models developed in Section 2.3.1 are useful in treating response times from terminals into the Austin switch. The nature of communications between the Austin switch and the Texas data bases in Austin, however, require the development of additional queueing equations.

Figure 2-21 presents a simplified block diagram of the TLETS System and shows specific connections between the Austin switch and the three data bases providing service to the TLETS Network - the Texas Crime Information Center, (TCIC), the Drivers License Records, (LIDR), and the Motor Vehicle Department (MVD).

When the Austin switch accesses these data bases, the line over which the inquiry passes to the data base is held in reserve until the response is constructed, and then used to return the response from the data base back to the Austin switch.

In analyzing this type of "Holding" operation, it is useful to treat the data base line facilities together with the data base facility as a single system. For example, Figure 2-22 shows the TCIC system as it appears to the Austin Switch. The system has a characteristic mean waiting time, $E(tW)_s$, a mean service time, $E(tS)_s$ and a utilization, ρ_s, where

$$\rho_s = \frac{E(n)_{TCIC}}{2} E(ts)_s$$

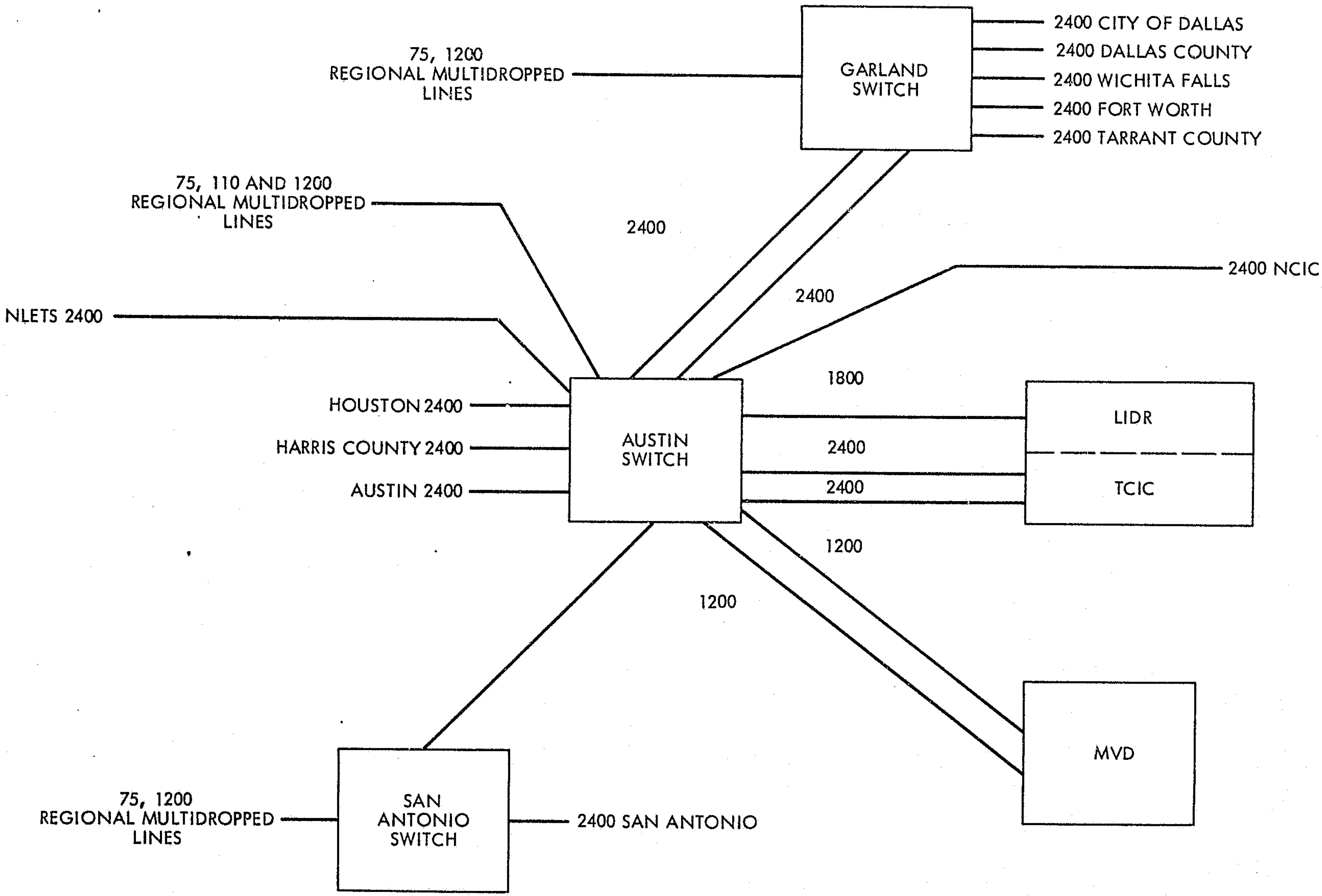


Figure 2-21. Simplified TLETS Diagram

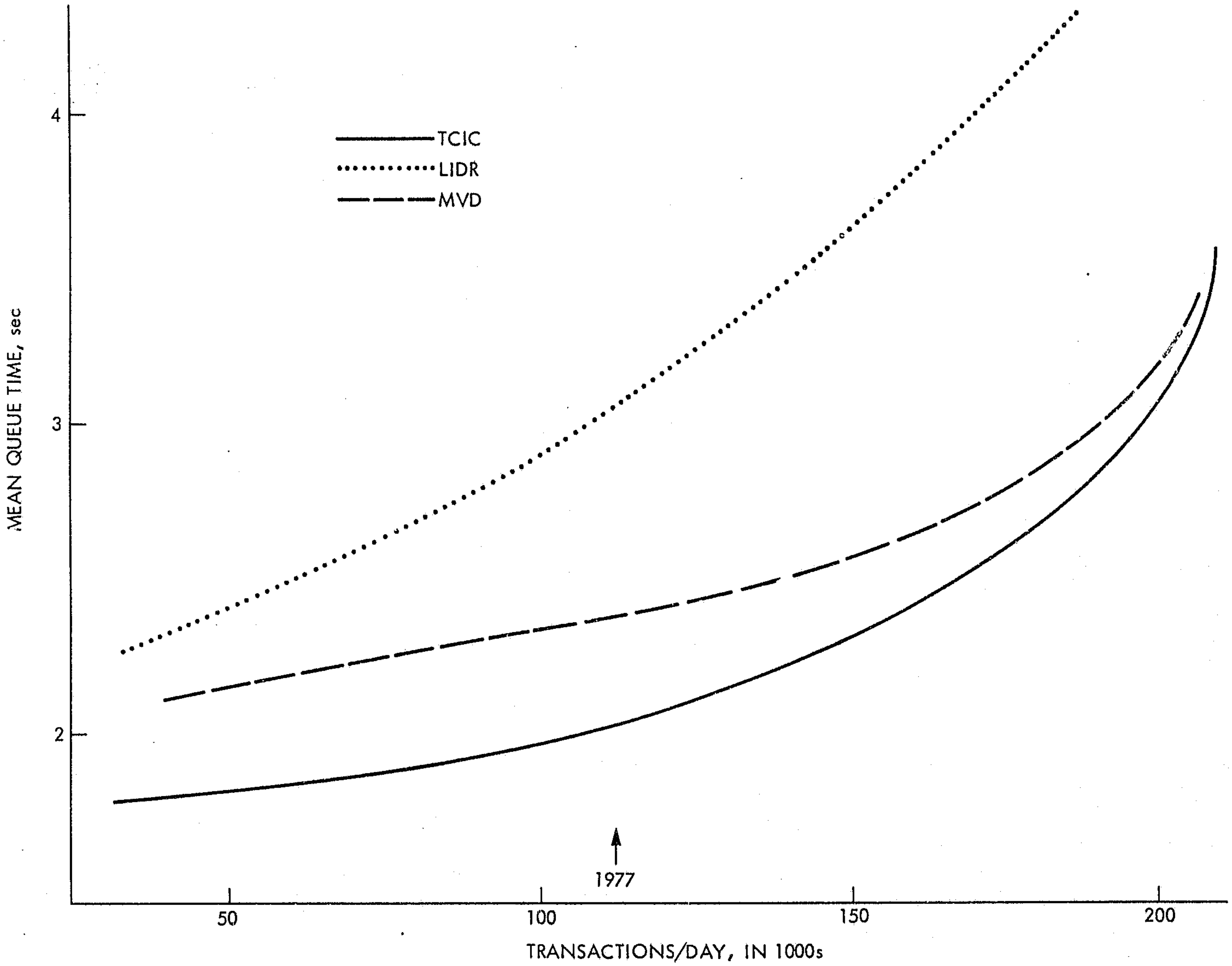


Figure 2-22. Data Base Mean Response Time as it Appears to Austin Switch

and

$E(n)_{TCIC}$ = mean arrivals per second of TCIC inquiries

Since there are two lines available to the Austin switch for service to the TCIC, the system appears to the Austin switch as a dual server queue. Thus, the value for system utilization, ρ_S, is halved by dividing the mean transaction arrival rate by 2, (see equation 3).

The TCIC computer is also loaded by LIDR traffic and traffic from in-house DPS terminals used for file update purposes. Thus, the total number of telecommunication transactions per second at the data base computer, $E(n)_{CD}$, is

$$E(nCD) = E(n)_{LIDR} + E(n)_{TCIC} + E(n)_{DPS}$$

And the computer utilization, from the telecommunications standpoint, ρ_{CD}, is

$$\rho_{CD} = E(nCD)\ E(tSCD)$$

where E(tSCD) is the mean service time per transaction of the IBM 370/155 single server data base computer.

The total mean queueing time for the TCIC system, $E(tQ)_{TCIC}$, is equal to the mean system waiting time plus the mean system service time,

$$E(tQ)_{TCIC} = E(tW)_S + E(tS)_S \tag{14}$$

From a system standpoint, the Austin switcher sees two 2400 Baud lines available for service to the TCIC system. Thus, from equation 3, the mean system waiting time for this dual server queue is given by,

$$E(tW)_S = \frac{\rho_S{}^2 E(tS)_S}{1 - \rho_S{}^2} \tag{15}$$

The mean service time in this equation, $E(tS)_S$, consists of the following components:

$E(tS)_S$ = line transmission time to TCIC from the Austin switch

+ wait time at the TCIC computer for data base service

+ mean service time per transaction at the TCIC computer

+ line transmission time back to the Austin switch from the TCIC

Note that there is no waiting time for the line when a response message is to be returned to the Austin switch from the TCIC since the line is "held" for return service once an input inquiry message begins transmission.

The components of the above equation are listed in the following paragraphs.

Let the line transmission time, (service time), from the Austin switch to the TCIC computer for input inquiries be $E(tS)_{ATI}$. Then,

$$E(tS)_{ATI} = \frac{(L(m)\ \text{TCIC IN} + OH)\ Bc}{C} + \text{PAUSE} \qquad (16)$$

where

L(m) TCIC IN = average message length of a TCIC input message, (inquiry).

OH = message overhead characters

U_c = bits per character

C = line capacity in Bauds

PAUSE = total pause time per message due to modem turn around time, etc.

The waiting time at the TCIC computer for a TCIC transaction is calculated by considering the probabilities that either another TCIC transaction is in front of it, an LIDR transaction is in front of it or a DPS in-house terminal transaction is in front of it, and/or all combinations of these possibilities exist. This analysis indicates that in the worst case, the wait time, $E(tW)_{TCIC}$, for a TCIC transaction in the TCIC computer can be approximated by,

$$E(tW)_{TCIC} = E(tSCD) \times \rho_{CD} \times 1.1 \qquad (17)$$

where ρ_{CD} = TCIC computer utilization

$E(tS)_{CD}$ = Mean transaction service time of the TCIC computer.

Since the value for ρ_{CD} cannot exceed 1, the multiplicative factor of 1.1 suggests that the waiting time for TCIC service for a TCIC transaction after it has arrived at the TCIC computer will never exceed one TCIC computer mean service time plus 10% of one mean service time on the average.

This finding is not unreasonable considering that the single LIDR and the two individual TCIC lines from the Austin switch are "held", as described above, so that queuing is limited at the TCIC computer. Further, LIDR and TCIC inquiries enjoy a non-preemptive priority interrupt over DPS in-house terminal messages.

The mean service time per transaction at the TCIC computer was arrived at by analyzing software statistics which provided means of determining total computer and disc time devoted to telecommunications and a measure of total transactions over a given period. The mean service time per transaction for the TCIC computer has been determined to be 394 milliseconds.

Line transmission time, $E(tS)_{ATO}$, for an output from the TCIC to the Austin Switch is given by:

$$E(tS)_{ATO} = \frac{(L(m)\ \text{TCIC out} + OH)\ B_c}{C} + \text{PAUSE} \tag{18}$$

The terms in this equation are identical to those in equation 16 with the exception of the average message length, L(m) TCIC out, which is the average message length of a TCIC response moving from the TCIC computer to the Austin switch.

We can now construct an equation for the mean service time for a transaction to the TCIC from the Austin switch as the system appears to the Austin switch. Using equations 16, 17 and 18 and a knowledge of the computer mean service time, E(tSCD), the equation for system mean service time, $E(tS)_S$, is

$$\begin{aligned} E(tS)_S = {} & E(tS)_{ATI} + E(tSCD) \times \rho_{CD} \times 1.1 \\ & + E(tSCD) + E(tS)_{ATO} \end{aligned} \tag{19}$$

Now, substituting equation 15 into equation 14, the desired expression for total queue time, or response time, $E(tQ)_{TCIC}$, for the TCIC system as it appears to the Austin switch becomes,

$$E(tQ)_{TCIC} = \frac{\rho_S^2\ E(tS)_S}{1 - \rho_S^2} + E(tS)_S \tag{20}$$

$$\text{where } \rho_S = \frac{E(n)_{TCIC} \times E(tS)_S}{2}$$

and $E(n)_{TCIC}$ = the mean arrivals per second of TCIC inquiries.

Equation 20 is used to analyze TCIC turn-around time from the Austin switch in the analyses carried out in Section XI of this report. For the remainder of the network, that is, from multidrops to the Austin switch and back, equations similar to equations 12 and 13 used in Ohio are employed, with the exception that the term, E(tQCD), in those equations is replaced by two Austin switch single server mean queue times - one for input from the multidrop through the switch to the NCIC and one for the return pass.

For example, the total response time equation for a terminal whose multidrop is connected to the Austin switch would be:

$$E(tr) = \left[\frac{M-1}{2}\right] E(tpoll) + E(tWM2) + E(tSM2) \tag{21}$$

$$+ E(tQAS) + \frac{\rho_S{}^2 \; E(tS)_S}{1 - \rho_S{}^2} + E(tS)_S$$

$$+ E(tQAS) + E(tWM1) + E(tSM1)$$

where E(tQAS) = mean queue time for the Austin switch and other terms are as they are presented in equations 12 and 20.

The response time for terminals multidropped from the Garland or San Antonio switches would include additional terms accounting for remote switcher queues and interregion line queues in the identical fashion that equation 13 accounts for these terms in Ohio.

Thus far, we have developed an equation for the treatment of TCIC data base inquiries and responses. A similar set of equations must be developed to treat LIDR and MVD traffic.

In the case of the LIDR data base, a single line provides service for message flow between the Austin switch and the data base. For this system, as for the MVD system, a slightly different set of equations will apply. For each of these systems, as for the TCIC system, there will be a system queue time, that is, a system wait time plus a system service time. In the discussion of the TCIC system, we simply used the subscript, S, to denote the system. Let us now expand our terminology for clarity by using the following terms:

$E(tQ)_{ST}$ = system queue time for the TCIC system

$E(tQ)_{SI}$ = system queue time for the LIDR system

$E(tQ)_{SM}$ = system queue time for the MVD system

Each of these systems has a wait time and a service time as viewed from the standpoint of the Austin switch, so that, we may write

$$E(tQ)_{ST} = E(tW)_{ST} + E(tS)_{ST} \tag{22}$$

$$E(tQ)_{SI} = E(tW)_{ST} + E(tS)_{ST} \tag{23}$$

$$E(tQ)_{SM} = E(tW)_{SM} + E(tS)_{SM} \tag{24}$$

For the LIDR system, we have a single line which competes for data base service with the TCIC lines and the in-house DPS terminals. The LIDR system appears as a single server queue to the Austin switch with a mean service time $E(tS)_{SI}$ and a system utilization of ρ_{SI}. Therefore, the mean wait time for this system, $E(tW)_{SI}$, is

$$E(tW)_{SI} = \frac{\rho_{SI}\ E(tS)_{SI}}{1 - \rho_{SI}} \tag{25}$$

where $\rho_{SI} = E(n)_{LIDR} \times E(tS)_{SI}$

The value for $E(tS)_{SI}$ is the sum of the following components:

$E(tS)_{SI}$ = line transmission time to LIDR data base

+ wait time at the data base computer for service

+ mean service time for the transaction at the data base computer

+ line transmission time back to the Austin Switch from the data base computer

Let the line transmission time, (service time), from the Austin switch to the LIDR data base computer for input inquiries be $E(tS)_{AII}$. Then

$$E(tS)_{AII} = \frac{(L(m)\ \text{LIDR IN} + OH)B_c}{C} + \text{PAUSE} \tag{26}$$

Where all terms are as they appear in equation 16 and L(m) LIDR IN is the average message length for a LIDR inquiry.

The waiting time of the data base computer is calculated by considering delay times for each possible combination of TCIC, LIDR, and DPS in-house terminal messages, weighting these by their probability of occurrence, and summing these weighted probabilities. The procedure follows that carried out for the TCIC system earlier. For the LIDR, this analysis indicates that the wait time, E(tW) LIDR, for service for an LIDR inquiry in the data base computer is a function of ρ_{CD} and can simply be written as:

$$E(tW)_{LIDR} = E(tS)_{CD} \times \rho_{CD} \tag{27}$$

The mean service time for the data base computer $E(tQ)_{CD}$ of 394 milliseconds is, of course, also employed here.

Line transmission time, $E(tS)_{AIO}$, for an output from the data base to the Austin switch is:

$$E(tS)_{AIO} = \frac{(L(m)\ \text{LIDR OUT} + OH)B_c}{C} + \text{PAUSE} \tag{28}$$

where terms are as they appear in equation 16 and L(m)(LIDR)OUT is the average message length for an LIDR output response message.

Equations 26, 27 and 28 are combined to give an expression for LIDR mean service time as it appears to the Austin switch:

$$E(tS)_{SI} = E(tS)_{AII} + E(tSCD) \times \rho_{CD} + E(tSCD) + E(tS)_{AIO} \quad (29)$$

Now, substituting equation 25 into equation 23, the desired expression for total queue time, or response time, $E(tQ)_{LIDR}$, for the LIDR data base system as it appears to the Austin switch becomes;

$$E(tQ)_{LIDR} = \frac{\rho_{SI}\, E(tW)_{SI}}{1 - \rho_{SI}} + E(tS)_{SI} \quad (30)$$

Equation 30 is used to carry out the LIDR analyses presented in Section 11.

For the MVD, we have two lines providing service to the MVD data base, which is separate from the TCIC/LIDR data base, (see Figure 2-21).

This system is analyzed in a similar way as the TCIC and LIDR systems above. For the dual server MVD system queue as it appears to the Austin switch, the mean waiting time, $E(tW)_{SM}$, is,

$$E(tW)_{SM} = \frac{\rho^2_{SM}\, E(tS)_{SM}}{1 - \rho^2_{SM}} \quad (31)$$

where $\rho_{SM} = \frac{E(n)_{MVD}}{2} \times \frac{E(tS)_{SM}}{1}$

and $E(n)_{MVD}$ = Arrival rate of TLETS traffic

The equation for $E(tS)_{SM}$ follows the rationale developed for the TCIC and LIDR systems above. Thus

$$E(tS)_{SM} = E(tS)_{AMI} + E(tW)_{MVD} + E(tS)_{CM} + E(tS)_{AMO} \quad (32)$$

where

$E(tS)_{AMI}$ = line transmission time to the MVD data base

$E(tW)_{MVD}$ = wait time at the MVD data base computer for service

$E(tS)_{CM}$ = mean service time per transaction at the MVD computer

$E(tS)_{AMO}$ = line transmission time from the MVD data base to the Austin switch.

For the MVD system, the wait time for service for a transaction at the MVD computer, $E(tW)_{MVD}$, must consider the fact that agencies other than those associated with the TLETS network also use the MVD data base. TLETS, however, has non-preemptive interrupt priority over other users. To treat this case, we consider the total arrival rate of telecommunications messages at the MVD data base to be comprised of TLETS MVD inquiries, $E(n)_{MVD}$, and "other" arrivals at a rate of $E(n)_{MO}$. Thus, the total arrival rate of messages, $E(n)_{MT}$, is given by

$$E(n)_{MT} = E(n)_{MVD} + E(n)_{MO}$$

Therefore, utilization of the MVD data base due to TLETS traffic, ρ_{ML}, is

$$\rho_{ML} = E(n)_{MVD} \times E(tS)_{CM}$$

and the utilization due to "other" traffic, ρ_{MO}, is

$$\rho_{MO} = E(n)_{MO} \times E(tS)_{CM}$$

So that the total utilization of the MVD data base computer due to telecommunications traffic, ρ_{CM}, is

$$\rho_{CM} = \rho_{ML} + \rho_{MO}$$

Under these conditions, the mean waiting time for a TLETS MVD inquiry at the MVD data base computer is,

$$E(tW)_{MVD} = \frac{\rho_{CM}\, E(tS)_{CM}}{1 - \rho_{ML}} \tag{33}$$

The mean service time for the MVD 370/155 computer per transaction is similar to the TCIC/LIDR data base computer, i.e., 394 milliseconds.

Thus, the total system mean queueing time, $E(tQ)_{MVD}$, for MVD data base system as it appears to the Austin switch is

$$E(tQ)_{MVD} = \frac{\rho^2_{SM}\, E(tS)_{SM}}{1 - \rho^2_{SM}} + E(tS)_{SM} \tag{34}$$

Equation 34 is used in the analyses of the MVD system carried out in Section 11.

Sample Calculation

By way of example, let us consider the total mean response time for a terminal connected to the Garland switcher into the TCIC system and back to the terminal. In this sample calculation we shall use TLETS circuit 4 out of Garland - a 75 Baud multidropped line with 10 terminals. The communication path is over the multidropped line, through the Garland switch, over a dual server set of interregion lines, through the Austin switch, through the TCIC system as it appears to the Austin switch and back through each component to the inquiring terminal.

The equation components are shown in Table 2-9.

The sample calculation presented here makes use of numerical values listed in Table 2-10.

The equation components of Table 2-9 then become;

$$\left[\frac{M-1}{2}\right] E(tpoll) = \left[\frac{M-1}{2}\right]\left[\frac{POH \times U_c}{C_m} + PPSEM\right] = \quad 3.15 \text{ sec}$$

$$E(tW)2) = \frac{\rho_m \ E(tSM2)}{(1-\rho_{m1})\ (1-\rho_{m1}-\rho_{m2})} = \quad 5.9 \text{ sec}$$

$$E(tSM2) = \frac{(Lm2 + OH)\ Uc}{Cm} + MPSEM = \quad 15 \text{ sec}$$

$$E(tQ)CR = \frac{E(tS)CR}{1-\rho cR} = \quad 0.35 \text{ sec}$$

$$E(tQ)RI = \frac{E(tS)RI}{1-\rho RI^2} = \quad 0.55 \text{ sec}$$

$$E(tQ)CA = \frac{E(tS)CA}{1-\rho cA} = \quad 0.86 \text{ sec}$$

$$E(tQ)\ TCIC = \frac{\rho_S T\ E(tS)ST}{1-\rho S_T} + E(tS)ST = \quad 2.1 \text{ sec}$$

$$E(tQ)CA = \text{See Above} = \quad 0.86 \text{ sec}$$

$$E(tQ)RO = \frac{E(tS)RO}{1-\rho R_{O}2} = \quad 0.9 \text{ sec}$$

Table 2-9. Equation Components

Equation Component	Meaning
$E(tr) = \left[\frac{M-1}{2}\right] E(tpoll) + E(tWM2) + E(tSM2)$	Wait on multidrop for service (priority 2, input) plus service time on multidrop to Garland switch
$+ E(tQ)_{CR}$	Wait plus service time at Garland switch for TCIC input message
$+ E(tQ)_{RI}$	Wait plus service time for dual server inter-region lines - input message - one priority
$+ E(tQ)_{CA}$	Wait plus service time at Austin switch for input message
$+ E(tQ)_{TCIC}$	Wait plus service time for TCIC system as it appears to Austin switch
$+ E(tQ)_{CA}$	Wait plus service time through Austin switch for output message
$+ E(tQ)_{RO}$	Wait plus service time for dual server inter-region lines - output message - one priority
$+ E(tQ)_{CR}$	Wait plus service time at Garland switch for TCIC output message
$+ E(tSM1)$	Wait plus service time for output message onto multidrop line - (priority 1, i.e., output over input)

Table 2-10. Sample Calculation Input Values

Term	Meaning	Value
M	Number of terminals on multidrop	10
Cm	Line capacity of multidrop	75 Baud
POH	Polling overhead	3 char
PPSEM	Total line turn around time for a poll	0.4 sec
MPSEM	Total line turn around time for a message	0.4 sec
OH	Message overhead on multidrop	12 char
Uc	Units per character on multidrop	7.5 bit/char
Lm2	Input average message length from multidrop - priority 2	134 char
Lm1	Output average message length to multidrop - priority 1	208 char
Lm	Overall average message length on multidrop	177 char
E(nM1)	Arrival rate of output messages to multidrop	0.006/sec
E(nM2)	Arrival rate of input messages from multidrop	0.005/sec
E(tS)CR	Mean service time of Garland Switcher	0.300 sec
E(n)CR	Total arrival rate of messages at Garland Switcher	0.5 sec
Cr	Line capacity of interregion lines	2400 Baud
MPSER	Total line turn around time per message on interregion lines	0.056 sec
LmRI	Average message length of messages from Garland Switcher to Austin Switcher	134 char

Table 2-10. Sample Calculation Input Values (Continuation 1)

Term	Meaning	Value
LmRO	Average message length of messages from Austin Switcher to Garland Switcher	208 char
E(n)RI	Rate of message flow from Garland to Austin	0.2/sec
E(n)RO	Rate of message flow from Austin to Garland	0.22/sec
UcR	Units per character on high speed lines	8 bits/char
E(tS)CA	Mean service time of Austin Switcher	0.400 sec
E(n)CA	Total arrival rate of messages at Austin Switcher	1.34/sec
CAT	Line capacity for lines between Austin Switcher and TCIC	2400 Baud
OHH	Overhead characters on high speed lines	13 char
PSAT	Total line turn around time per message on TCIC lines	0.032 sec
LmATI	Average message length of messages from Austin Switcher to TCIC	183 char
LmATO	Average message length of messages from TCIC to Austin Switcher	168 char
E(tS)CD	Mean service time of TCIC computer (data base computer)	0.400 sec
E(nT)	Arrival rate of messages to TCIC data base	0.23/sec
E(nI)	Arrival rate of messages to LDIR data base	0.12/sec
E(nT)	Arrival rate of transactions from DPS in-house terminals	1.27/sec

$$E(tQ)CR = \text{See Above} = \qquad 0.35 \text{ sec}$$

$$E(tWM1) = \frac{\rho m \; E(tS)M1}{(1-\rho m1)} = \qquad 4.7 \text{ sec}$$

$$E(tSM1) = \frac{(Lm1 + OH) \; Uc}{Cm} + MPSEM = \qquad 22.4 \text{ sec}$$

Thus the total response time, E(tR), in this sample calculation is the sum of the above terms:

$$E(tR) = 57.1 \text{ sec}$$

SECTION III

OHIO NETWORK STUDIES

SECTION III

OHIO NETWORK STUDIES

Ohio Network studies consist of examining eight optional network configurations, and the execution of two additional network performance studies.

Options 1 through 4 investigate potential cost savings in trading off network line costs with regional switcher costs. Options 5 and 6 examine the cost tradeoff between maintaining separate LEADS and BMV networks, vs. integrating these functions in a single network. Options 7 and 8 study a similar concept for separate versus integrated LEADS and New Data type networks. Two additional network performance studies include consideration of network cost increases as terminal response times are reduced, and an inquiry into the impact on network cost and performance due to adding digitized fingerprints data as a traffic type.

The following paragraphs outline these studies in more detail.

3.1 OPTIONS 1 THROUGH 4

As the number of regional switchers serving terminals within their regions are increased in a network, total network line costs may be expected to decrease due to the fact that total network line length has decreased. The placement of additional regional switchers, however, imposes an additional network cost which may or may not offset cost savings due to decreased line lengths.

Options 1 through 4 seek to understand whether the addition of regional switchers throughout Ohio has the potential to realize meaningful network cost savings.

Option 1 considers the present LEADS single region concept with a switching data base computer located in Columbus. Option 2 considers the cost effect of adding a regional switcher in Cleveland. In Option 3, two regional switchers are added -- one in Cleveland and one in Cincinnati and in Option 4 three regional switchers are considered with one in Cleveland, Cincinnati and Toledo.

In each of these cases, the STACOM Program described in Section 2 of this report, seeks near optimum, (least cost), network line topologies.

3.2 OPTIONS 5 and 6

A first observation of the present LEADS and BMV networks suggests that line cost savings may be realized through combining terminals of the now two separate networks into a single integrated LEADS/BMV Network.

The LEADS network alone is subject to interstate line tariff schedules and the BMV network alone operates under an intrastate tariff. Should the networks be combined, the single integrated network would be subject to an interstate tariff.

Option 5 considers cost totals for operation of separate optimized (least cost) BMV and optimized LEADS networks.

Option 6 considers cost totals for a single integrated LEADS/BMV network.

In both cases the LEADS network used for comparative purposes, shall be the least cost LEADS network that develops from the studies of Options 1 through 4.

3.3 OPTIONS 7 and 8

Options 7 and 8 are similar conceptually to Options 5 and 6 except that they investigate separate LEADS and New Data networks versus a single integrated LEADS/New Data network. The options are designed to understand cost and performance consequences of including non-law enforcement criminal justice data types of statewide interest on the LEADS network.

As in the case of Options 5 and 6, the LEADS network used for comparative purposes shall be the least cost LEADS network that develops from the studies of Options 1 through 4.

3.4 COST SENSITIVITY to RESPONSE TIME

A study designed to clarify the extent to which total network costs increase as terminal response times are reduced is to be carried out. As response times are reduced from the 9 second goal specified in the OHIO Functional Requirement, networks will be called for that drop fewer terminals on given multidrops and, hence, require more lines. Higher speed lines may also be required as response time requirements are made more stringent. These factors will tend to increase overall network costs.

This study will determine the extent of cost increases as a function of decreasing network response times for the least cost LEADS network that results from studies of Options 1 through 4.

3.5 IMPACT of ADDING FINGERPRINTS as a DATA TYPE

Estimates of fingerprint traffic in Ohio made in the traffic level estimation task of the Ohio project assume the use of automated digital classifying equipment at strategic locations throughout the state. The potential impacts of the addition of such data types to the LEADS network in terms of cost and performance are a matter of interest. From the performance standpoint the principal consideration is the extent to which the addition of fingerprint data may effect response time characteristics of higher priority officer safety type messages.

This study determines the extent of such impacts on the least cost LEADS network which develops from Options 1 through 4.

SECTION IV

OHIO NETWORK COST ANALYSIS

SECTION IV

OHIO NETWORK COST ANALYSIS

This section presents assumptions and bases for costing OHIO Network options. Total network costs are comprised of recurring costs and one time installation costs. Table 4-1 shows the basic cost items considered and describes the meaning of each item.

The costs considered here include the primary items that affect relative costs between network configurations involving different numbers of switchers and different traffic types. Costs for required upgrades of the central data base computer in Columbus are not included, since these costs are present to the same degree in all of the alternative network configurations studied. Detailed costing of data base computer upgrades is not within the scope of STACOM Study which is primarily oriented toward network alternatives. Basic data base computer performance requirements, however, are treated in Section 7.2 of this report.

The following paragraphs develop costing values for each item listed in Table 4-1.

4.1 LINE, MODEM and SERVICE TERMINAL COSTS

Two types of line tariffs were used in the STACOM/OHIO program. For the LEADS Network, or any networks that included the LEADS System, such as the integrated BMV/LEADS network and the integrated New Data/LEADS Network, the Interstate Multi-schedule Private Line, (MPL), Ohio tariff was used. The specific MPL tariff used is shown in Table 4-2. Cost for modems and service terminals under MPL are shown in Table 4-3.

For the BMV Network, which is wholly contained within the State of Ohio (intrastate), line, modem and service terminal costs shown in Table 4-4 were used.

4.2 TERMINAL COSTS

At the time of initiation of this study, the Ohio LEADS system employed 127 high speed terminals and 263 low speed terminals on a leased basis. Since the STACOM functional requirements call for line upgrade to 1200 Baud or higher, it is asumed that low speed terminals shall be replaced. It is also assumed that existing high speed terminals can now be replaced by lower cost units that meet terminal performance requirements.

Since the STACOM/OHIO Network designs are configured to last a period of greater than three years, (to 1985), it is more cost effective to purchase new terminals and carry maintenance contracts than to lease terminals. Therefore, terminal costing assumes purchasing rather than leasing. An industry wide representative cost for a pollable CRT terminal with keyboard, operation speed to 9600 Baud, printer and Univac

Table 4-1. Cost Items and Descriptions

Item	Recurring Costs	One-Time Installation Costs
Lines, Modems, Service Terminals	Annual Tariff Costs	Modem and Service Terminal Installation
Terminals	Maintenance Costs	Purchase Costs
Regional Switchers	Maintenance Costs	Purchase Costs
Switcher Floor Space	Regional Switcher Site Rental Costs	Regional Switcher Site Preparation Costs
Switcher Backup Power	Maintenance Costs	Purchase Costs
Switcher Personnel	Regional Switcher Personnel Salaries	Not Applicable
Engineering	Not Applicable	Network Procurement Costs

Table 4-2. MPL Line Tariff

Schedule		Mileage Breakdown	Cost ($)
I	Between any Schedule		
	I cities listed:	1	$ 51.00
	Akron	2 - 14	51.00 + 1.80/mi over 1 mi
	Cincinnati	15	76.20
	Cleveland	16 - 24	76.20 + 1.50/mi over 15 mi
	Columbus	25	91.20
	Canton	26 - 99	91.20 + 1.12/mi over 25 mi
	Dayton	100	175.20
	Toledo	101 - 999	175.20 + 0.66/mi over 100 mi
	Youngstown	1000	769.20
		1000 +	769.20 + 0.40/mi over 1000 mi
II	Between Schedule		
	I cities and any	1	$ 52.00
	other city	2 - 14	52.00 + 3.30/mi over 1 mi
		15	98.20
		16 - 24	98.20 + 3.10/mi over 15 mi
		25	129.20
		26 - 39	129.20 + 2.00/mi over 25 mi
		40	159.20
		41 - 99	159.20 + 1.35/mi over 40 mi
		100	240.20
		101 - 999	240.20 + 0.66/mi over 100 mi
		1000	834.20
		1000 +	834.20 + 0.40/mi over 1000 mi
III	Between two non-		
	schedule I cities	1	$ 53.00
		2 - 14	53.00 + 4.40/mi over 1 mi
		15	114.60
		16 - 24	114.60 + 3.80/mi over 15 mi
		25	152.60
		26 - 39	152.60 + 2.80/mi over 25 mi
		40	194.60
		41 - 59	194.60 + 2.10/mi over 40 mi
		60	236.60
		61 - 79	236.60 + 1.60/mi over 60 mi
		80	268.60
		81 - 99	268.60 + 1.35/mi over 80 mi
		100	295.60
		101 - 999	295.60 + 0.68/mi over 100 mi
		1000	907.60
		1000 +	907.60 + 0.40/mi over 1000 mi

Table 4-3. MPL Modems and Service Terminal* Costs

Baud Rate	Modems		Service Terminal	
	Install $	Maintenance $/mo	Install $	Maintenance $/mo
1200	54.15	32.50	50.00	25.00
2400	81.20	59.55	50.00	25.00
4800	163.00	135.00	50.00	25.00

*Also referred to as station charge

Table 4-4. Intrastate Line Tariff

Baud Rate		Modems		Service Terminals	
	Line Cost/ mile/mo $	Install $	Maint. $/mo	Install $	Maint. $/mo
1200	2.00	25.00	20.00	80.00	31.00
2400	2.00	138.00	55.00	80.00	31.00
4800	2.00	100.00	100.00	80.00	31.00

compatibility is $5540 per unit. A 35% quantity discount is assumed for the 390 required terminals so that the unit cost is $3,600. This unit cost includes installation costs. It is estimated that a maintenance contract is available at $50 per unit per month.

4.3 REGIONAL SWITCHER COSTS

A suitable Regional Switcher configuration that meets STACOM/OHIO Functional Requirements includes the following items:

- 64 line synchronous/asynchronous front end
- A Central Processing Unit
- 64K Bytes Memory
- I/O Controller
- 10M Byte Disk Storage
- U-100 Console
- Line Handling Equipment

A representative purchase price for this configuration, including all necessary software, is $180,000 per switcher with a monthly maintenance charge of $1,000. As in the case with terminals, the cost effectiveness of purchasing regional switching equipment as opposed to leasing, for systems whose life expectency is greater than 40 months is evident. It is assumed, therefore, in network options that involve the use of regional switchers that these switchers are purchased.

4.4 REGIONAL SWITCHER FLOOR SPACE

It is assumed that 1000 ft^2 of floor space is sufficient for housing a regional switcher facility including personnel office space. Facility preparation costs are estimated at $30,000 per switcher facility including personnel office space. Monthly rental is estimated at $\$0.40/ft^2$ so that monthly rental per switching facility is $400.

4.5 SWITCHER BACKUP POWER

Uninterruptable power supplies, (UPS), are provided at each regional switching facility to ensure commercial power continuity during momentary power transients as well as over extended time periods.

Solid-state static inverter type UPS including a rectifier/charger, and autobypass switch are available at approximately $13,000 per unit. Batteries for the unit are estimated to cost $2,500. A gasoline engine generator for use when lengthy outages occur include weatherproof housings and auto transfer switches that operate when commercial power fails. These units are priced at $4,500 each.

The total one-time purchase price for each installation is, therefore, $20,000. A maintenance contract for both the UPS and engine generator is estimated at $500 per month.

4.6 ENGINEERING COSTS

Engineering costs associated with network implementation were estimated for single and multiple region configurations. Networks involving a single region concept are the LEADS single region network, (Option 1), the integrated LEADS/BMV network, (Option 6), the integrated LEADS/New Data network, (Option 8), the separate BMV network configuration, (Option 5), and the separate New Data network, (Option 7). Table 4.5 shows manpower estimates in man-months for assumed engineering costs. The values shown for the single region separate New Data network are reduced with respect to other single region networks since the network is considerably smaller. Cost per man-month including overhead and benefits is estimated at $4,000.

4.7 PERSONNEL COSTS

Regional switching facilities require supervisory, programming and computer operations personnel. This study assumes that each regional switcher facility requires one supervisor, two programmers and six computer operators. Two computer operators are provided per shift for safety reasons so that at no time during a 24-hour day the facility is manned by one person alone. Table 4-6 presents estimated salaries for the required personnel.

4.8 COST SUMMARY

Table 4-7 summarizes recurring and one-time installation costs developed in this section for convenient reference.

4.9 OHIO NETWORK IMPLEMENTATION

The networks presented in this study are designed to meet STACOM/ OHIO traffic requirements presented in the Task 2.0 Report through the year 1985. A cost analysis on the feasibility of constructing an intermediate network to meet 1981 traffic level requirements, and then upgrading this network in 1981 to meet 1985 traffic level requirements, as opposed to building a single network to meet traffic requirements through 1985, was carried out. It was found that building a single network now to meet 1985 traffic requirements would not involve additional cost over intermediate phasing of network upgrades. A single exception to this rule occurs in the cases of networks where New Data Types are involved, (Options 7 and 8).

Table 4-5. Engineering Cost Estimates
(man months)

Task	2, 3, & 4 Regions	1 Region New Data Types	1 Region Others
Final Functional Requirements	2	1	2
Switcher Design Spec/RFP	4	-	-
Network Design Spec/RFP	4	1	4
Switcher Facilities RFP	4	-	-
Switcher Procurement Monitor	6	-	-
Network Procurement Monitor	6	3	6
Facilities Procurement Monitor	6	-	-
Switcher Test Plan	2	-	-
Switcher Testing	2	-	-
Network Test Plan	2	1	2
Network Testing	2	1	2
Documentation	6	1	6
Supporting Analysis	6	2	6
User Operators Manual	6	2	6
TOTALS - Man Months	58	12	34
APPROXIMATE COST AT $4K/MM ($K)	230	50	130

Table 4-6. Personnel Costs

Personnel	No. Required	($K) Annual Salary	($K) Annual Cost
Supervisor	1	20	20
Programmers	2	18	36
Operators	6	12	72
TOTAL PERSONNEL ANNUAL COST			$128K

Table 4-7. Cost Summary by Item

Item	Annual Recurring Cost Per Unit ($k)	One-Time Installation Cost Per Unit ($k)
Lines, Modems, Service Terminals	see Tariffs Tables 4.2, 4.3, 4.4	None
Terminals	0.6	3.6
Regional Switchers	12.0	180.0
Switcher Floor Space	4.8	30.0
Switcher Backup Power	6.0	20.0
Switcher Personnel	128.0	None
Engineering	None	50/130/230 See Paragraph 4.6

Growth in new data type volumes from the present through 1985 is such that it is less costly to implement one network to handle traffic volumes up to 1980 and to then add to the network to meet traffic demands from 1981 through 1985.

For these reasons costs presented in Sections 7 and 8 are based on the construction in 1978 of networks that will accommodate predicted traffic levels through 1985 with the exception of networks involving new data types that are phased as indicated.

Thus, STACOM/OHIO Networks can be regarded as involving cost over a period of eight years. Therefore, total eight year costs including installation and recurring costs are used as a basis of network option cost comparisons.

SECTION V

OHIO NETWORK FUNCTIONAL REQUIREMENTS

SECTION V

OHIO NETWORK FUNCTIONAL REQUIREMENTS

This section presents the functional requirements as the top level network specification, to serve as a basis, for all lower level design specifications involved in the total network.

Included is a basic description of the Ohio STACOM network, the network elements and required functions.

The use of the term STACOM Network refers to a single network or a group of networks that meet the functional requirements outlined herein.

5.1 NETWORK PURPOSE

The purpose of the STACOM Network is to provide efficient telecommunications capable of transporting information between Ohio state criminal justice agencies on a statewide scale and to and from specific interstate criminal justice agencies. Criminal justice agencies are agencies whose primary functions encompass law enforcement, prosecution, defense, adjudication, corrections and pardon and parole. The network shall be designed to handle communication requirements among these agencies projected through the year 1985.

5.2 STACOM USERS

Users of the STACOM Network shall consist of any authorized agency within the Ohio Criminal Justice System. Users shall consist of the present users of the Ohio Law Enforcement Automated Data System, (LEADS), and other criminal justice agencies to the extent that their needs and contributions are compatible with the overall network goals of th Ohio STACOM Network Management.

5.3 BASIC NETWORK CONFIGURATION

The basic configuration of the STACOM Network is an array of network system terminations connected through Regional Switching Center, (RSC), facility(s) to a single data base located in Columbus, Ohio. There may be one or more networks comprising the STACOM Network to be determined during network analysis and design phases of the STACOM Project.

Each system termination on the STACOM Network shall be defined as one of three types:

(1) Individual terminals

(2) Groups of terminals in cities

(3) Interfaces to regional criminal justice systems

Any of the system terminations shall be able to communicate with any other system termination. Each system termination shall not be routed through more than one RSC in gaining access to the Columbus data base, not including the Columbus switching facility, during normal network operation.

Each system termination shall be connected to an RSC which serves the region in which the system termination is located. System terminations shall be connected to RSCs in minimum cost configurations that meet the functional requirements outlined herein. Direct connections between system terminations and RSCs and multidropped configurations shall be considered.

5.4 MESSAGE CHARACTERISTICS

5.4.1 Digital Message Types

The STACOM network shall handle the following five basic types of messages.

- Data File Interrogations/Updates
  These messages shall be inquiries, entries, modifiers, cancels, clears and responses to and from a data file at the state or national level. The text is generally in fixed format.

- Administrative Messages
  These are messages between network users which do not involve data file access. The text is in a less restrictive format.

- Network Status
  These messages shall provide information at terminals initiating messages in the event that destination terminals or intermediate switchers or lines are unable to function.

- Error Messages
  These messages shall contain information regarding the nature of errors detected in transmitted messages. Messages in which errors are detected are not automatically retransmitted on the network, but may be re-sent at the user's discretion.

- Fingerprints
  Digitized and/or analog representations of fingerprints shall be included on the STACOM Network.

5.4.2 Message Content

Criminal justice messages shall contain the following information in known locations:

Internal LEADS messages shall contain

- Message Origin
- Message Type

Regional LEADS messages, (RCIC, NCIC), shall contain

- Message Type
- Message Sequence Number
- Message Origin

The State Data Base Computer in Columbus shall determine for each message

- Message Destinations
- Message Number
- NCIC Identifiers of Sending Agency
- Sending Authority

5.4.3 Message Lengths

Digital messages transmitted over the STACOM Network shall not exceed 500 characters in length. Actual messages exceeding 500 characters shall be blocked in message segments which shall not exceed 500 characters each. Multisegment messages shall have a single overall message number and distinct message segment numbers. Each segment shall be transmitted as a separate message. The destination terminal(s) must reassemble the overall message upon reception.

5.5 NETWORK MESSAGE HANDLING

5.5.1 Message Routing

The STACOM Network shall provide communications routing for all messages between any two of its system terminations.

The following specific routing capabilities shall be provided:

- Data base inquiry/update messages shall be routed from the originating terminal to the Columbus data base through no more than one intermediate Regional Switching Center, not including the Columbus switcher, under normal network operation. Interface routing to NLETS and the NCIC shall be maintained as in the present Ohio LEADS system.

- Administrative messages shall be routed from the originating terminal to the destination terminal through no more than two RSCs under normal network operation. Administrative messages shall also have a capability for ALL POINTS routing as currently employed by the Ohio LEADS system.

- Digitized fingerprint data shall be routed from the originating terminal to the Ohio Bureau of Criminal Investigation, London, Ohio through no more than two RSCs under normal network operation.

Message routing shall be accomplished by the regional switcher(s) utilizing the destination information in the message. Single messages destined for the same region in which they originate shall be switched to the appropriate system termination by the regional switcher servicing that region.

When more than one system termination is specified as the destination point, the message shall first be routed through the Columbus switcher where STACOM Network Management may exercise the option to grant message approval. The Columbus switcher shall then generate the required number of messages and transmit them to designated system terminations in its own region, and shall transmit a single message to other regional switchers which serve system terminations that are also designated, where the appropriate messages shall be generated and transmitted.

5.5.2 Message Prioritization

Prioritization of messages shall be incorporated in the STACOM Network to the extent required to meet the message response time goals outlined in Paragraph 5.2.2.3.

Messages shall be handled on a non-preemptive priority basis. In this scheme, messages or message segments in process of being transmitted shall not be interrupted, but allowed to complete before higher priority messages are honored.

Under the above conditions, the STACOM Network shall be capable of recognizing and handling message types in accordance with the following prioritization:

Priority 1: Items that may be directly related to officer safety, such as inquiries into Auto Alert, Vehicle Registration, Operators License and Wants/Warrants files, and ALL POINTS Administrative messages of a tactical nature.

Priority 2: Administrative messages not related to officer safety or tactical needs, and CCH/OBTS, WE, SJIS, and OBSCIS messages.

Priority 3: Fingerprint data or other criminal justice data consisting of large numbers of message segments.

The assignment of message types by the STACOM Network to a given priority level shall be under computer software control so that such assignments may be altered by STACOM Network management as needs arise.

5.5.3 Response Time Goals

Response time for the STACOM Network is defined as the time duration between the initiation of a request for service of an inquiry message by the network at a system termination and the time at which a response is completed at the inquiring system termination.

The response times shown below are maximum times for mean response times and for response times of messages 90% of the time. These response times represent maximum allowable goal values on the STACOM Network.

Stacom Response Time Goals Maximums

Message Priority	Mean Response Time	90% of Responses to Inquiries Received in Less Than
1	9 sec	20 sec
2	1 min	2.3 min
3	2 hr	4.5 hr

5.5.4 Line Protocol

(1) Half Duplex:
The standard interface to system terminations shall be half duplex.

(2) Full Duplex:
Full duplex line discipline may only be used interregionally.

5.5.5 Message Coding

All STACOM Network messages shall be coded using the American Standard Code for Information Interchange (ASCII), USAS X3.4-1968. Message coding for interaction with the NCIC, RCIC, and NLETS systems shall conform to existing practices of the Ohio LEADS Network.

5.5.6 Error Detection

The STACOM Network regional switchers shall provide for bit error detection of erroneous messages. Error messages shall be transmitted to system terminations in accordance with present practices of the Ohio LEADS Network. The computer shall detect format errors and transmission errors on incoming messages and notify the sending terminal appropriately. The computer shall also detect off-line or inoperative terminals.

Messages shall not be automatically retransmitted upon error detection. Messages may be retransmitted at the discretion of the user.

5.5.7 Network Status Messages

The STACOM Network shall provide for notification to system terminations of any conditions which prevent operation in the normal specified manner. System terminations shall receive such status messages upon attempting to use the network when the network is in a degraded mode. System terminations so notified shall receive a further status message indicating normal network operation has been restored when malfunctions have been corrected.

5.6 SYSTEM TERMINATIONS

STACOM Network system terminations having interface capability of 1200 BPS or greater shall interface with the network using half duplex protocol. Terminals shall have the capability for off-line construction of input messages and for hard copy production of received messages.

All terminals shall be pollable and provide for parity error detection.

The number of system terminations per multidropped line shall not exceed 25.

5.7 REGIONAL SWITCHING CENTERS

The STACOM/Ohio Network shall be comprised of one dual processor Regional Switching Center (RSC) with a redundant data base located in Columbus and up to three additional RSCs without data bases. The following describes the capabilities of each type of RSC.

5.7.1 Switchers Without Data Bases

5.7.1.1 Communication Line Interfaces. An input communication line interface shall convert incoming serial bit streams into assembled characters and furnish electrical interface for the modem and logic required for conditioning.

An output communication line interface shall convert characters into a bit stream. It shall also provide logic necessary to condition the modem for transmission and furnish the necessary electrical interface.

RSCs shall be designed to handle either full or half duplex line protocols on any line interface.

5.7.1.2 <u>Message Assembly/Disassembly.</u> A message assembly unit shall assemble messages by deblocking the character stream.

A message disassembly unit shall segregate messages into logical blocks for output. It shall also disassemble the blocks into a character stream for presentation to the communication line interface.

5.7.1.3 <u>Error Control.</u> The error control function shall provide error detection capability and initiate error messages in accordance with requirements outlined in Section 5.5.6. The error detection function is highly dispersed. Character parity is most efficiently checked during assembly of characters in the interface. Block parities are checked upon assembly of blocks. Additionally, all internal data transfers shall require a parity check.

5.7.1.4 <u>Message Control and Routing.</u> The message control and routing function shall provide logic which examines the assembled message, determines its priority, destination, and forms the appropriate pointers and places them in the proper queue, (the pointers are queued, not the messages).

Message routing shall be performed by RSCs in accordance with procedures outlined in Section 5.5.1.

In addition, this function shall maintain network status information for the purposes of determining availability of alternate communication paths in degraded modes of operation.

5.7.1.5 <u>Queue Control.</u> This function shall provide buffer and queue storage used to assemble input messages, buffer them for output and to form space to queue the message pointers.

Regional switchers shall maintain necessary queues for each system termination they service and for interregional traffic. These queues shall hold messages that cannot be sent immediately due to line usage conflicts. However, the regional switchers shall not maintain a long term store and forward capability. In the event that queue space is full, the regional switcher shall not accept any more messages and shall notify the other switcher not to accept messages destined for the switcher in question.

This capability shall be provided through use of upper and lower queue threshold specifiable by the regional switcher operator. All system terminations sending messages to the regional switcher which would demand queue space in excess of the upper threshold shall be sent negative acknowledgement responses. Once the upper threshold has been exceeded, the regional switcher shall enter the input control mode (i.e., the regional switcher shall output only). Any request for regional switcher service while it is in the input control mode shall result in a wait acknowledgement being sent to that system termination. The regional switcher shall stay in the input control mode until the lower threshold is attained.

Queue control procedures at the regional switchers shall be comprised of the following basic functions:

- Provide three independent queues for each system termination by priority as required.
- Dynamic queue management where a common core pool is made available for queueing on an as-need basis.
- Queue overflow management as discussed above.
- Provide queue statistics for input to statistics gathering function, as discussed.

5.7.1.6 Line Control. The line control function shall provide the capability of controlling and ordering the flow of data between the various message switchers. It also determines which line discipline is to be used. Full-duplex, half-duplex, polled or contention line discipline capabilities shall be possible.

5.7.1.7 Network Statistics. The STACOM Network shall be capable of collecting statistical data fundamental to the continued efficient use of traffic level prediction and network design tools developed by the STACOM Project.

The STACOM Network shall be capable of collecting the following statistical data:

- Number of messages by message type received from each system termination at State Data Bases.
- Number of messages by message type sent to each system termination from State Data Bases.
- Average message lengths by message type received at State Data Bases.
- Average message lengths by message type sent from State Data Bases.

The STACOM Network shall provide for periodic sampling of the following statistics:

- Origin-Destination message volumes by system termination.
- Percent of "HITS" and "NO-HITS" on each data base type.

- Average waiting times of input messages at switching and data base computers for CPU service.

- Average waiting times of output messages at switching and data base computers for output lines after CPU service.

- Average CPU service time per message at switching and data base computers.

- Total number of messages received each hour at the State Data Base.

- Total response time for data base interrogations/ updates of selected system terminations.

5.7.1.8 Operator Interface. The regional switcher shall provide means of interfacing with the operator. This interface shall be used to control and monitor the regional switcher and its network. The following functions are to be provided:

- The regional switcher shall provide a set of commands for the purpose of communicating with the operator.

- The regional switcher shall provide means of outputting data to the operator at a rate of at least 30 characters per second.

- The regional switcher shall provide means of accepting operator control input.

- The regional switcher shall provide high speed data output capability. This data output capability shall not be less than 300 lines per minute. A line shall have 132 characters.

5.7.2 Switchers With Data Base

RSCs with data base capability employ the additional function of providing file search and update capability. This function involves receiving messages from the switchers message control and routing function (see 5.5.1), and placing their pointers in queue by priority for access to data base files. Upon completion of data base access, messages are returned to the message control and routing.function in preparation for output.

RSCs with data bases shall maintain redundant data base files, each of which is updated in parallel at the time of file update.

5.8 NETWORK AVAILABILITY GOAL

The availability goal for the STACOM Network shall be 0.979 for the worst case Origin-Destination, (O-D), pair of system terminations on the network. The worst case O-D pair is defined as that link from system termination to the data base computer that employs the largest number of system components in its path, or the one that is most vulnerable to failure.

Availability of 0.979 implies an average outage of less than or equal to 30.2 minutes per day for the worst case path.

5.9 TRAFFIC VOLUMES

The STACOM Network shall be designed to handle traffic projections through the year 1985. These projections shall include traffic estimates plus design margins for peak vs. average loading. The total network throughput projected from 1977 to 1985 is as follows:

Total STACOM Network Throughput

(Average Msg/Day in 1000s)

Year	Leads	BMV	New Data Types
1977	147	9	14
1981	214	85	142
1986	284	98	170

5.10 CONSTRAINTS AND BOUNDARIES

5.10.1 Data Handling Constraints

- All data transmission shall be digital with the exception of fingerprint data which may be transmitted analog, or digitally, or both.
- No unscrambling or decryption shall be performed within the STACOM Network. (Some modems perform scrambling in the normal course of their operation but this scrambling is transparent to the user.)
- Traffic loading by network users in excess of the traffic safety margins for which their system terminations are designed could result in degraded message response time.

5.10.2 Data Rate Constraints

The minimum service goal for the STACOM/Ohio Network shall be 1200 Baud half-duplex lines. All available line capacity services above this rate shall be eligible for consideration in a cost/performance effective manner.

5.10.3 Security and Privacy Constraints

The STACOM Network shall be configured to allow management control by an authorized criminal justice agency or group of such agencies. Only STACOM Network operating personnel who have been authorized by STACOM Network management shall have physical access to the network equipment. These personnel shall have been thoroughly screened. It shall be the responsibility of the STACOM Network management to institute and maintain security measures and procedures consistent with good practice.

It shall be the responsibility of the STACOM Network Management to insure that unauthorized personnel are not allowed access to system terminations and that authorized personnel do not employ the network facilities for any purposes other than those for which the STACOM Network is specifically intended.

STACOM Network design shall assist in the realization of adequate security to the extent that engineering considerations can contribute. The STACOM Network shall consider in its design methods to prevent any alteration of the content of messages once they have been routed over the network. All of the equipment comprising the STACOM Network, except for the communication lines, shall provide adequate physical security to protect them against any unauthorized personnel gaining access to the STACOM Network. The computers and other network accessing equipment comprising the STACOM Network shall be located in controlled facilities. Redundant elements should be configured such that a single act of sabotage will not disable both redundant elements.

SECTION VI

ANALYSIS OF EXISTING NETWORKS IN OHIO

SECTION VI

ANALYSIS OF EXISTING NETWORKS IN OHIO

This section presents a brief description of the existing LEADS system in Ohio and a comparison of network characteristics with the design criteria presented in the OHIO Functional Requirements.

Areas of discrepancy in the existing system are noted, analyzed and discussed.

6.1 THE EXISTING LEADS NETWORK

The LEADS Network presently consists of ten, 2400 Baud line configurations serving 102 Ohio State Patrol offices and twenty, 150 Baud multidropped lines serving 287 sheriffs and Police Departments. The network also provides lines for the Toledo NORIS System, the Cleveland Police Department, the Cincinnati CLEAR System, NLETS and the NCIC.

Figure 6-1 shows a layout for the 2400 Baud lines and Figure 6-2 shows the layout for the 150 Baud lines. The figures show the present LEADS system to consist of a single regional switching facility located in Columbus, along with state data bases, serving the Ohio law enforcement community.

The present system shows no more than 15 terminals multi-dropped on any one line. This restriction is due to earlier computer front end limitations when the LEADS system employed a UNIVAC 1106 dual processor in Columbus.

In December of 1976, the 1106 was replaced with a UNIVAC 1100/42 system which is presently in service.

Total costs for the present LEADS system for lines, modems and service terminal arrangements is $606,000 per year.

UNIVAC Uniscope-100 terminals are used on 2400 Baud lines and NCR 260-6 terminals are used on the 150 Baud lines. The total lease annual cost for terminals on the LEADS System is $745,000.

6.2 COMPARISONS OF EXISTING NETWORKS WITH STACOM/OHIO FUNCTIONAL REQUIREMENTS

Table 6-1 summarizes conformity to STACOM/Ohio Functional Requirements by existing networks. Two main areas of deviation exist;

(1) Response times on LEADS 150 Baud lines are inadequate. Response times on 2400 Baud lines are inadequate at times of peak traffic loading.

Figure 6-1. Present Ohio LEADS Network 2400 Baud Lines

Figure 6-2. Present Ohio LEADS Network 150 Baud Lines

Table 6-1. Conformity Summary of Existing Networks to STACOM Functional Requirements

Requirement	Section V Requirements Met	Section V Requirements Not Met
Message Characteristics	All	---
Network Message Handling	Routing, Protocol, Coding, Error Detection, Status Messages	Response Time on 150 Baud Lines (Note-1)
System Terminations	All	---
Regional Switching Centers	All	---
Network Availability Goal	All	---
Traffic Volumes	Average traffic levels	Peak traffic levels
Constraints and Boundaries	Data Handling, Security and Privacy	Data Rates

(Note-1); Message Prioritization Requirements Not Applicable in Existing Networks

(2) Line rate restrictions to 1200 Baud or greater are not met on the LEADS network.

The following section discusses the nature of these deviations in more detail.

6.2.1 Response Times

Response time for the STACOM Network is defined as the time duration between the initiation of a request for service for an inquiry message at a network system termination and the time at which a response is completed at the inquiring system termination.

The response time goal for the STACOM Network for law enforcement traffic is to achieve a mean response time of less than or equal to 9 seconds, which insures that 90% of the time, responses to inquiries shall be received in less than 20 seconds.

Figure 6-3 shows a plot of mean response time vs traffic loads in thousands of transactions per day for the 2400 Baud Lines in the existing LEADS system.

Three curves are shown for different computer configurations. The first is for the recently replaced (December 1976) 1106 computer; the second is for the existing 1100/42 configuration; and the third is for the existing 1100/42 with additional core and fixed head discs added. (The 1106 configuration has been included to provide a feeling for the significance of the upgrade from the 1106 to the present 1100/42).

Each configuration functions with the mean service times indicated in the figure. Table 6-2 presents a sample calculation used to arrive at a mean service time estimate for the existing 1100/42 using 8440 disc units. The mean service time of this configuration can be improved as future traffic requirements increase. For example, the addition of core memory units to the computer would relieve the necessity for periodic application software roll-in from disc. Also, replacement of the 8440 disc with a fixed head disc units with faster transfer rates, (such as the 8433 dual density disc with a transfer rate of 179,111 words/sec and a mean access time of 42.5 ms), would improve mean service time to 503 ms. Mean response time for this configuration is depicted as Curve 3 in Figure 6-3.

The response time curves can be used to anticipate system upgrade requirements. For example, at the time of the upgrade from the 1106 system with a mean service time of 790 ms to the 1100/42 with a mean service time of 650 ms, the LEADS system was handling approximately 170,000 transactions per day. At this point the computer utilization was approximately 0.80 for the 1106 system with a mean service time of 790 ms. The curve indicates that at this operating point, small deviations upward in the number of transactions per day will result in large increases in response times at terminals.

In particular, it is seen that during periods of peak loading when it is estimated that traffic may be as much as twice the average, system queues become excessive.

The second response time curve, (Curve 2, Figure 6-3), suggests that the current configuration with a mean service time of 0.650 seconds can sustain traffic volumes of 190,000 transactions per day before the computer utilization exceeds 0.70. It is desirable to maintain computer utilization at less than 0.70 to insure that service is not hampered by excessive queueing in the computer. Thus, to the extent that current traffic levels exceed 190,000 transactions per day on the average, or at points in the day when transaction levels exceed approximately 1/sec, the computer utilization will exceed 0.70 in the present dual processing system.

This analysis shows that there is little system margin over the current estimated 180,000 transactions per day, and that while most of the time the system provides adequate response times, (under 9 seconds), on 2400 Baud lines, system performance is not presently adequate during peak traffic demand periods.

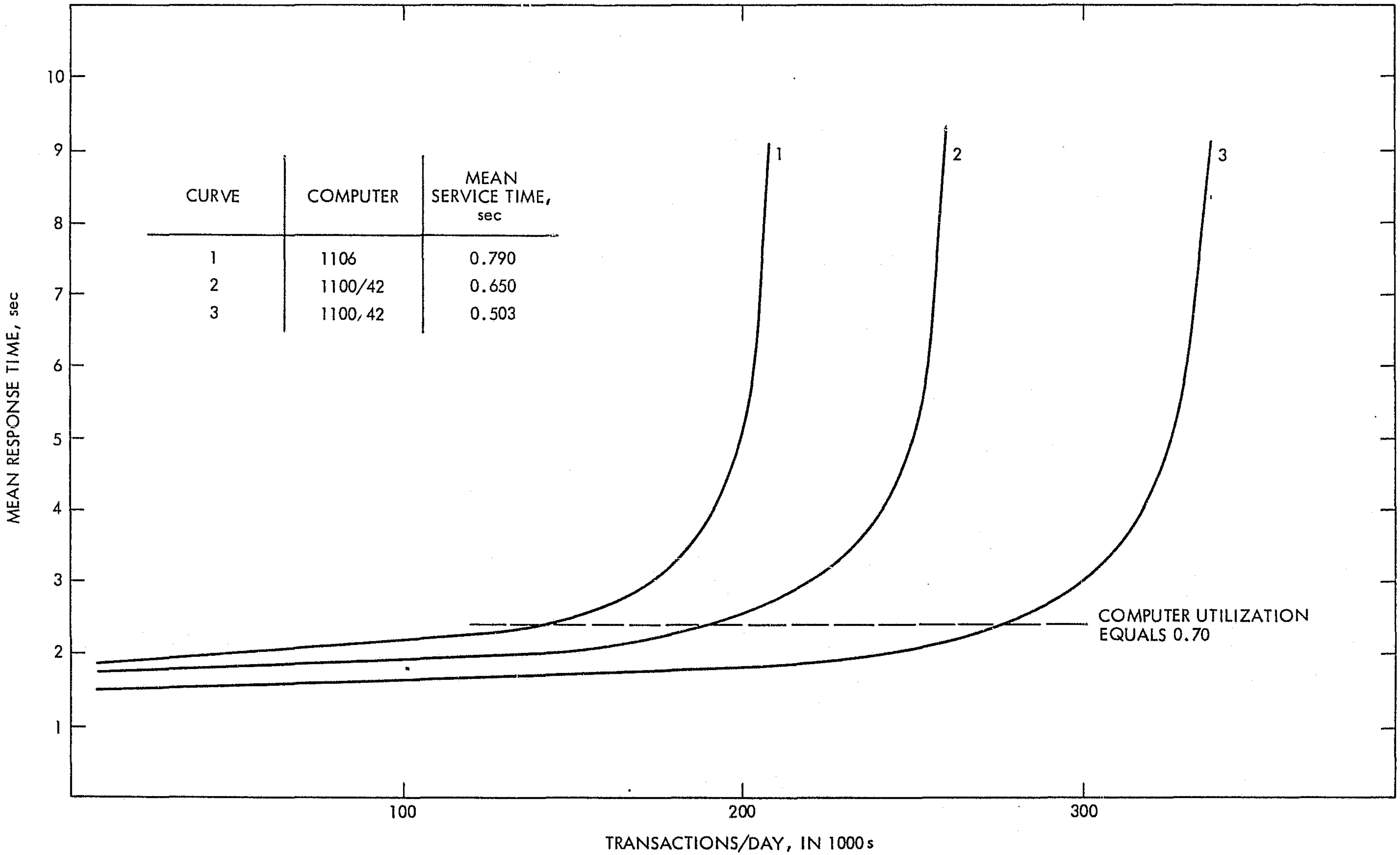


Figure 6-3. Existing LEADS Network Response Time vs Throughput--2400 Baud Lines

5030-99

Table 6-2. Mean Service Time Calculations
Leads UNIVAC 1100/42

Operation	Operation Mean Value Per Transaction	Disc Type	Disc Transfer Rate (Wds/ sec)	Disc Access Time (ms)	Mean Execute Time Per Instruction (ns)	Time (sec)
Program Roll In	16,000 Wds	8440	138,888	---	---	0.1152
System Software	150,000 Instructions	---	---	---	0.8	0.1200
Application Software	150,000 Instructions	---	---	---	0.8	0.1200
Disc I/O Access	6 I/O's	8440	---	47.5	---	0.285
Disc I/O Data	224 Wds 6 times	8440	138,888	---	---	0.010
			Total Mean Service Time =			.650

Response times at terminals for the existing 150 Baud lines on the LEADS Network are shown in Figure 6-4. The major component of waiting time for responses at these terminals is due to the low line speed employed, which dominates the response time characteristics. This is further evidenced by the fact that there is little difference exhibited in response time as a result of using the 1100/42 configuration with a mean service time of 0.650 seconds, (Curve 1, Figure 6-4), and the configuration with mean service time of 0.503 seconds, (Curve 2, Figure 6-4).

At all traffic levels, the present use of 150 Baud lines does not meet the functional response time requirements of the STACOM Network. For this reason, STACOM communication lines are limited to 1200 Baud or greater in capacity.

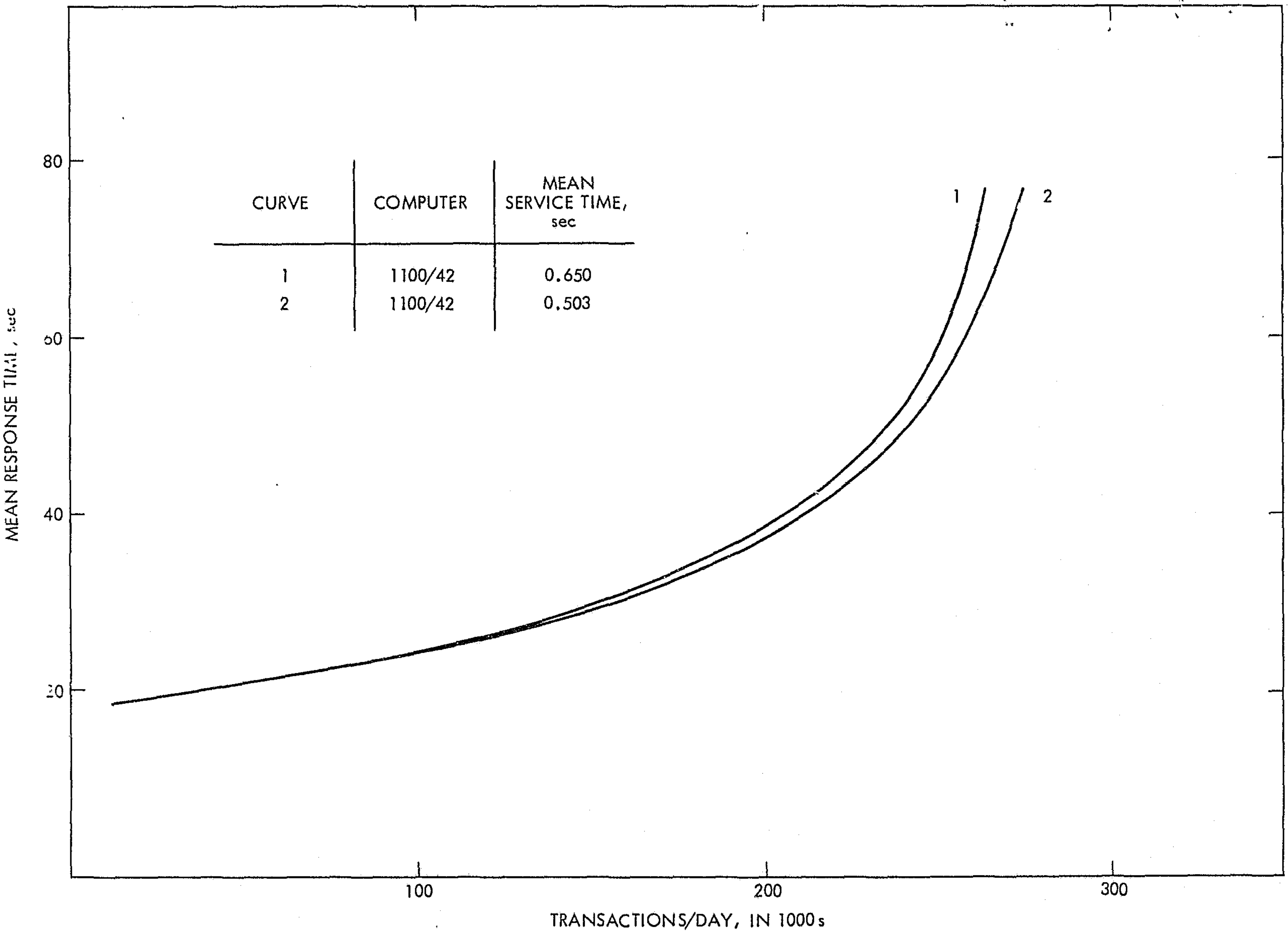


Figure 6-4. Existing LEADS Network Response Time vs Throughput--
150 Baud Lines

6.3 THE EXISTING BMV NETWORK

The existing Bureau of Motor Vehicles (BMV) network consists of 242 INCOTERM terminals distributed throughout BMV offices in the state of Ohio.

Vehicle registration and drivers license data is collected at each terminal during the working day and transmitted to Columbus during the evening to update LEADS, VR, and DL files. Inquires as to applicant status are made during the day hours into Columbus data bases as applicants appear at BMV offices. Figure 6-5 shows the present BMV network layout. The network employs 1200 Baud lines at a total annual cost of $295,000, for lines, modems, and service terminal arrangements.

Figure 6-5. Pres[illegible] Ohio Bureau of Motor Vehicles Network

SECTION VII

NEW OR IMPROVED OHIO NETWORKS

SECTION VII

NEW OR IMPROVED STACOM/OHIO NETWORKS

This section presents detailed topology, cost and performance data for each of the network options as outlined in Section 3. Section 8 of this report presents a comparative discussion of cost and performance data for the options considered.

7.1 GENERAL CONSIDERATIONS

The networks presented here have been constructed subject to the MPL line tariff discussed in Section 4 for interstate networks, with the exception of those BMV and New Data network options that were considered as separate from the LEADS network and subject to an intrastate tariff. The high density MPL Ohio cities used in MPL runs are Akron, Cincinnati, Cleveland, Columbus, Canton, Dayton, Toledo, and Youngstown.

7.2 COMPUTER PERFORMANCE REQUIREMENTS

It is considered mandatory that STACOM/OHIO response time functional requirements are to be met for all network options at peak network traffic loads. To this end, computer mean service times per transaction at peak traffic loads have been assumed such that computer utilization never exceeds 0.700. It is important to realize that increasing line speeds does not appreciably decrease network response times when computer utilization becomes high, i.e., increasing line speeds is not an effective solution for alleviating computer queueing pressure.

Table 7-1 summarizes computer mean service time requirements per transaction required to meet estimated peak loading of the Columbus computer. The second column in the table labeled Average Messages per Day includes estimates of present law enforcement data types, law enforcement use of CCH and computer loading due to BMV transactions. It is assumed that the computer will be loaded by BMV transactions whether or not the BMV network consists of separate lines from the LEADS network. The figure presented is the number of messages arriving at the computer that result in computer switching or data base access demand.

The third column shows Average Transactions per Day. This value takes into account the fact that some data base inquiries automatically trigger inquiries/responses (transactions) to other data bases in the system. LEADS system computer studies indicate that there are 1.3 computer transactions generated on the average for each arriving message.

The fourth column presents the resulting Average Transactions per Second and the fifth column shows the resulting Peak Transactions per Second, LEADS traffic studies indicated that at the busiest time of day the peak traffic load is twice the overall daily average load.

Table 7-1. Mean Computer Service Times Required for Peak Loading

Year	Av Msg Per Day arriving at Computer (1000's)	Av Trans Per Day (1000's)	Av Trans Per Sec	Peak Trans Per Sec	Processor Config	Required Mean Service Time Per Transaction Per Processor (ms)
1977	99	129	1.5	3.0	2 x 2	467
1981	219	285	3.3	6.6	4 x 4	424
1985	274	356	4.1	8.2	4 x 4	342

Column six indicates the dual 2 x 2 and the 4 x 4 UNIVAC processor configurations assumed for the 1977, 81, and 85 network topology design runs.

The last column indicates the required mean service time per processor per transaction to maintain the computer utilization at less than or equal to .700 at all times.

For example, the following equation defines the data base computer RHO as:

$$\rho CD = \frac{E(nCD)}{N} \times E(tSCD)$$

Where:

E(nCD) = Computer Transaction Arrival Rate per Second

N = Number of parallel processors

E(tSCD) = Mean Service Time per Transaction

Thus, the required Means Service Time is

$$E(tSCD) = \frac{N \times \rho CD}{E(nCD)}$$

And for the 1977 case, we have,

$$E(tSCD) = \frac{2 \times .7}{3.0} = 0.467 \text{ seconds}$$

The network designs presented in the following pages of Section 7 call for an upgrade of the Columbus Computer at the present time to meet 1981 traffic levels and an additional upgrade in 1980-81 to meet 1985 throughput requirements shown in Table 7-1.

While it is not within the scope of this statewide network option study to detail computer system upgrade planning, general approaches to the problem do suggest themselves.

For example, roughly half of the six average disc I/O's carried out per transaction, are involved in catalogue access. If these master locator arrays, indexes and name files were implemented on fixed head discs, access time could be reduced to approximately 10 ms per access, or less. Allowing three remaining file accesses at 34 ms per access leaves 210 ms for mean CPU processsing time per transaction to total 342 ms as shown in Table 7-2.

Such an approach calls for a substantial change in existing telecommunications software, and is only intended here to clarify the order of magnitude of requirements. Obviously, any reduction in the mean number of disc accesses would substantially alleviate mean CPU processing time requirements. However, the values presented in Table 7-2 are not unrealistic in the present day state of the art at costs comparable to the 1100/44 type configuration.

As mentioned in Section 4, in the discussion of the approach to comparative network option costing, the costs for accomplishment of mean service time performance at the Columbus computer are not estimated in this report nor included in cost estimates for the specific network options which follow in this section.

This is not unreasonable, since the computer upgrades called for are a function of data base computer loading, and, as such, are essentially independent of network topology alternatives. The costing presented in this section is still valid in terms of providing relative cost advantages for all options considered.

7.3 OPTION 1 - SINGLE REGION LEADS

7.3.1 Topology

The STACOM/OHIO single region LEADS network layout is shown in Figure 7-1. The network consists of a single regional switcher and data base computer located in Columbus. There are 23 multidropped lines serving system terminations consisting of a mix of 1200 Baud and 2400 Baud

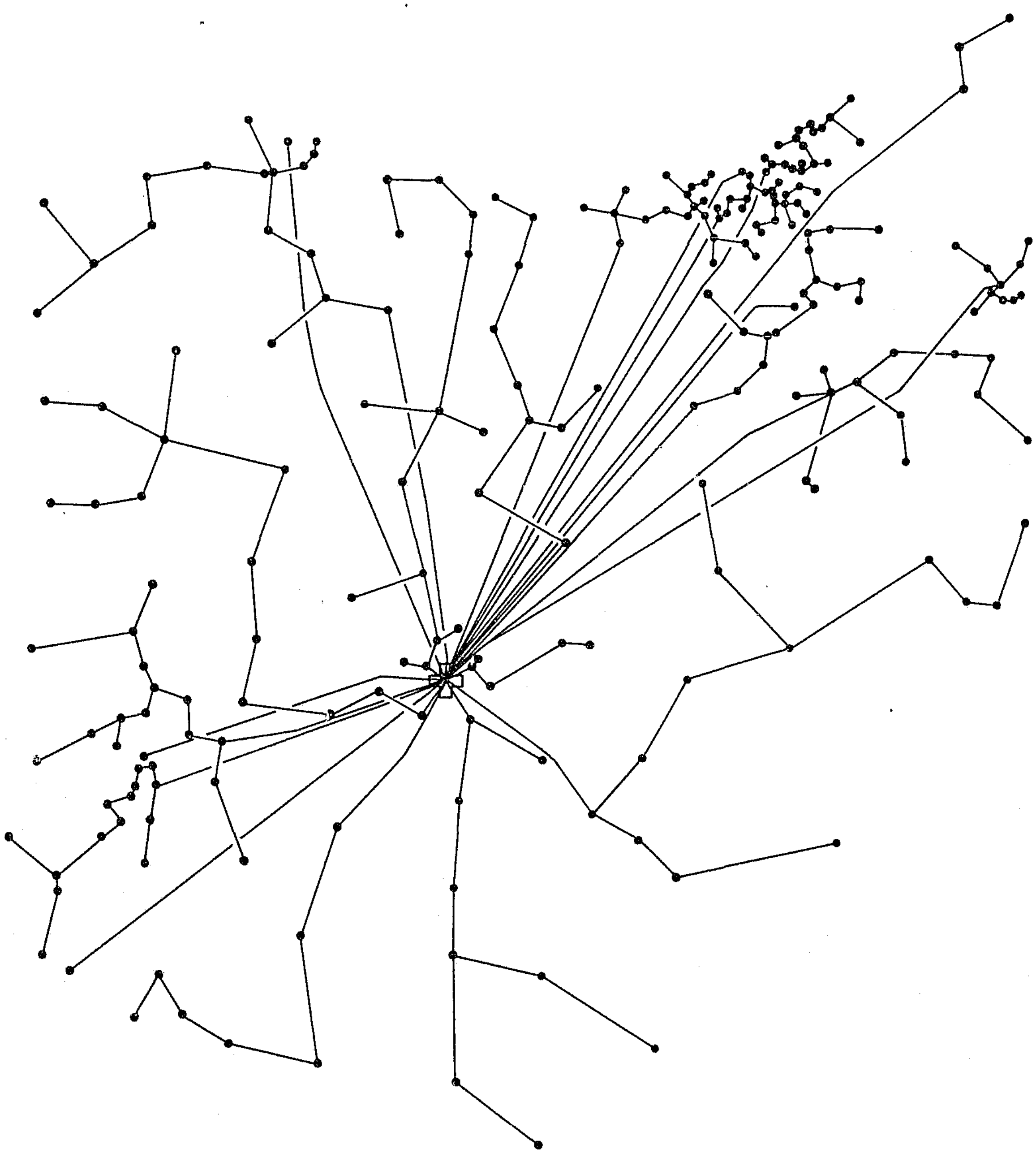


Figure 7-1. Single Region LEADS Network

Table 7-2.

Operation	Accesses	Time/Access	Total Time (ms)
Catalogue Access	3	10	30
File Access	3	34	102
CPU Processing Time	---	---	210
Mean Service Time			342 ms

lines. Table 7-3 presents the detailed terminal assignments for each of the 23 multidrops by PID Number. Reading from left to right, the table shows the line number, (1 to 23), the total number of terminals on the drop, the PID number of the first terminal out of Columbus, and the remaining PID numbers of terminals in the order in which they appear on the drop.

7.3.2 Costs

Total 8 year costs to 1985 for the single region case are presented in Table 7-4. Total 8 year costs amount to $7,960,000. About 40% of this total cost is due to terminal recurring and purchase costs. Lines, modems and service terminals account for almost 60% of costs. Regional switches are not required in this option.

7.3.3 Line Performance

Table 7-5 summarizes performance characteristics by line for the single region LEADS Network. Reading from left to right, the table presents the line number, the first terminal on the drop by PID number, the total number of terminals on the drop, the line capacity in Bauds, the peak line utilization value, total mileage on the drop, and the mean response time for any single terminal on the drop.

Mean response times on the single region network run between 1.8 and 7.5 seconds depending on the specific multidrop line. Of the 23 lines in the network, 8 have mean response times of 5 seconds or less. The worst case mean response time is 7.5 seconds.

7.3.4 Network Availability

The availability of the data base to any terminal on the network is 0.988 calculated in accordance with the procedure outlined in Section 2.4. An availability of 0.988 implies an outage of 17.3 minutes per day.

Table 7-3. Terminal Assignments

NETWORK OPTION: LEADS

NUMBER OF REGIONS: 1

REGION	LINE NO.	TOTAL NO.	TERMINALS STARTING	TERMINALS REMAINING
1				
	1	9	416	417,104,324,100,325,321, 99,322,
	2	25	353	108,109,335,328,117,346,345,157, 17,163, 154, 24,155, 18,160,166,159, 19,158,368, 162,164,165, 20,
	3	25	95	367,365,364, 45,366,161,357,356, 27,379, 378, 28,193,186, 30,382,377,371,180,181, 32,358,376,414,
	4	4	146	113,114,112,
	5	24	343	340,330,110, 98,329,349,336,138,142,152, 251,139,151,351,115,344,140,149, 16,144, 145,150, 25,
	6	12	323	107, 12, 0, 0, 0, 0, 0, 0, 0, 0, 0,
	7	5	13	26;173: 34;168:
	8	17	116	331,334,111,332,143,350,352,348,338,341, 102,318,101,339,319,148,
	9	25	383	380,169,178,170, 22,141, 23,182,171,171, 33,175,174,179,176,172, 35,362,360,361, 359, 21,156,363,
	10	5	64	354,247, 63,249,
	11	6	54	235,231, 52,238, 59,
	12	25	44	236,390,230,200,241, 56,265,393,225,220, 396,394,226, 55,219,223,224,216,221,243, 242,233, 38, 50,
	13	22	229	58,244,217, 57,222,388,397, 60,232,237, 387,248, 61,252,409, 62,245,246,218,386, 234,
	14	21	408	407, 67,194,198,392,196,189,190, 29,188, 195,187,192, 31,185,184, 37,191,197, 39,
	15	23	385	204,205,202,201, 47,212,389, 48,211, 49, 391,250,254,410,206,208,207,210, 51,395, 203,209,
	16	4	43	

Table 7-3. Terminal Assignments (Continuation 1)

			42, 41,406,
17	25	400	401, 68,402,255,257,266,215,214, 40,256, 258,262,259,261,263,287,264, 71, 70,147, 403,260,239, 72,
18	7	370	381,295, 76,423,415,419,
19	9	422	228,105, 46, 36, 85,337,421,347,
20	20	308	418, 96, 86,412,413, 88,320,315,316,314, 90,317, 94,420, 89, 93,300,301, 87,
21	24	302	303,311,309, 77,312,304, 78,298,399,292, 81,375,374,373, 80,305,306,307, 91,310, 404,405, 92,
22	16	84	275,274,295,273,272,271,270, 73,278,279, 283, 83,280,276,277,
23	19	74	75,286,297,287, 79,284, 69,282,269,291, 281,288,294,290,296,289, 82,372,

Table 7-4. Network Option Costs (Thousands of Dollars)

Item	No. Reqd.	Recurring Costs: Annual Cost Each	Recurring Costs: Total Annual Cost	Recurring Costs: Eight Year Cost	One Time Installation Costs: Unit Cost	One Time Installation Costs: Total Purchase Cost	Total Eight Year Cost by Item
Lines, Modems Service Terminals	-	-	564	4,512	-	42	4,554
Terminals	310	0.6	234	1,872	3.6	1,400	3,272
Regional Switchers	0						
Switcher Floor Space	0						
Switcher Back up Power	0						
Switcher Personnel	0						
Engineering					-	130	130
Subtotals			798	6,384		1,572	7,956
				Total Eight-year Cost			7,960

Table 7-5. Network Line Characteristics

Network LEADS Number of Regions 1

Remarks Columbus as Regional Center

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	416	9	1200	0.161	145	4.9
2	353	25	1200	0.679	212	7.5
3	95	25	1200	0.503	195	6.8
4	146	5	2400	0.433	66	3.5
5	343	24	1200	0.518	183	6.8
6	323	3	2400	0.584	101	4.6
7	13	5	2400	0.460	120	3.6
8	116	17	1200	0.664	159	6.8
9	383	25	1200	0.540	256	7.0
10	64	5	1200	0.123	192	4.5
11	54	6	2400	0.412	126	1.9
12	44	25	1200	0.674	186	7.4
13	229	22	1200	0.590	188	6.9
14	408	21	1200	0.493	158	6.5
15	385	23	1200	0.498	190	6.7
16	43	4	2400	0.349	110	3.1
17	400	25	1200	0.574	184	7.1
18	370	7	1200	0.213	40	4.9
19	422	9	2400	0.649	0	5.2
20	308	20	1200	0.418	181	6.3
21	302	24	1200	0.448	229	6.6
22	84	16	1200	0.667	188	6.8
23	74	19	1200	0.659	227	7.0

7.4 OPTION 2 - TWO REGION LEADS

7.4.1 Topology

The STACOM/OHIO two region network is shown in Figure 7-2. In addition to the switcher data base computer located in Columbus, a regional switcher is located in Cleveland which serves system terminations in the northeast as shown. A single 4800 Baud line connects the Columbus and Cleveland computers.

There are twelve multidropped lines in the Cleveland Region, all of which are 1200 Baud lines with the exception of one 4800 Baud line. The Columbus region also has twelve lines, four of which are

Figure 7-2. Two Region LEADS Network

2400 Baud lines. The remaining eight lines are 1200 Baud lines. Table 7-6 details the terminal assignments to lines by PID number for the two region case.

7.4.2 Costs

Eight year total costs for the two region case are presented in Table 7-7. Total costs are $9,470,000.

The costs of the additional switcher amounts to about 16% of this total.

Note that costs for lines, modems and service terminals drop from $564,000 per year in the single region case to $561,000 in the two region case.

7.4.3 Line Performance

Table 7-8 lists line performance characteristics. Mean response times on the two region network vary between 3.7 seconds to 8.6 seconds on specific multidrop lines. On 13 of the total of 24 lines in the network the mean response time is less than 7 seconds. The worst case mean response time for any given line is 8.6 seconds.

7.4.4 Network Availability

The availability of the data base in Columbus to any system termination on the network is 0.982. An availability of 0.982 implies an average outage of approximately 26 minutes per day.

7.5 OPTION 3 - THREE REGION LEADS

7.5.1 Topology

The STACOM/OHIO three region LEADS network layout is presented in Figure 7-3. The network consists of regional switcher in Cleveland and Cincinnati, and the switcher data base computer in Columbus. A 4800 Baud line connects the Columbus computer to the Cleveland switcher and another 4800 Baud line connects the Columbus computer to the Cincinnati Switcher.

Line assignment details are presented in Table 7-9.

There are 11 multidropped lines serving the Cleveland region from the Cleveland switchers, all of which are 1200 Baud lines with the exception of one 2400 Baud line, and one 4800 Baud line.

The Cincinnati switcher handles three 1200 Baud lines and two 2400 Baud lines in its region. The Columbus switcher data base computer handles nine 1200 Baud lines in servicing the central region.

Table 7-6. Terminal Assignments

NETWORK OPTION: LEADS

NUMBER OF REGIONS: 2

REGION	LINE NO.	TERMINALS TOTAL NO.	TERMINALS STARTING	TERMINALS REMAINING
1	1	16	191	197, 39,185,184, 37,408,407, 67,198,392, 196,193,379,378, 28,
	2	24	207	208,204,385,205,188,189,190, 29,195,187, 192, 31, 30,382,377,371,180,181, 32,383, 380,169,186,
	3	18	390	236, 50,211, 49, 48,395,210, 51,206,389, 212,202,201, 47,203,209, 44,
	4	6	54	235,231, 52,238, 59,
	5	14	242	233,234, 58,244,217,386,222,388,218,409, 62, 57,219,
	6	14	60	397,232,237,387,248, 61,252,245,246, 64, 354,247, 63,
	7	12	200	230,241, 56,265,393, 38,410,391,215,214, 40,
	8	21	229	243, 55,394,216,223,221,239,260, 72,272, 271,270, 73,226,225,220,396,250,254,224,
	9	18	294	290, 83,283, 84,275,274,295,273,278,279, 280,276,277,296,289, 82,372,
	10	13	269	284, 69,282,286,297,287, 79, 74, 75,291, 281,288,
	11	4	43	42, 41,406,
	12	21	403	259,262,258,256,257,266,255,402,400,401, 68,399,298,261,263,267,264, 71, 70,147,
2	1	25	300	301, 87,303,302,305,306,307, 91,310,404, 405, 92,311,309, 77,312,304, 78,292, 81, 375,374,373, 80,
	2	18	370	381,295,308,418, 96, 86, 76,423,415,419, 376,367,365,364, 45,366,161,
	3	9	422	228,105, 46, 36, 85,337,421,347,
	4	23	353	416,417,412,413, 88,320,315,316,314, 90, 317, 94,420, 89, 93,104,324,100,325,321,

Table 7-6. Terminal Assignments (Continuation 1)

			99,322,
5	25	95	414,357,356, 27,194,358,163,154,178,178, 22,368, 24,155, 18,160,166,159, 19,158, 162,164,165, 20,
6	1	146	
7	24	343	340,330,110, 98,329,349,336,138,142,152, 251,139,151,351,115,344,140,149, 16,144, 145,150, 25,
8	3	323	107, 12,
9	5	13	26,173, 34,168,
10	19	33	23,182,141,179,176,171,171,172, 35,362, 360,361,359, 21,156,363,175,174,
11	9	108	109,335,328,117,346,345,157, 17,
12	17	116	331,334,111,332,143,350,352,348,338,341, 102,318,101,339,319,148,

Table 7-7. Network Option Costs (Thousands of Dollars)

Item	No. Reqd.	Recurring Costs: Annual Cost Each	Recurring Costs: Total Annual Cost	Recurring Costs: Eight-year Cost	One Time Installation Costs: Unit Cost	One Time Installation Costs: Total Purchase Cost	Total Eight-year Cost by Item
Lines, Modems Service Terminals	-	-	561	4,488	-	42	4,530
Terminals	390	0.6	234	1,872	3.6	1,400	3,272
Regional Switchers	1	12	12	96	180	180	276
Switcher Floor Space	1	4.8	4.8	38	30	30	68
Switcher Back-up Power	1	6.0	6.0	48	20	20	68
Switcher Personnel	1 set	128	128	1,024	-	-	1,024
Engineering						230	230
Subtotals			946	7,566		1,902	9,468
			Total Eight-year Cost				9,470

Table 7-8. Network Line Characteristics

Network LEADS Number of Regions 2
Remarks Cleveland as Regional Center

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	191	16	1200	0.367	144	7.9
2	207	24	1200	0.416	159	8.6
3	390	18	1200	0.503	58	8.4
4	54	6	4800	0.417	0	3.9
5	242	14	1200	0.370	40	7.8
6	60	15	1200	0.408	81	7.9
7	200	12	1200	0.370	46	7.7
8	229	21	1200	0.516	92	8.7
9	294	18	1200	0.549	140	8.6
10	269	13	1200	0.544	111	8.2
11	43	4	2400	0.696	31	5.1
12	403	21	1200	0.494	132	8.6

Network LEADS Number of Regions 2

Remarks Columbus as Regional Center

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	300	25	1200	0.496	241	6.9
2	370	18	1200	0.444	112	6.3
3	422	9	2400	0.649	0	5.3
4	353	23	1200	0.426	289	6.6
5	95	25	1200	0.623	233	7.3
6	146	5	2400	0.433	66	3.6
7	343	24	1200	0.518	183	6.9
8	323	3	2400	0.584	101	4.7
9	13	5	2400	0.460	120	3.7
10	33	19	1200	0.394	258	6.2
11	108	9	1200	0.321	78	5.3
12	116	17	1200	0.664	159	6.9

Table 7-9. Terminal Assignments

NETWORK OPTION: LEADS

NUMBER OF REGIONS: 3

REGION	LINE NO.	TOTAL NO.	TERMINALS STARTING	TERMINALS REMAINING
1				
	1	6	54	235,231, 52,238, 59,
	2	2	242	233,
	3	17	58	229,234,244,217,386,222,388,218,409, 62, 272,271,270, 73, 57,219,
	4	15	60	397,232,237,387,248, 61,252,245,246, 64, 354,247, 63,249,
	5	22	241	56,243, 55,394,216,223,221,226,225,220, 396,250,391,410,215,214, 40,254,224,265, 393,
	6	16	200	230, 38,390,236, 50,211, 49, 48,206,207, 210, 51,208,395, 44,
	7	22	389	212,202,201, 47,204,203,209,205,188,189, 190, 29,196,191,197, 39,195,187,192, 31, 385,
	8	18	294	290, 83,283, 84,275,274,295,273,278,279, 280,276,277,296,289, 82,372,
	9	7	269	284, 69,282, 74, 75,291,
	10	4	43	42, 41,406,
	11	22	260	403,259,262,258,256,257,266,255,402,400, 401, 68,261,263,267,264, 71, 70,147,239, 72,
2				
	1	14	322	321, 99,325,100,104, 98,340,330,110,343, 329,349,324,
	2	1	172	
	3	3	323	107, 12,
	4	13	148	319,102,318,101,339,351,115,144,145,341, 334,111,
	5	18	338	331,348,352,350,143,251,139,151,152,142, 138,344,140,141,332,116,146,
3				
	1	25	346	

Table 7-9. Terminal Assignments (Continuation 1)

			345,157, 17,163,154,150, 25,160,166, 24, 155, 18,368,162,164,165, 20,159, 19,158, 335,328,117,336,
2	25	365	364, 45,357,356, 27,194,193,379,378, 28, 358,198,392,186, 30,382,377,371,180,181, 32,185,184, 37,
3	17	370	308,300,301, 87,302,303,305,306,307, 91, 310,404,405, 92,381,419,
4	9	422	228,105, 46, 36, 85,337,421,347,
5	17	353	418, 96, 86,412,413, 88,320,315,316,314, 90,317, 94,420, 89, 93,
6	24	295	76,423,415,311,309, 77,312,304, 78,298, 399,286,297,287, 79,288,292, 81,375,374, 373, 80,281,
7	13	95	367,376,408,407, 67,414,366,161,108,109, 416,417,
8	5	13	26,173, 34,168,
9	25	383	380,169,178,178, 22,141, 23,182,171,171, 33,175,174,179,176,172, 35,362,360,361, 359, 21,156,363,

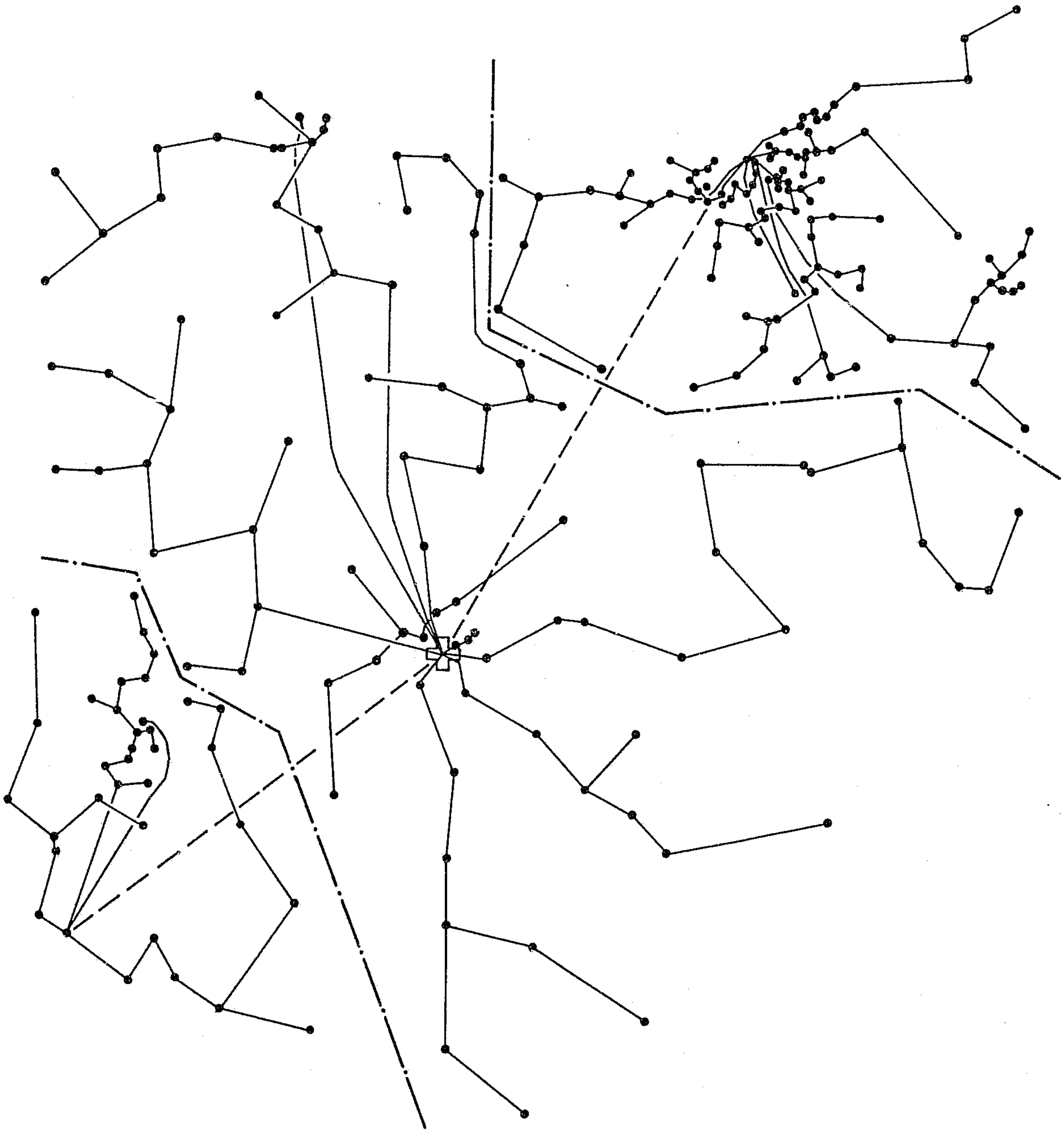


Figure 7-3. Three Region LEADS Network

7.5.2 Costs

Total eight year costs for the three region LEADS case amount to $10,950,000 as indicated in Table 7-10. The regional switchers amount to approximately 27% of the total cost.

Note that recurring costs for lines, modems and service terminals are slightly higher than in the two region case. The small increase is due to an increase in inter-regional line costs in the three region case. The intra-regional line costs in the two and three region cases are almost identical.

7.5.3 Line Performance

Line performance characteristics are presented in Table 7-11.

Mean response times on multidropped lines for the three region case vary from 4.0 to 8.7 seconds. On 11 of the total of 25 network lines the response time is less than 7.0 seconds. The worst case mean response time is 8.7 seconds.

7.5.4 Network Availability

Network availability for the three region case is 0.982 which corresponds to an average daily outage of 26 minutes per day.

7.6 OPTION 4 - FOUR REGION LEADS

7.6.1 Topology

The STACOM/OHIO four region LEADS network is shown in Figure 7-4. Three regional switchers in Cleveland, Cincinnati and Toledo service the network in addition to the switcher data base in Columbus. Line layout details are shown in Table 7-12. The Cleveland switcher handles nine 1200 Baud lines and one 4800 Baud line. The Toledo region is served by four 1200 Baud lines and one 2400 Baud line. The Columbus switcher data base computer services the central region with five 1200 Baud lines and one 2400 Baud line. The Cincinnati switcher handles the same terminals in the four region case as in the three region case consisting of three 1200 Baud lines and two 2400 Baud lines. The total number of lines in the four region LEADS network is 26.

The Cleveland, Toledo, and Cincinnati switchers are each connected to the Columbus switcher data base with a single 4800 Baud line.

Table 7-10. Network Option Costs (Thousands of Dollars)

Network LEADS Number of Regions 3

Remarks - Data Base Switcher in Columbus; Regional Switchers in Cleveland and Cincinnati

		Recurring Costs			One Time Installation Costs		
Item	No. Reqd.	Annual Cost Each	Total Annual Cost	Eight Year Cost	Unit Cost	Total Purchase Cost	Total Eight Year Cost by Item
Lines, Modems Service Terminals	-	-	567	4,536	-	42	4,578
Terminals	390	0.6	234	1,872	3.6	1,400	3,272
Regional Switchers	2	12	24	192	180	360	552
Switcher Floor Space	2	4.8	1.6	76.8	30	60	136.8
Switcher Back-up Power	2	6	12	96	20	40	136
Switcher Personnel	2 Sets	128	256	2,048	-	-	2,048
Engineering				-		230	230
Subtotals			1,103	8,821		2,132	10,953
				Total Eight Year Cost			10,950

Table 7-11. Network Line Characteristics

Network LEADS Number of Regions 3

Remarks Cincinnati as Regional Center

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	322	14	1200	0.276	154	7.2
2	172	3	2400	0.423	49	5.5
3	323	3	2400	0.584	0	6.6
4	148	13	1200	0.465	106	7.9
5	338	20	1200	0.530	116	8.6

Network LEADS Number of Regions 3

Remarks Cleveland as Regional Center

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	54	6	4800	0.417	0	4.0
2	242	2	1200	0.098	1	6.5
3	58	17	1200	0.549	74	8.5
4	60	15	1200	0.408	81	7.9
5	241	22	1200	0.497	77	8.7
6	200	16	1200	0.433	51	8.1
7	389	22	1200	0.456	127	8.6
8	294	18	1200	0.549	140	8.6
9	269	7	1200	0.446	67	7.5
10	43	4	2400	0.349	31	5.1
11	260	22	1200	0.493	12	8.7

Table 7-11. Network Line Characteristics
(Continuation 1)

Network LEADS Number of Regions 3

Remarks Columbus as Regional Center

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	346	25	1200	0.673	231	7.5
2	365	25	1200	0.578	194	7.1
3	370	17	1200	0.345	132	5.9
4	422	9	2400	0.649	0	5.3
5	353	17	1200	0.332	163	5.9
6	295	24	1200	0.519	241	6.9
7	95	13	1200	0.257	115	5.4
8	13	5	2400	0.460	120	3.7
9	383	25	1200	0.540	256	7.0

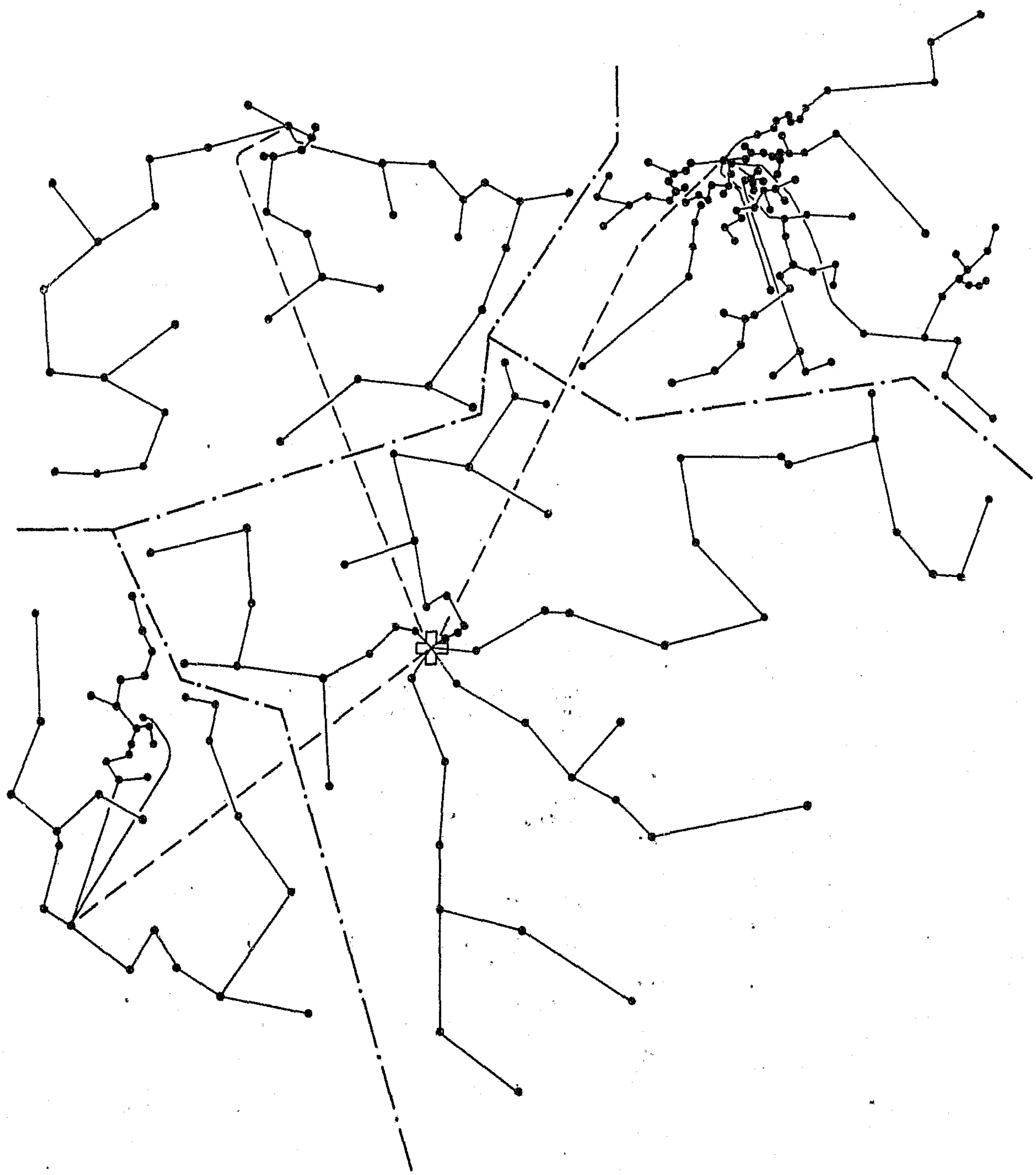


Figure 7-4. Four Region LEADS Network

CONTINUED

2 OF 4

Table 7-12. Line Layout Details

NETWORK OPTION: LEADS

NUMBER OF REGIONS: 4

REGION	LINE NO.	TOTAL NO.	TERMINALS STARTING	TERMINALS REMAINING
1				
	1	6	54	235,231, 52,238, 59,
	2	19	242	233,241, 56,243, 55,394,225,220,396,250, 254,216,223,221,226,224,265,393,
	3	15	60	397,232,237,387,248, 61,252,245,246, 64, 354,247, 63,249,
	4	16	51	210,207,206, 48,395,389,212,202,201, 47, 204,203,209,385,208,
	5	17	200	230,390,236, 50,211, 49, 44,391,410,215, 214, 40,191,197, 39, 38,
	6	17	229	58,234,244,217,386,222,388,218,409, 62, 272,271,270, 73, 57,219,
	7	18	294	290, 83,283, 84,275,274,295,273,278,279, 280,276,277,296,289, 82,372,
	8	7	269	284, 69,282, 74, 75,291,
	9	4	43	42, 41,406,
	10	22	260	403,259,262,258,256,257,266,255,402,400, 401, 68,261,263,267,264, 71, 70,147,239, 72,
2				
	1	14	322	321, 99,325,100,104, 98,340,330,110,343, 329,349,324,
	2	1	172	
	3	3	323	107, 12,
	4	13	148	319,102,318,101,339,351,115,144,145,341, 334,111,
	5	19	338	331,352,350,143,251,139,151,152,142,138, 344,140,149, 16,332,116,146, 0,
3				
	1	21	35	362,360,361,359, 21,363,156,164,165, 20, 162,368, 24,155, 18,160,166,159, 19,158,
	2	5	13	26,173, 34,168,

Table 7-12. Line Layout Details (Continuation 1)

	3	2	179	176,
	4	25	371	180,181, 32,382,377, 30,186,195,187,192, 31,188,189,190, 29,196,379,378, 28,358, 163,154,193,205,
	5	15	175	33,171,171, 23,182,141,169,178,178, 22, 383,380,172,174,
4	1	22	370	381,419,376,367,365,364, 45,366,161,357, 356, 27,194,408,407, 67,198,392,185,184, 37,
	2	9	422	228,105, 46, 36, 85,337,421,347,
	3	17	353	418, 96, 86,412,413, 88,320,315,316,314, 90,317, 94,420, 89, 93,
	4	14	308	300,301, 87,302,303,305,306,307, 91,310, 404,405, 92,
	5	24	295	76,423,415,311,309, 77,312,304, 78,298, 399,286,297,287, 79,288,292, 81,375,374, 373, 80,281,
	6	16	95	414,108,10[illegible],416,417,335,328,117,346,345, 157, 17,150, 25,336,

7.6.2 Costs

Total eight year costs for the four region LEADS network amount to $12,410,000. These costs are detailed in Table 7-13. The three regional switchers, in this network account for approximately 36% of total costs. Costs for lines, modems and service terminals are higher in this network than in any of the other four LEADS options. The observed increment over the three region case is due to additional interregional line costs.

7.6.3 Line Performance

Line performance data for the four region case is shown in Table 7-14. Mean response times vary from 4.0 seconds to 8.7 seconds maximum depending on the multidrop line. Of the 26 total lines in this network, 10 have response times less than or equal to 7.0 seconds. Only one line in this network carries as many as 25 terminals.

7.6.4 Network Availability

Network availability for the three region case is 0.982 which corresponds to an average daily outage of 26 minutes.

7.7 OPTION 5 - BMV NETWORK SEPARATE FROM LEADS

7.7.1 Topology

The STACOM/OHIO BMV Network is shown in Figure 7-5. The network consists of a single region network serving BMV terminals throughout the state with lines separate from the signal region LEADS network. Table 7-15 shows the detailed terminal assignments by PID number for the ten lines called for in the network. All ten multidrops in the network consist of 1200 Baud lines.

7.7.2 Costs

Total 8 year costs for the optimized BMV Network separate from the LEADS Network is $1,700,000. Totals are presented in Table 7-16. Costs for INCOTERM Terminals are not included in this analysis, nor are they included in the costing of Option 6 which considers the integration of LEADS with BMV. Since these costs are constant in both networks, the cost comparisons summarized in Section 8 are valid. The separate BMV network shown was optimized using the intra-state tarrif discussed in Section 4 of this report. Note that under this optimization, annual line costs are $193,000 as opposed to $295,000 in the existing system.

Table 7-13. Network Option Costs (Thousands of Dollars)

Network LEADS Number of Regions 4

Remarks Data Base Switcher in Columbus; Regional Switches in Cleveland, Cincinnati and Toledo

	Recurring Costs				One Time Installation Costs		Total Eight Year Cost by Item
Item	No. Reqd.	Annual Cost Each	Total Annual Cost	Eight Year Cost	Unit Cost	Total Purchase Cost	
Lines, Modems Service Terminals	-	-	570	4,560	-	42	4,602
Terminals	390	0.6	234	1,872	3.6	1,400	3,272
Regional Switchers	3	12	36	288	180	540	828
Switcher Floor Space	3	4.8	14.4	115.2	30	90	205.2
Switcher Back up Power	3	6	18	144	20	60	204
Switcher Personnel	3 sets	128	384	3,072	-	-	3,072
Engineering					-	230	230
Subtotals			1,256	10,051		2,362	12,413
Total Eight Year Cost							12,410

Table 7-14. Network Line Characteristics

Network LEADS Number of Regions 4

Remarks Cincinnati as Regional Center

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	322	14	1200	0.276	154	7.5
2	172	3	2400	0.423	49	5.5
3	323	3	2400	0.584	0	6.6
4	148	13	1200	0.465	106	7.9
5	338	20	1200	0.530	116	8.6

Network LEADS Number of Regions 4

Remarks Cleveland as Regional Center

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	54	6	4800	0.417	0	4.0
2	242	19	1200	0.478	55	8.4
3	60	15	1200	0.408	81	8.0
4	51	16	1200	0.370	62	7.9
5	200	17	1200	0.439	75	8.2
6	229	17	1200	0.549	73	8.5
7	294	18	1200	0.549	140	8.6
8	269	7	1200	0.446	67	7.5
9	43	4	2400	0.349	31	5.1
10	260	22	1200	0.493	112	8.7

Table 7-14. Network Line Characteristics (Continuation 1)

Network LEADS Number of Regions 4

Remarks Toledo as Regional Center

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	35	21	1200	0.449	192	8.5
2	13	5	2400	0.460	0	5.7
3	179	2	1200	0.043	10	6.2
4	371	25	1200	0.436	190	8.7
5	175	15	1200	0.351	85	7.8

Network LEADS Number of Regions 4

Remarks Columbus as Regional Center

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	370	22	1200	0.595	148	7.0
2	422	9	2400	0.649	0	5.3
3	353	17	1200	0.332	163	5.9
4	308	14	1200	0.251	122	5.5
5	295	24	1200	0.519	241	6.9
6	95	16	1200	0.468	142	6.2

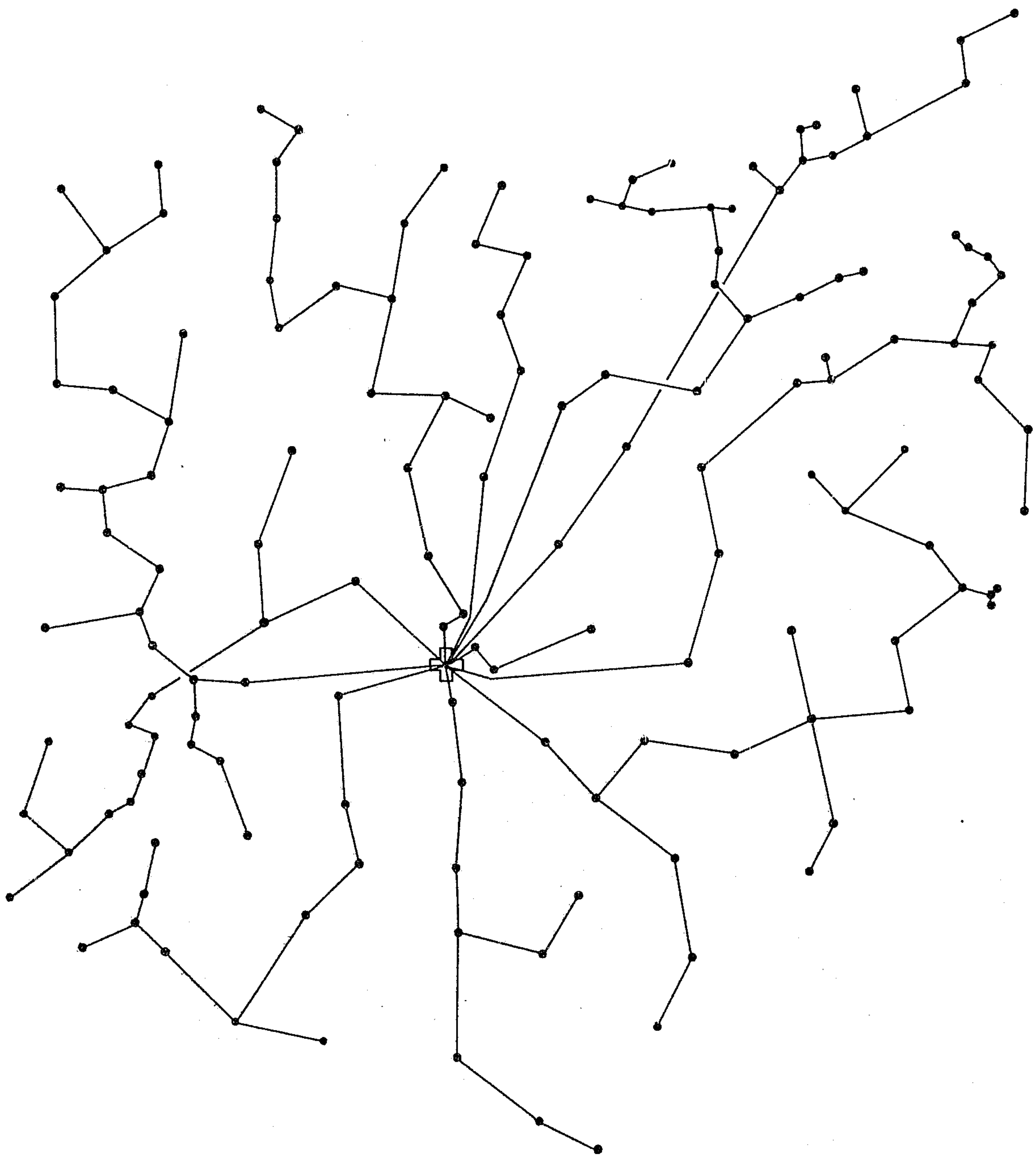


Figure 7-5. BMV Network

Table 7-15. Terminal Assignments

NETWORK OPTION: BMV

NUMBER OF REGIONS: 1

REGION	LINE NO.	TOTAL NO.	TERMINALS STARTING	TERMINALS REMAINING
1				
	1	24	435	436,645,644,578,598,439,440,441,454,453,448,449,450,652,451,452,653,655,656,657,654,455,442,
	2	25	643	565,566,567,568,666,665,664,579,659,660,580,581,582,584,585,586,587,588,599,600,601,602,603,569,
	3	18	649	445,437,438,646,590,591,592,593,594,595,596,662,663,647,661,446,650,
	4	22	552	668,479,669,670,671,489,571,672,572,651,573,574,575,576,635,636,637,638,639,673,674,
	5	21	467	468,469,470,471,459,473,474,472,460,462,461,546,547,548,464,465,463,475,476,477,
	6	23	444	487,533,562,563,564,641,642,480,553,554,555,557,556,558,559,560,534,457,541,542,543,544,
	7	25	458	545,524,525,535,536,537,515,526,527,528,538,539,549,550,516,517,518,519,529,530,531,520,521,522,
	8	23	508	907,620,621,622,623,628,629,636,631,632,633,613,614,615,513,606,607,609,610,611,616,605,
	9	6	488	490,491,493,492,675,
	10	25	481	482,506,502,497,498,499,500,501,509,510,511,512,503,504,617,618,484,483,494,495,485,624,625,626,

Table 7-16. Network Option Costs
(Thousands of Dollars)

Network BMV Number of Regions 1

Remarks Optimized Separate BMV Network

	Recurring Costs				One Time Installation Costs		Total Eight Year Cost by Item
Item	No. Reqd.	Annual Cost Each	Total Annual Cost	Eight Year Cost	Unit Cost	Total Purchase Cost	
Lines, Modems Service Terminals	-	-	193	1,544	-	30	1,574
Terminals							
Regional Switchers							
Switcher Floor Space							
Switcher Back-up Power							
Switcher Personnel							
Engineering					-	130	130
Subtotals			193	1,544		160	1,704
				Total Eight Year Cost			1,700

7.7.3 Line Performance

Line performance data for each of the ten 1200 Baud lines for the BMV Network is presented in Table 7-17. Mean response time at all terminals is fairly constant barying from 4.1 to 5.1 seconds with the exception of line 9 which is comprised of only six terminals each of which has a mean response time of 2.1 seconds.

Table 7-17. Network Line Characteristics

Network BMV Number of Regions 3

Remarks Columbus as Regional Center

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	435	24	1200	0.218	334	4.8
2	643	25	1200	0.287	191	5.0
3	649	19	1200	0.273	215	4.1
4	552	22	1200	0.312	234	4.6
5	467	21	1200	0.150	347	4.3
6	444	23	1200	0.273	199	4.7
7	454	25	1200	0.304	253	5.0
8	508	24	1200	0.384	231	4.9
9	488	6	1200	0.059	121	2.1
10	481	25	1200	0.450	219	5.1

7.7.4 Network Availability

The network availability for the single region BMV network is calculated at 0.988 which corresponds to a daily average outage of 17.3 minutes per day.

7.8 OPTION 6 - AN INTEGRATED LEADS AND BMV NETWORK

7.8.1 Topology

The integrated LEADS and BMV Network is shown in Figure 7-6. The network is comprised of a single region with 30 multidropped lines out of Columbus. In general, there is a mix of terminals on these lines serving law enforcement agencies and BMV offices. Table 7-18 details terminal assignments to each of the 30 lines by PID number. There are two 4800 Baud lines in the network and four 2400 Baud lines in the network and four 2400 Baud lines. The remaining lines are 1200 Baud lines.

7.8.2 Costs

Total 8 year costs for the integrated LEADS BMV Network are shown in Table 7-19. The total cost is $9,800,000. These comparative costs include LEADS terminals as did the single region LEADS network costs, but not the already acquired BMV terminals. Lines, modems and service terminals amount to 64% of total costs as presented.

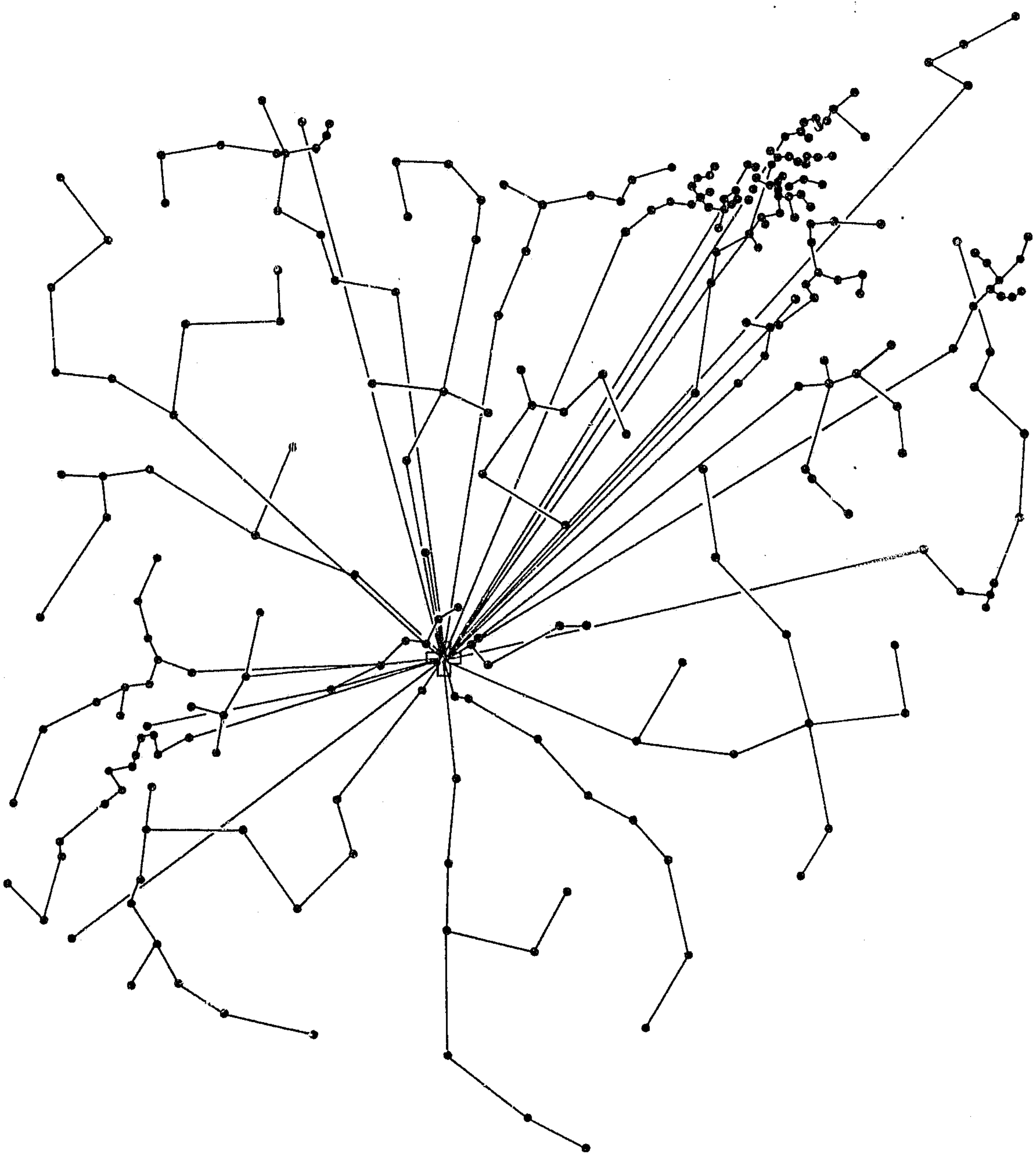


Figure 7-6. Integrated LEADS and BMV Network

Table 7-18

NETWORK OPTION: LEADS WITH HMV

NUMBER OF REGIONS: 1

REGION	LINE NO.	TOTAL NO.	TERMINALS STARTING	TERMINALS REMAINING
1				
	1	9	64	354,609,247, 63,610,249,611,608,
	2	25	220	225,393,265,620,621,622,623, 56,241,290, 230, 38,242,233,243,394,226, 55,219,223, 224,216,221,396,
	3	12	54	235,231, 52,238, 54,628,629,636,631,632, 633,
	4	17	60	397,616,388,232,237,387,605,248, 61,252, 409, 62,606,245,246,607,
	5	21	196	491,189,190, 29,493,188,205,494,204,483, 203,209,495,208,485,195,187,192, 31,675,
	6	18	408	407, 67,508,194,488,198,392,490,185,184, 37,481,191,197, 39,482,507,
	7	25	385	202,201, 47,484,212,389, 48,211, 49,617, 618, 44,391, 50,390,624,625,626,236,206, 207,210, 51,395,
	8	10	43	42, 41,406,497,498,499,500,501,509,
	9	23	402	255,257,266,502,256,258,262,259,261,263, 267,510,511,264, 71, 70,512,147,403,260, 239, 72,
	10	25	400	401, 68,506,215,214, 40,503,410,504,250, 229, 58,244,217,613,614,615,222,218,513, 386, 57,234,254,
	11	25	24	155, 18,449,450,368,652,178,178, 22,651, 573,162,451,164,165, 20,452,156,653,359, 21,655,363,654,
	12	25	336	436,138,142,437,438,152,251,139,646,151, 351,115,647,339,663,344,140,439,149, 16, 440,150, 25,441,
	13	15	335	328,117,435,346,345,445,343,340,330,110, 578,329,349,645,
	14	24	353	416,417,565,566,104,567, 98,598,334,111, 579,331,664,665,321, 99,666,325,100,568, 324,569,322,
	15	14	95	

Table 7-18 (Continuation 1)

			367,552,668,365,364, 45,669,376,479,414, 108,109,643,
16	9	146	533,113,114,112,590,591,592,593,
17	18	323	107, 12,659,660,580,581,582,584,585,586, 587,588,599,600,601,602,603,
18	10	13	26,173, 34,168,576,635,636,637,638,
19	23	357	356, 27,670,379,378, 28,671,193,489,186, 492, 30,382,377,674,371,180,181, 32,673, 358,571,
20	25	383	380,672,169,572,141, 23,182,574,171,171, 33,175,170,179,176,639,172,575, 35,362, 657,360,361,656,
21	22	366	161,649,157, 17,446,447,163,154,650,160, 166,448,159, 19,453,454,144,145,442,158, 455,
22	19	644	116,332,143,350,352,594,348,338,595,341, 596,102,318,101,662,319,148,661,
23	23	290	527, 83,516,283,280,276,277, 84,275,274, 295,517,518,519,529,530,531,273,520,521, 278,279,
24	13	370	381,534,295,457,541,542,543, 76,423,415, 544,419,
25	17	422	228,105, 46, 36, 85,337,421,347,444,487, 533,562,563,564,641,642,
26	25	292	461, 81,462,464,465,375,463,374,373, 80, 549,550,372,539,289, 82,538,296,528,272, 271,270, 73,522,
27	23	303	469,311,309, 77,458,470,471,312,304, 78, 459,298,545,399,524,404,405, 92,473,474, 472,460,
28	23	418	96, 86,553,412,413, 88,554,320,315,555, 420, 89,557,556,316,314, 90,558,317, 94, 559,560,
29	23	74	75,535,536,537,286,297,287, 79,547,546, 284, 69,282,525,269,515,291,281,288,548, 294,526,
30	17	480	308,300,301, 87,467,302,468,305,306,307, 91,310,475,476, 93,477,

Table 7-19. Network Option Costs (Thousands of Dollars)

Network Integrated LEADS/BMV Number of Regions 1
Remarks Single Network

Item	No. Reqd.	Recurring Costs: Annual Cost Each	Recurring Costs: Total Annual Cost	Recurring Costs: Eight Year Cost	One Time Installation Costs: Unit Cost	One Time Installation Costs: Total Purchase Cost	Total Eight Year Cost by Item
Lines, Modems Service Terminals	-	-	790	6,320	-	68	6,388
Terminals	390	0.6	234	1,872	3.6	1,400	3,272
Regional Switchers							
Switcher Floor Space							
Switcher Back-up Power							
Switcher Personnel							
Engineering					-	130	130
Subtotals			1,024	8,192		1,598	9,790
				Total Eight Year Cost			9,800

The integrated network was optimized subject to the MPL tariff discussed in Section 4 of this report since the LEADS Network qualifies as an inter-state network.

7.8.3 Line Performance

Line performance data for the integrated LEADS BMV Network is presented in Table 7-20. Mean response time at terminals varies between 1.7 and 7.2 seconds. Message priorization is not required to meet these response time values.

7.8.4 Network Availability

The network availability to any terminal on the integrated LEADS BMV Network is 0.988, which implies a daily average outage of 17.3 minutes.

7.9 OPTION 7 - NEW DATA NETWORK SEPARATE FROM LEADS

7.9.1 Topology

Growth of new data types is such that a new data network separate from the LEADS network should be constructed in two phases. An interim network to handle traffic through 1980 is shown in Figure 7-7. A complete network sufficient to handle predicted new traffic volumes from 1981 through to 1985 is shown in Figure 7-8. Both networks are basically starred networks with some lines involving a drop consisting of two terminals. Table 7-21 lists cities included in the network which functions through 1980 and whose PID numbers were used in the computer runs. Table 7-22 lists terminals for the final new data network to function from 1981 through 1985. The first network employs nine lines in total and the second network adds six new lines as shown.

7.9.2 Costs

Total eight year costs for the separate new data network amount to $724,000 as shown in Table 7-23. Costs for lines, modems, service terminals and network terminals are broken out for required network phasing. It is assumed that the first network is built in 1978 and the second in 1981. As in previous costing, new terminals for the network are purchased.

7.9.3 Line Performance

Line performance characteristics for the 1985 new data network are shown in Table 7-24. Response time varies from 2.2 to 14.2 seconds. These response times are in keeping with functional requirements for response times for these data types.

Table 7-20. Network Line Characteristics

Network LEADS with BMV Number of Regions 1
Remarks Under MPL

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	64	9	1200	0.156	192	4.7
2	220	25	1200	0.636	175	7.1
3	54	12	4800	0.460	126	2.0
4	60	17	1200	0.394	171	5.8
5	196	22	2200	0.390	158	6.2
6	408	18	1200	0.376	126	5.8
7	385	25	1200	0.623	157	7.1
8	43	10	2400	0.419	110	3.3
9	402	23	1200	0.448	172	6.4
10	400	25	1200	0.513	160	6.7
11	24	25	1200	0.467	211	6.6
12	336	25	1200	0.460	143	6.6
13	335	15	1200	0.437	83	5.8
14	95	24	1200	0.362	202	6.2
15	146	14	1200	0.265	56	5.3
16	146	9	2400	0.465	66	3.6
17	323	18	2400	0.681	101	5.7
18	13	10	2400	0.515	120	3.9
19	357	22	1200	0.379	166	6.1
20	383	25	1200	0.439	193	6.5
21	366	22	1200	0.273	154	5.9
22	644	19	1200	0.700	142	6.9
23	290	23	1200	0.561	178	6.7
24	370	13	1200	0.300	40	5.3
25	422	17	4800	0.356	0	1.7
26	292	25	1200	0.532	216	6.8
27	303	23	1200	0.312	242	6.0
28	418	23	1200	0.359	162	6.1
29	74	23	1200	0.693	192	7.2
30	480	17	1200	0.257	110	5.5

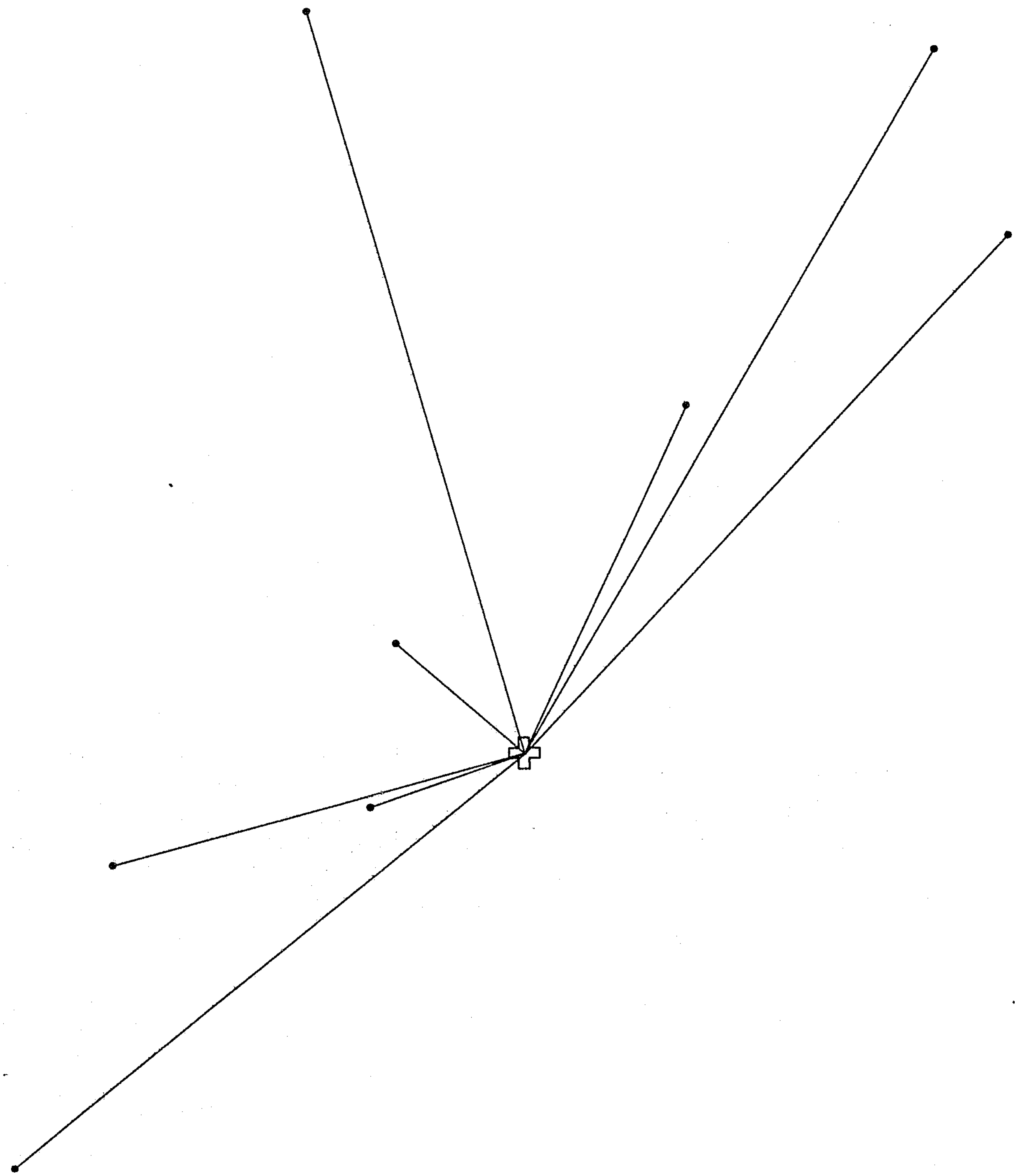


Figure 7-7. New Data Network Through 1980

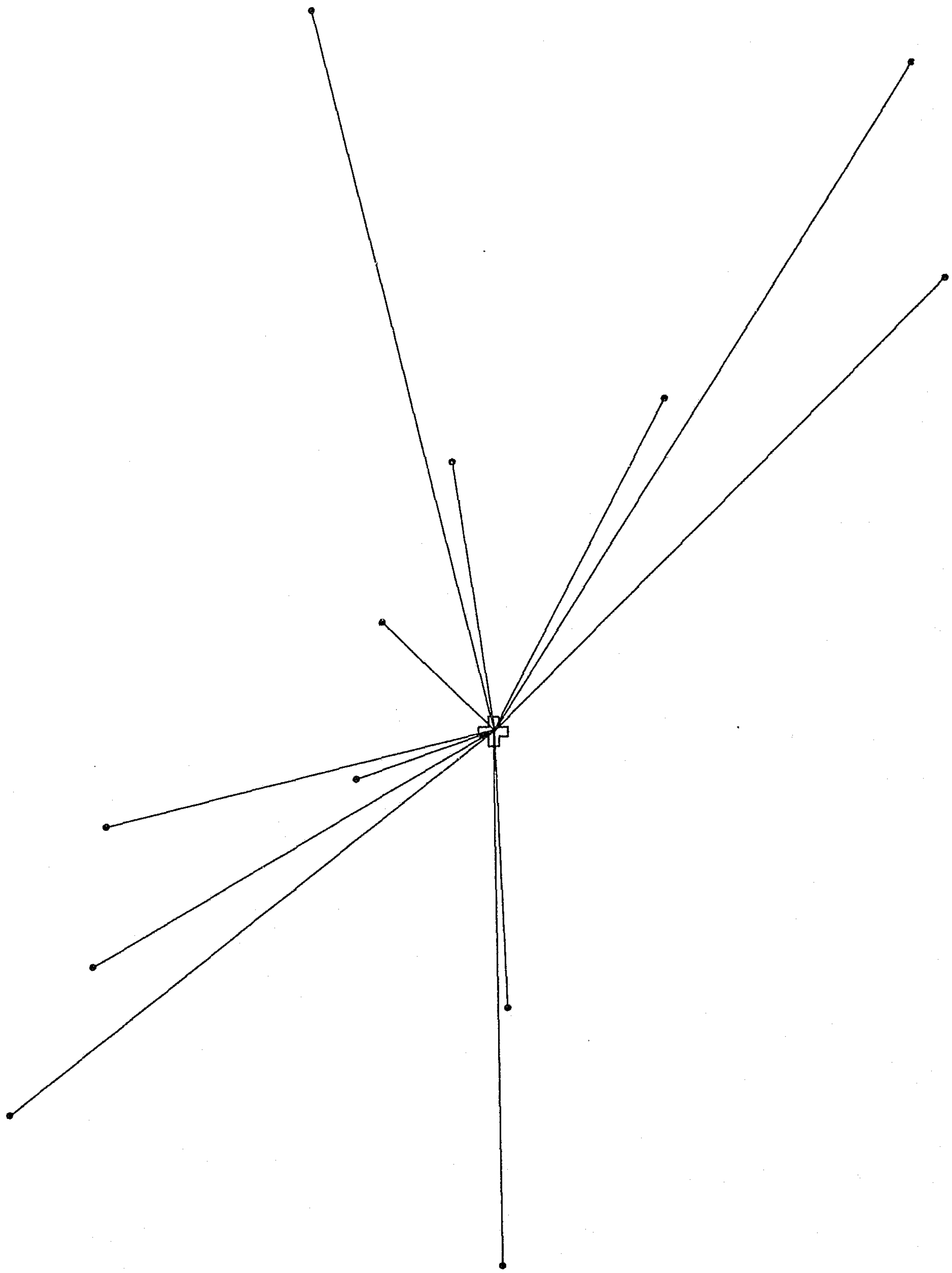


Figure 7-8. New Data Network From 1981 to 1985

Table 7-21. Separate New Data Network Terminal Assignments Through 1980

Line No.	First PID No.	Remaining PID Nos	Terminal Location
1	701		Dist 8 Courts, Cleveland
2	702		Dist 1 Courts, Cincinnati
3	703		Dist 2 Courts, Dayton
4	705		Dist 6 Courts, Toledo
5	707		ODC Headquarters
		706	Dist 9 Courts, Akron
6	708		Mansfield ODC
7	709		Columbus ODC
		704	Dist 10 Courts, Columbus
8	710		Marysville ODC
9	716		London BCI, Data Conv.

Table 7-22. Separate New Data Network Terminal Assignments 1981 Through 1985

Line No.	First PID	Remaining PIDs	Terminal Location
1	701		Dist 8 Courts, Cleveland
2	702		Dist 1 Courts, Cincinnati
3	703		Dist 2 Courts, Dayton
4	704		Dist 10 Courts, Columbus
5	705		Dist 6 Courts, Toledo
6	706		Dist 9 Courts, Akron
7	707		ODC Headquarters
		710	Marysville ODC
8	708		Mansfield ODC
9	709		Columbus ODC
10	711		Lebanon ODC
11	712		Lucasville ODC
12	713		London ODC
13	714		Marion ODC
14	715		Chillicothe ODC
15	716		London BCI, Data Conv.

Table 7-23. Network Option Costs (Thousands of Dollars)

Network New Data   Number of Regions 1
Remarks Optimized Separate New Data Network

Item	No. Reqd.	Recurring Costs: Annual Cost Each	Recurring Costs: Total Annual Cost To 1980	Recurring Costs: Total Annual Cost 1981-1985	Recurring Costs: Eight Year Cost	One Time Installaion Costs: Unit Cost	One Time Installaion Costs: Total Purchase 1978	One Time Installaion Costs: Cost 1981	Total Eight Year Cost by Item
Lines, Modems Service Terminals	-	-	50	78	540	-	4	4.3	548.3
Terminals	11/16	0.6	6.6	9.6	67.8	3.6	40	18	125.8
Regional Switchers									
Switcher Floor Space									
Switcher Back up Power									
Switcher Personnel									
Engineering							40	10	50
Subtotals			12	88	608		84	32	724

Total Eight Year Cost 724

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Table 7-24. Network Line Characteristics

Network New Data Type — Number of Regions 1

Remarks Columbus as Regional Center

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	701	1	9600	0.535	126	2.6
2	702	1	9600	0.499	101	2.4
3	703	1	9600	0.392	66	2.2
4	704	1	4800	0.689	0	5.9
5	705	1	4800	0.658	120	5.5
6	706	1	4800	0.619	110	5.1
7	707	2	2400	0.449	27	5.6
8	708	1	4800	0.641	61	5.3
9	709	1	4800	0.447	0	3.9
10	711	1	1200	0.469	74	14.2
11	712	1	1200	0.462	85	14.1
12	713	1	1200	0.383	25	12.7
13	714	1	1200	0.301	44	11.5
14	715	1	1200	0.279	44	11.2
15	716	1	9600	0.384	25	2.2

7.9.4 Network Availability

The network availability is 0.988, which implies an average daily outage of 17.3 minutes.

7.10 OPTION 8 - AN INTEGRATED LEADS AND NEW DATA NETWORK

7.10.1 Topology

Integration of new data type terminals into the LEADS network involves a two step implementation procedure as new data terminals are added to the network in the same manner that the separate new data type network implementation is phased (see Section 7.9). The network is basically the single region LEADS Network with the new data terminal star network added. The integrated network which serves through 1980 is identical with the exception that the five new data type terminals to be added in 1981 are absent from the network. The PID number of these five terminals are: 711, 712, 713, 714, and 715.

7.10.2 Costs

Total eight year costs for the integrated LEADS New Data Type Network are $8,580,000 as shown in Table 7-25. The phasing for line reconfiguration and addition of the five required terminals in 1981 is indicated.

7.10.3 Line Performance

Line performance for the integrated LEADS New Data Type Network is tabulated in Table 7-26. Response times vary from 1.2 seconds to 8.6 seconds. Line configurations are such that prioritization of law enforcement message types is not required.

7.10.4 Network Availability

Network availability for the single region integrated LEADS New Data Type Network is 0.988, which implies an average daily outage of 17.3 minutes.

7.11 COMPILATION OF COST AND PERFORMANCE DATA - OPTION 1 THROUGH 8

Table 7-27 compiles cost and performance data presented for each of the eight options presented in this section. The next section discusses these findings and also presents results of additional network studies carried out in Ohio.

Table 7-25. Network Option Costs (Thousands of Dollars)

Network Integrated Leads/New Data   Number of Regions 1
Remarks Single Network

Item	No. Reqd.	Recurring Costs: Annual Cost Each	Recurring Costs: Total Annual Cost To 1980	Recurring Costs: Total Annual Cost 1981-1985	Recurring Costs: Eight Year Cost	One Time Installation Costs: Unit Cost	One Time Installation Costs: Total Purchase 1978	One Time Installation Costs: Cost 1981	Total Eight Year Cost by Item
Lines, Modems Service Terminals	-	-	598	638	4984	-	44	4.3	5032
Terminals	401/406	0.6	241	244	1943	3.6	1444	18	3405
Regional Switchers									
Switcher Floor Space									
Switcher Back up Power									
Switcher Personnel									
Engineering							130	10	140
Subtotals			839	882	6927		1618	32	8577

Total Eight Year Cost 8580

Table 7-26. Network Line Characteristics

Network LEADS With New Data Type — Number of Regions 1
Remarks Columbus as Regional Center

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	64	5	1200	0.122	192	5.4
2	54	6	4800	0.413	126	2.2
3	44	25	1200	0.669	186	8.6
4	229	22	1200	0.586	188	8.1
5	408	21	1200	0.490	158	7.6
6	385	23	1200	0.495	190	7.8
7	43	4	2400	0.350	110	8.5
8	400	25	1200	0.570	184	8.2
9	701	1	9600	0.547	126	1.4
10	708	1	4800	0.652	61	3.0
11	706	1	4800	0.629	110	2.9
12	365	20	1200	0.682	166	8.3
13	416	13	1200	0.697	180	7.8
14	353	23	1200	0.639	208	8.4
15	95	7	1200	0.524	41	6.7
16	146	5	2400	0.429	66	4.2
17	343	23	1200	0.485	165	7.7
18	323	3	2400	0.599	101	5.5
19	13	5	2400	0.456	120	4.3
20	116	15	1200	0.626	149	7.7
21	383	25	1200	0.536	256	8.1
22	366	3	2400	0.406	27	3.2
23	702	1	9600	0.510	101	1.4
24	703	1	9600	0.400	66	1.2
25	706	1	4800	0.669	120	3.2
26	706	1	4800	0.629	110	2.9
27	716	1	9600	0.391	25	1.2
28	422	9	2400	0.694	0	6.2
29	308	16	1200	0.563	130	7.5
30	302	25	1200	0.403	281	7.6
31	84	16	1200	0.662	188	8.0
32	74	18	1200	0.695	222	8.3
33	704	1	9600	0.355	0	1.2
34	707	8	1200	0.330	40	6.2
35	709	1	4800	0.455	0	2.2
36	712	6	1200	0.602	108	6.9

Table 7-27. Compilation of Cost and Performance Data for Ohio New or Improved Networks

	Option	1	2	3	4	5	6	7	8
	Network	1 Region	2 Region	3 Region	4 Region	LEADS BMV	LEADS and BMV	LEADS New Data	LEADS and New Data
Item	Parameter								
1	One-Time Cost ($K)	1.6	1.9	2.1	2.4	1.7	1.6	1.7	1.7
2	Eight-year Recurring Cost ($K)	6.4	7.6	8.8	10.1	7.93	7.9	7.0	6.9
3	Mean Response Time (sec)	7.5	7.3	7.5	6.9	7.5/ 5.3	7.3	7.5/ 14	8.6
4	Availability	0.988	0.982	0.982	0.982	0.988	0.988	0.988	0.988

SECTION VIII

OHIO NETWORK COMPARISONS

SECTION VIII

STACOM/OHIO NETWORK COMPARISONS

This section provides a comparative overview of the eight STACOM/OHIO Network Options and also presents results of two additional studies. One additional study deals with impacts on the LEADS Network of the inclusion of fingerprint data, and a second study assesses the impact on network costs of reducing response time as required at terminals to less than the 9 seconds called for in the OHIO Functional Requirements.

8.1 COMPARISON OF THE FOUR LEADS OPTIONS

Each of the four LEADS options, Options 1 through 4, involving the use of from 0 to 3 regional switchers in addition to the existing Columbus switcher data base computer, have been designed to meet or exceed the STACOM/OHIO Functional Requirements. The principal issue of comparison between networks thus becomes cost. Costs presented here, and in the previous Section 7, are based upon total eight year installation and recurring costs for the years 1978 through 1985 as discussed in Section 4.

Figure 8-1 presents total eight-year costs for Options 1 through 4 and also includes eight-year costs for continuation of the present system for comparative purposes only. The single region LEADS Network is the cheapest. The two, three and four region options follow in order. These results show that line savings due to the use of regional switchers located throughout the state do not offset the additional costs incurred for regional switcher hardware, sites, personnel, interregion lines and increased engineering costs.

Since all networks meet functional requirements, the conclusion is that the STACOM/OHIO single region network is the most cost-effective option of the first four options.

8.2 SEPARATE VS INTEGRATED LEADS/BMV NETWORK(S)

The least cost LEADS network derived from Options 1 through 4, the single region case, was used to compare costs of separate vs integrated networks for LEADS and BMV traffic.

In considering the BMV network as a possible separate entity, network optimization was carried out subject to the intrastate tariff presented in Section 4. This led to a considerable annual recurring cost savings over the existing BMV network of approximately $100,000. When this value is added to recurring costs for a separate single region LEADS network, (which is subject to the interstate MPL tariff), a total annual recurring cost for separate networks is obtained. This value together with the total of one-time installation costs for each network is displayed in the left-hand portion of Figure 8-2. The bars to the right show one-time installation and annual recurring costs for an integrated

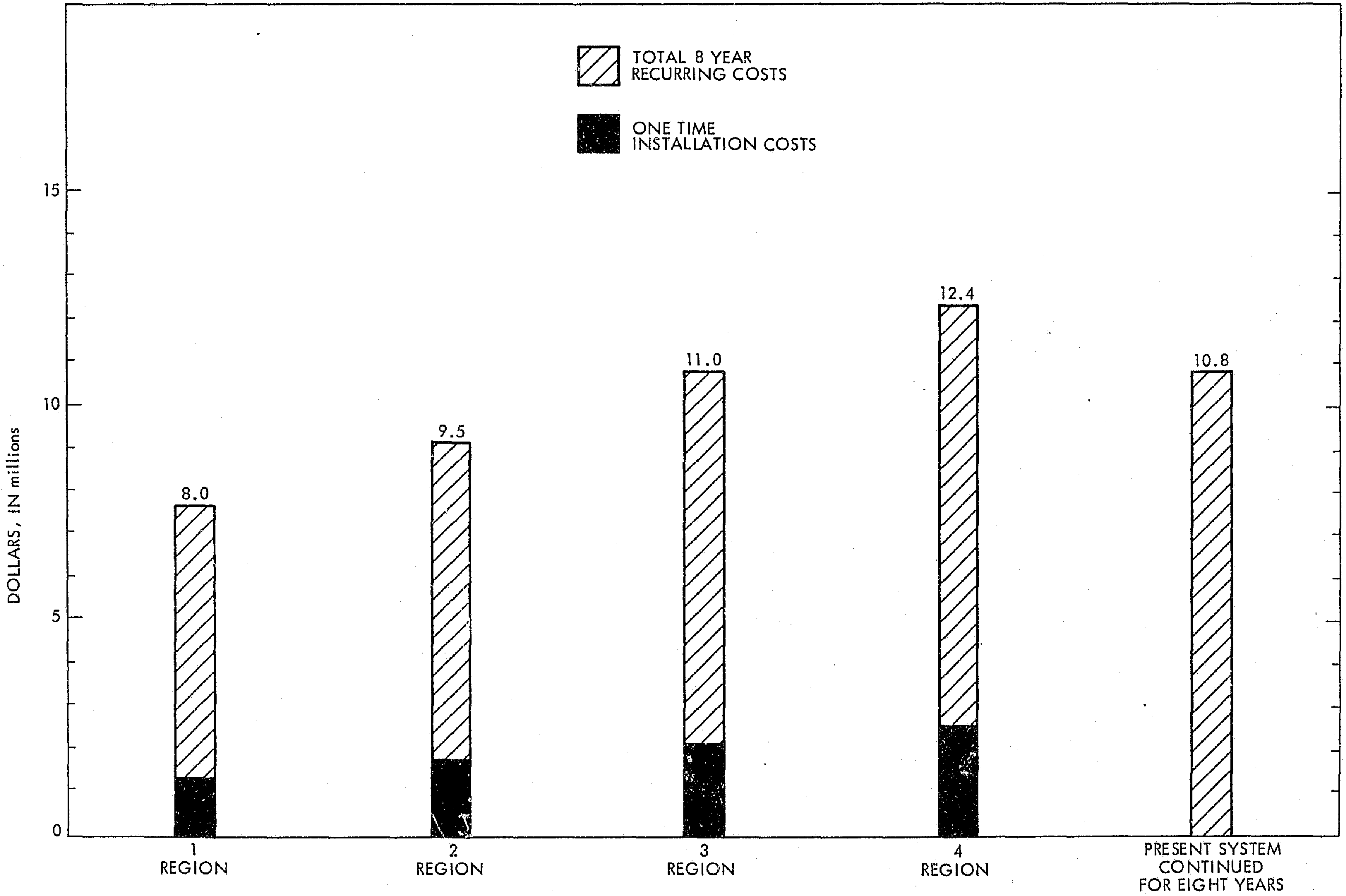

Figure 8-1. Total Cost -- 1978 Through 1985 Options 1 Through 4 and Present System

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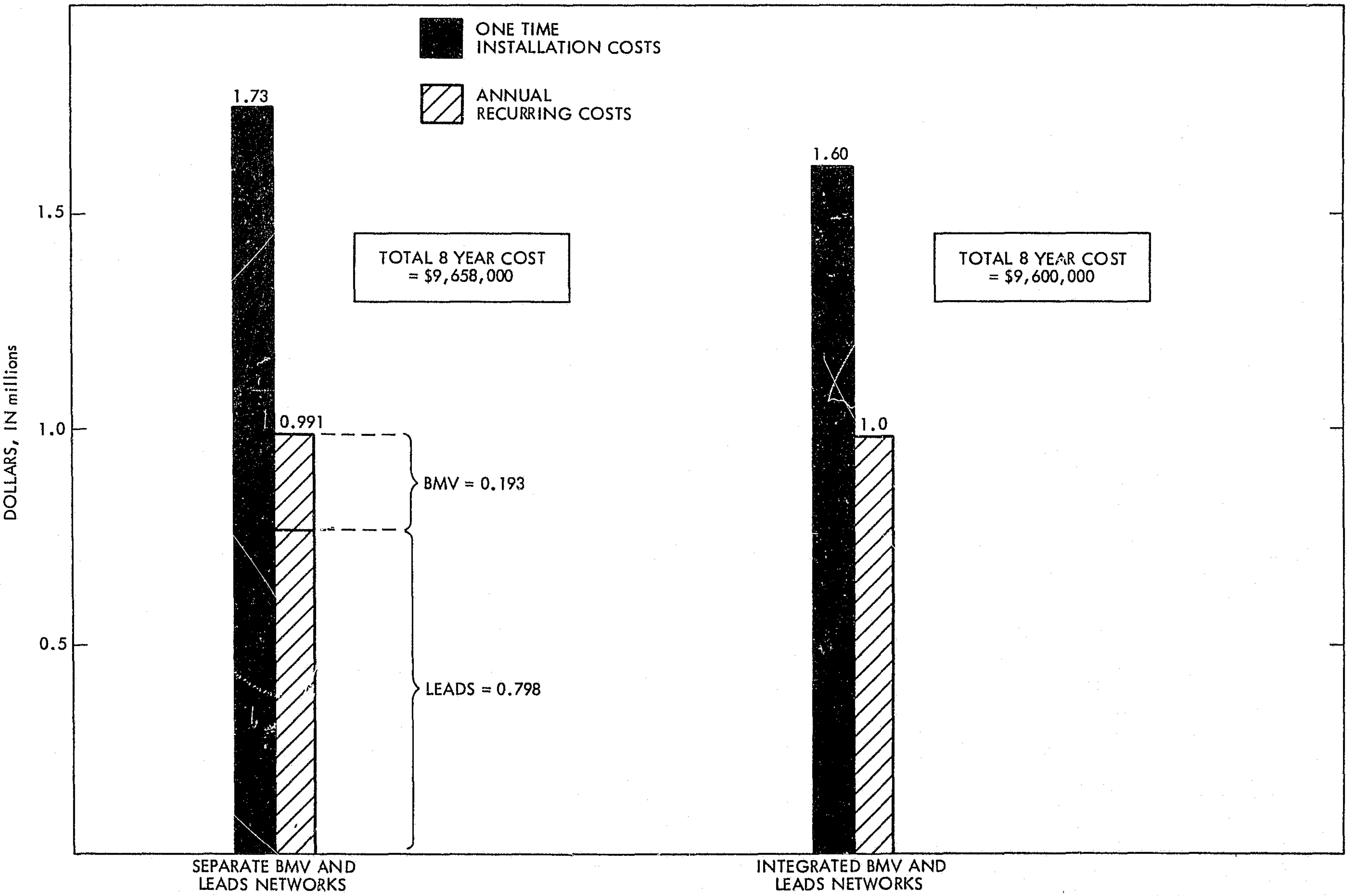

Figure 8-2. Separate vs Integrated BMV and LEADS Network

LEADS/BMV Network with the entire network subject to the interstate MPL tariff outlined in Section 4.

The figures indicate that total eight-year costs are not appreciably different. For example, referring to Figure 8-2, the total eight-year cost for separate networks is:

1.73 + 8(.991) = $9,658,000

and for the integrated case:

1.60 + 8(1.0) = $9,600,000

The figures indicate an eight-year savings estimate of $58,000.

It is evident that the use of different tariff structures plays an important role in the final costings of the two alternatives. It would be reasonable to assume that a more substantial cost saving would be realized by combining two such state-wide networks if the same tariff were used in all cases. However, as long as the networks in question are subject to the tariff structures assumed in this study, it would appear that cost is not an overwhelming consideration to the management decision to integrate or not to integrate the two networks.

This is not the case, however, if the LEADS and BMV networks could be integrated under the intrastate tariff used for BMV alone. A separate investigation of this possibility was carried out. In this case, annual line costs would amount to $530,000 and line installation costs would be $72,000. Substituting these line costs, into Table 7-19, total network annual recurring and installation costs (including terminals and engineering costs) would be $764,000, and $1,600,000 respectively. This yields an eight year total cost of

1.6M + 8 (764K) = 7.712M

This represents a meaningful savings of $1,940,000 over the separate LEADS and BMV network, option 5.

8.3 SEPARATE VS INTEGRATED LEADS/NEW DATA NETWORK(S)

Whether integrated with the LEADS Network or not, the estimated growth of new data types from the present until 1985 calls for the implementation of 11 terminals through 1980, and the addition of 5 more terminals in 1981, for a total of 16 operational terminals from 1981 through 1985. This means that in each case there is a small additional one-time installation cost incurred in 1981. Figure 8-3 depicts these cost comparisons for the separate and integrated network cases. The family of bar graphs to the left shows that the LEADS and new data type networks taken separately require a total present installation cost of $1.66M and a total annual recurring cost of $840K through the year 1980. The 1981 upgrade requires a $77K investment and recurring costs increment to $885K. The family of bar graphs to the right of

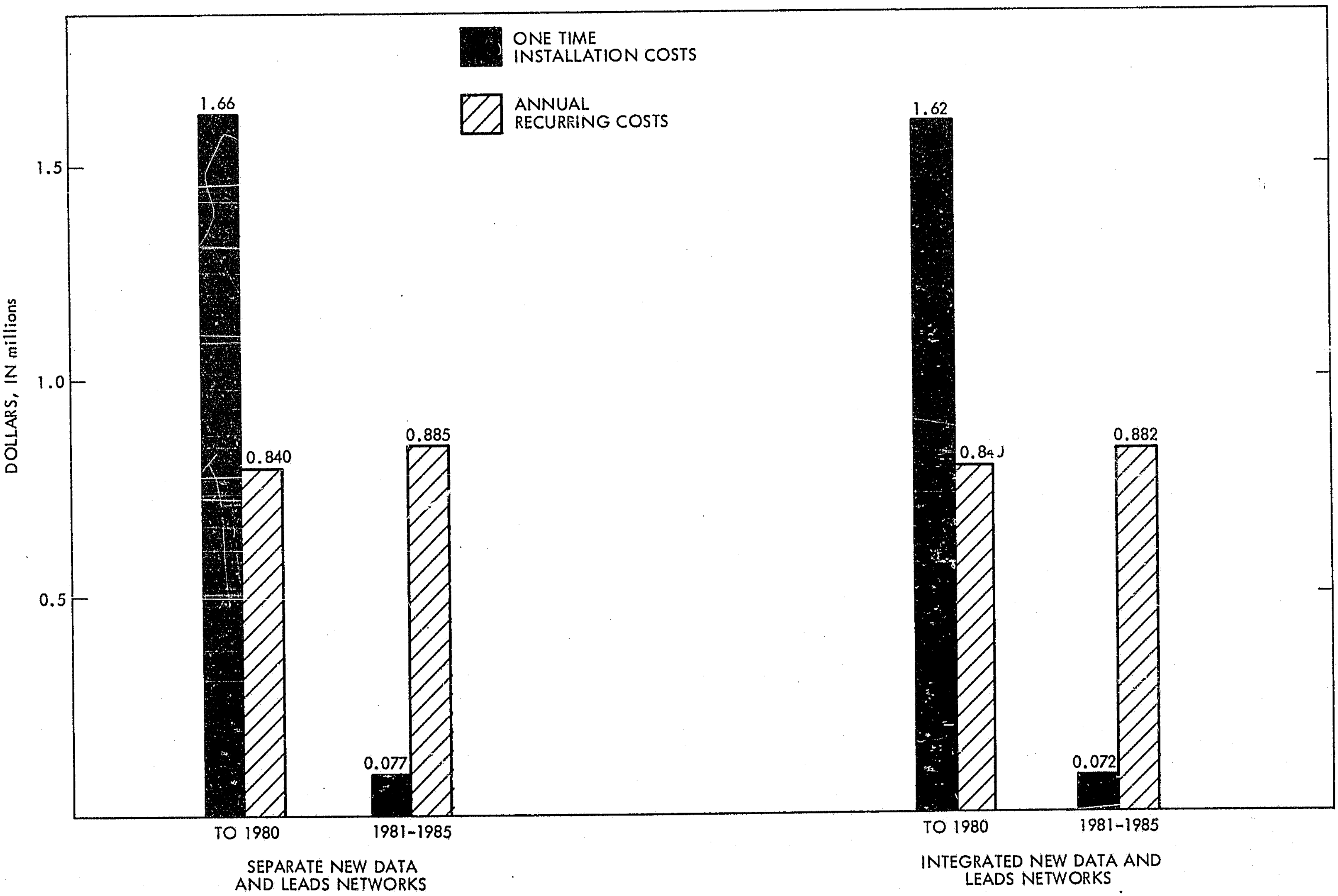

Figure 8-3. Separate vs Integrated New Data and LEADS Network

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Figure 8-3 show similar cost breakdowns for pre and post 1981 years for the case in which the two networks are integrated into a single entity.

Assuming that network implementation takes place in 1978, then the life of either network before upgrade is three years to 1980, and the life of the upgraded network is five years. The total eight-year cost estimate for the case where the networks are separate, then becomes:

$$1.66 + 3(.840) + 0.077 + 5(0.885) = \$8,682,000$$

and the total eight-year cost for the integrated option is

$$1.62 + 3(.840) + 0.072 + 5(0.882) = \$8,622,000$$

for an eight-year estimated difference of $60,000.

As in the case of considering BMV/LEADS integration, the monetary benefits of integration are not significant when compared to total cost. The reason, however, in this case is not due to tariff structures but is due to the fact that there are so few new data type lines in comparison to LEADS lines.

Both networks function within specifications of STACOM/OHIO network functional requirements. The conclusion, therefore, is that cost considerations alone do not represent a significant factor in the management decision to implement Options 7 or 8.

8.4 IMPACT OF FINGERPRINT DATA ON LEADS NETWORK

8.4.1 Topology

Predicted growth of fingerprint data types is contingent on the development and use of encoding and classifying equipment located in major Ohio cities. The implementation schedule calls for a first digitizer classifier to be located in the Cleveland PD in 1981 and five more to be added to the system in 1983 at PDs in Columbus, Cincinnati, Toledo, Dayton and Akron. The incorporation of these facilities involves a slight modification to the topology of the single region LEADS case, (see Paragraph 7.3). The LEADS Network with fingerprint data added as specified requires a total of 23 multidropped lines. These lines, and their principal characteristics, are summarized in Table 8-1.

8.4.2 Costs

Total eight-year costs for a LEADS Network which handles fingerprint data are broken down in Table 8-2. Costs for the LEADS Network from 1978 to 1985 are shown separately. In 1981, the increment costs for the first terminal in Cleveland are shown. These costs are incurred through 1985. The three-year costs for the addition of the final five terminals in 1983 through 1985 are also listed.

Table 8-1. Network Line Characteristics

Network LEADS with Fingerprint Number of Regions 1
Remarks Columbus as Regional Center

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	416	9	1200	0.160	145	5.3
2	355	25	1200	0.677	212	8.0
3	95	25	1200	0.502	195	7.3
4	146	5	2400	0.678	66	5.8
5	343	24	1200	0.517	183	7.3
6	323	3	4800	0.458	101	2.2
7	13	5	4800	0.389	120	2.0
8	116	17	1200	0.662	159	7.3
9	383	25	1200	0.538	256	7.4
10	64	5	1200	0.123	192	4.9
11	54	6	4800	0.693	126	3.2
12	44	25	1200	0.672	186	7.9
13	229	22	1200	0.589	188	7.4
14	408	21	1200	0.492	158	7.0
15	385	23	1200	0.497	190	7.1
16	43	4	2400	0.562	110	4.5
17	400	25	1200	0.573	184	7.5
18	370	7	1200	0.213	40	5.3
19	422	9	4800	0.536	0	2.4
20	308	20	1200	0.417	181	6.7
21	302	25	1200	0.405	281	7.0
22	84	16	1200	0.665	188	7.2
23	74	18	1200	0.698	222	7.5

Total eight-year costs are $9,298,000. Costs for lines, modems, and service terminals, (listed as LINES in Table 8-2), account for about 3% of the eight-year cost increase over the single region LEADS without fingerprints and the costs for fingerprint processing equipment accounts for 97% of the additional cost.

As indicated in Table 8-2, the purchase cost for a single fingerprint encoder-classifier is estimated at $200,000 per unit. Annual maintenance is assumed to run at $12,000.

Table 8-2. Cost Summary by Year for LEADS Network with Fingerprint Data ($1000's)

Year(s)	Item	No. Reqd.	Annual Cost Each	Total Annual Cost	Eight Year Re-curring Cost	Unit Cost	Total Pur-chase Cost
1978-1985	Lines	-	-	564	4,512	-	42
	Leads Terminals	390	0.6	234	1,872	3.6	1,400
198 - 1985	Lines*	-	-	1.5	7.5	-	0.25
	Fingerprint* Terminals	1	12	12	60	200	200
1983 - 1985	Lines*	-	-	7.5	22.5	-	1.25
	Fingerprint* Terminals	5	12	60	180	200	1,000
Totals					6,654		2,643
Total Eight-Year Cost							$9,297

*Added costs in years shown

8.4.3 Performance

The principal performance question of interest when considering the addition of messages with long average message lengths, such as fingerprint data, to the LEADS Network is the potential degrading effect on response times for higher "priority" type messages involving officer safety.

An analysis of the mean and standard deviation of message service times on the LEADS Network with fingerprint data added, indicates that mean response time goals specified in the OHIO Functional Requirements will be met satisfactorily without the necessity of message blocking or message prioritization by the computer.

This result stems from two considerations. First, the classification of fingerprint data allows for substantial reductions in the actual amount of data characters transmitted for each fingerprint (1852 characters). Second, while this message length is still comparatively long with respect to the normal LEADS message types, the occurrence of fingerprint messages on the network accounts for only about 2% of the total traffic predicted for 1985.

For these reasons, the mean response time goal of less than equal to 9 seconds is met for the network topology presented in Paragraph 8.4.1.

8.5 NETWORK COST SENSITIVITY TO RESPONSE TIME

The effect of reducing network response time requirements on annual recurring costs for lines, modems and service terminals in the single region LEADS case, (Option 1), was investigated. Network optimization computer runs were carried out at a number of points where the required response time was set at less than 9 seconds. The program then found the required networks and produced costs for each run.

Figure 8-4 shows the results of this analysis, which was carried out with the same mean service times for the Columbus computer to clarify the effect on network costs. The figure shows that for the OHIO single region LEADS Network, there is virtually no cost penalty for specifying a response time down to approximately 7.0 seconds. Stating the case alternatively, a network that meets a 9.0 second response time requirement also meets a 7.0 second requirement.

A slight increase in cost begins to appear at 6.0 seconds, due primarily to the reduction of the number of multidropped terminals on some of the lines. This reduction is required to meet the lower response time goal.

A substantial increase in cost of about 13% is required to realize a reduction in response time from 6.0 to 5.0 seconds. Reductions in mean response time below 5.0 seconds result in rapidly increasing costs.

The curve suggests that mean service times at network terminals in the neighborhood of 4 seconds would require substantial expenditures in the Columbus computer.

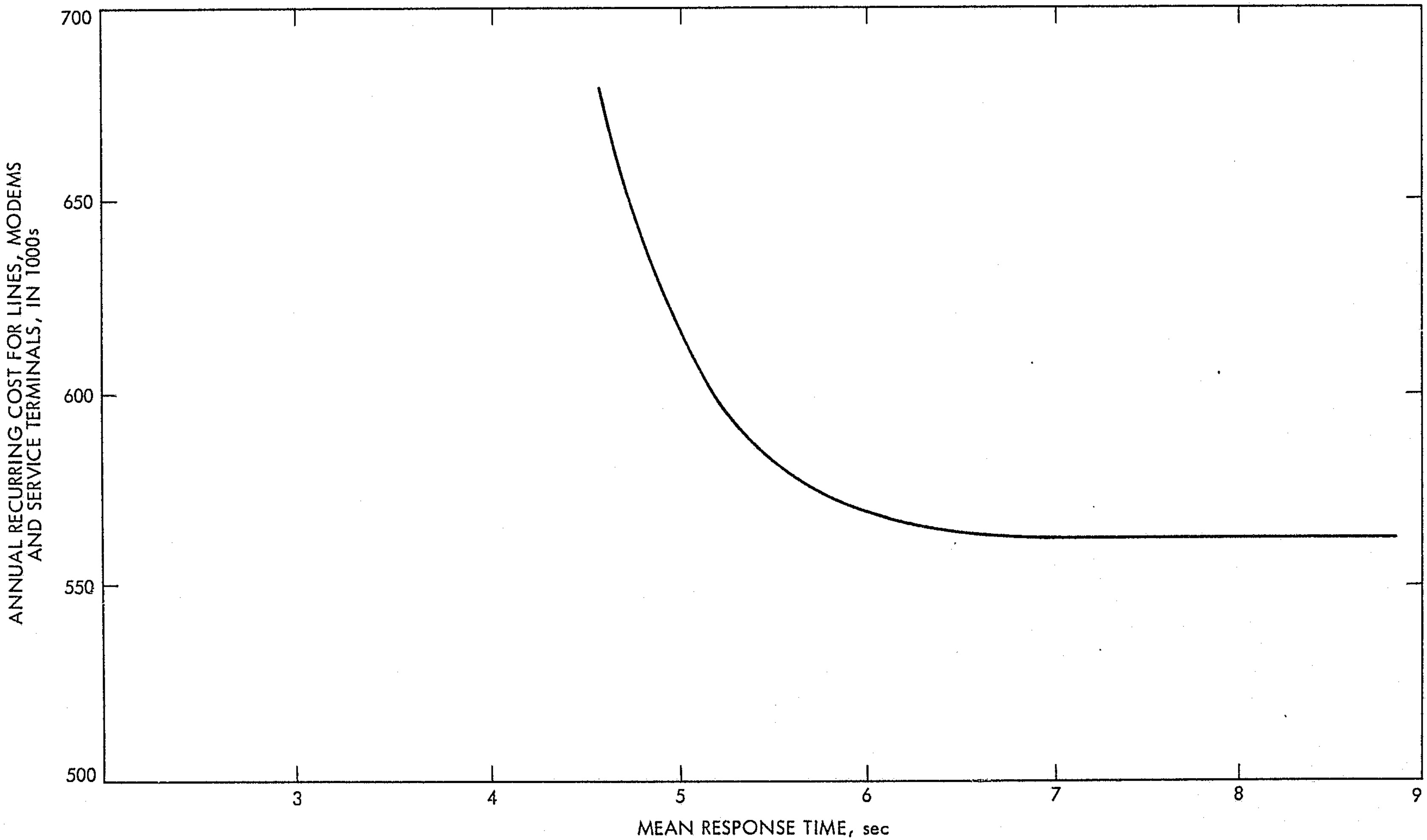


Figure 8-4. Recurring Line Costs vs Mean Response Time

SECTION IX

TEXAS NETWORK STUDIES

SECTION IX

STACOM/TEXAS NETWORK STUDIES

STACOM/TEXAS Network Studies consist of examining five optional network configurations, and the execution of three additional network studies.

Options 1, 2 and 3 investigate potential cost savings in trading off network line costs with regional switcher costs. Options 4 and 5 examine cost tradeoffs between construction of a separate network to accommodate predicted growth in New Data Type traffic, and the integration of New Data Type criminal justice traffic with TLETS traffic into a single network.

Three additional network studies consider, 1- network cost increases as terminal mean response times are decreased, 2- the impact on network cost and performance due to adding digitized classified fingerprints as a data type, and 3- the relative difference in network costs between maintaining and abandoning network line service oriented toward the existing regional Councils of Government.

The following paragraph discuss these studies in more detail.

9.1 OPTIONS 1 THROUGH 3

As the number of regional switchers serving terminals within their regions is increased, total network line costs may be expected to decrease due to the fact that total network line length has decreased. The placement of additional regional switchers, however, imposes an additional network cost which may or may not offset cost savings due to decreased line lengths.

Options 1 through 3 seek to understand the effects of the placement of regional switchers throughout the State of Texas on costs.

Option 1 considers the use of a single regional switcher located in Austin.

Option 2 analyzes the use of two regional switchers. One switcher is located in Austin and the second switcher is located in one of four different cities in an attempt to search for a minimum cost two region configuration. The four locations considered were restricted to the major candidate cities of Dallas, Midland, Lubbock and Amarillo.

Option 3 considers costing effects of the use of three regional switchers. Two of the switchers are located in Austin and Dallas respectively and the location of the third is varied from Houston, Midland, Lubbock, Amarillo and San Antonio. The San Antonio location is included to provide a comparison of optimized networks with an optimized network with switchers located as they are in the present TLETS system.

9.2 OPTIONS 4 AND 5

The New Data Type traffic communication requirements identified in Task 2.0 can either be met by constructing a separate network dedicated to these needs or by integrating this traffic flow with the TLETS Network.

Option 4 considers cost totals for operating separate networks for the TLETS System and the New Data Types.

Option 5 considers total costs for meeting traffic requirements of both TLETS and New Data Types in a single integrated network.

In both cases, the TLETS network considered will be the least cost network identified from the studies of Options 1 through 3.

9.3 COST SENSITIVITY TO RESPONSE TIME

A study designed to clarify the extent to which total network costs increase as terminal response times are reduced is to be carried out. As response times are reduced from the 9 second goal specified in the STACOM/TEXAS Functional Requirement, networks will be called for that drop fewer terminals on given multidrops hence, require more lines. Higher speed lines may also be required as response time requirements are made more stringent. These factors will tend to increase overall network costs.

This study will determine the extent of cost increases as a function of decreasing network response times for the least cost TLETS network that results from studies of Options 1 through 3.

9.4 IMPACT OF ADDING FINGERPRINTS AS A DATA TYPE

Estimates of fingerprint traffic in Texas assume the use of automated digital classifying equipment at strategic locations throughout the state. The potential impacts of the addition of such data types to the TLETS Network in terms of cost and performance are a matter of interest. From the performance standpoint the principal consideration is the extent to which the addition of fingerprint data may affect response time characteristics of higher priority officer safety type messages.

This study determines the extent of such impacts on the least cost TLETS Network which develops from Options 1 through 3.

9.5 C.O.G. SERVICE STUDY

In the present TLETS system, multidropped lines providing service to agencies throughout the state are generally organized such that single multidrop lines service agencies in jurisdictions of a single Council of Governments, (COG).

This study investigates the potential for line savings if network multidropping is carried out without the restriction of serving COG agencies on separate lines.

The specific COGs considered in this study are shown in Section 12 of this report, Figure 12-4.

SECTION X

TEXAS NETWORK COST ANALYSIS

SECTION X

TEXAS NETWORK COST ANALYSIS

This section presents assumptions and bases for costing STACOM/TEXAS Network Options. Total network costs are comprised of recurring costs and one-time installation costs. Table 10-1 shows the basic cost items considered and describes the meaning of each item.

The costs considered here include the primary items that affect relative costs between network configurations involving different numbers of switchers and different traffic types. Costs for required upgrades of the central data bases in Austin and in the Austin Switcher are not included, since these costs are present to the same degree in all of the alternative network configurations studied. Detailed costing of data base computer upgrades is not within the scope of the STACOM Study which is primarily oriented toward network alternatives. Basic data base computer performance requirements, however, are treated in Section 13 of this report.

The following paragraphs develop costing values for each item listed in Table 10-1.

10.1 LINE, MODEM, AND SERVICE TERMINAL COSTS

The line tariff structure used for costing of lines, modems and service terminals for the Texas computer network topology runs was supplied by Southwestern Bell Telephone Company. Table 10-2 displays

Table 10-1. Cost Items and Descriptions

Item	Recurring Costs	On-Time Installation Costs
Lines, Modems, Service Terminals	Annual Tariff Costs	Modem and Service Terminal Installation
Terminals	Maintenance Costs	Purchase Costs
Regional Switchers	Maintenance Costs	Purchase Costs
Switcher Floor Space	Regional Switcher Site Rental Costs	Regional Switcher Site Preparation Costs
Switcher Backup Power	Maintenance Costs	Purchase Costs
Switcher Personnel	Regional Switcher Personnel Salaries	Not Applicable
Engineering	Not Applicable	Network Procurement Costs

Table 10-2. STACOM/Texas Line Tariff

Line Speed (Baud)	Cost/mi/mo		Modems		Service* Terminals		Drop Charge
	IXC $	Telpak $	Inst $	Month $	Inst $	Month $	Month $
1200	3.00	0.60	50.00	22.00	10.00	15.00	10.00
2400	3.00	0.60	100.00	54.00	10.00	15.00	10.00
4800	3.00	0.60	100.00	135.00	10.00	15.00	10.00

*For TELPAK the term Channel Terminal is used
For IXC the term Connection Arrangement is used

installation and monthly charges used. For 1200, 2400 and 4800 Baud lines the table shows costs per mile per month for the Inter eXchange Charges (IXC) when a non-TELPAK city is involved. The TELPAK column shows cost per mile per month for connections between any two cities in the TELPAK inventory. Cities in the TELPAK inventory do not stay constant over long periods of time, however, for the purposes of this study, the TELPAK cities listed in Table 10-3 were used.

10.2 TERMINAL COSTS

The State of Texas has recently procured replacement terminals for the TLETS system capable of operation at 1200 Baud and at higher rates. It is planned that these terminals will be placed at user agencies within the next few years. The STACOM/Texas Network study assumes that 564 terminals will be operational by 1978 and continue operation through 1985. Since the life of the system is greater than 3 years, it is assumed that the cost effective policy of purchasing the terminals and carrying a monthly maintenance charge would be carried out.

In this costing exercise, the unit cost per terminal is known to be $8,847 and the annual maintenance charge is $1,260 ($105/month).

10.3 REGIONAL SWITCHER COSTS

The purchase price for regional switchers now in use in the TLETS system in Garland and San Antonio range between $320,000 and $380,000. It is assumed that similar regional switching facilities would be incorporated in any future network making use of them. For simplicity in network topology comparisons, a purchase price of $350,000 is assumed.

The annual maintenance charge for regional switchers is estimated at $18,000 ($1,500 per month).

Table 10-3. Texas Telpak Inventory Used in STACOM/Texas Study

1.	Abilene	25.	Donna	49.	Pharr
2.	Alpine	26.	Edinburg	50.	Plainview
3.	Amarillo	27.	El Paso	51.	Port Arthur
4.	Angleton	28.	Euless	52.	Richmond
5.	Arlington	29.	Fort Stockton	53.	Rusk
6.	Atlanta	30.	Fort Worth	54.	San Angelo
7.	Austin	31.	Galveston	55.	San Antonio
8.	Beaumont	32.	Gonzales	56.	Seguin
9.	Belton	33.	Greensville	57.	Sherman
10.	Big Spring	34.	Harlingen	58.	Sweetwater
11.	Brenham	35.	Houston	59.	Tahoka
12.	Bridge City	36.	Huntsville	60.	Temple
13.	Brownsville	37.	Kilgore	61.	Terrell
14.	Brownwood	38.	Killeen	62.	Texarkana
15.	Bryan	39.	Kingsville	63.	Texas City
16.	Canyon	40.	Laredo	64.	Tyler
17.	Childress	41.	Longview	65.	Vernon
18.	Colorado	42.	Lubbock	66.	Victoria
19.	Commerce	43.	Midland	67.	Waco
20.	Conroe	44.	Mcallen	68.	Weslaco
21.	Corpus Christi	45.	Mt. Pleasant	69.	Wharton
22.	Corsicana	46.	Nacogdoches	70.	Wichita Falls
23.	Dallas	47.	Odessa	71.	Yoakum
24.	Denton	48.	Paris		

10.4 REGIONAL SWITCHER FLOOR SPACE

It is assumed that 1000 ft^2 of floor space is sufficient for housing a regional switcher facility including personnel office space. Facility preparation costs are estimated at $30,000 per switcher facility. These preparation costs do not appear in cases where switchers are located in Dallas or San Antonio. Monthly rental is estimated at $0.40 per ft^2 so that monthly rental per switching facility is $400.

10.5 SWITCHER BACKUP POWER

Uninterruptable power supplies, (UPS), are considered necessary at each regional switching facility to ensure commercial power continuity during momentary power transients as well as over extended periods.

Solid-state static inverter type UPS including a rectifier/charger, and autobypass switch are available at approximately $13,000 per unit. Batteries for the unit are estimated to cost $2,500. A gasoline engine generator for use when lengthy outages occur include weatherproof housings and auto transfer switches that operate when commercial power fails. These units are priced at $4,500 each.

The total one-time purchase price for each installation is, therefore, $20,000. A maintenance contract for both the UPS and engine generator is estimated at $500 per month.

10.6 ENGINEERING COSTS

Engineering costs associated with network implementation were estimated for single and multiple region configurations. Table 10-4 shows manpower estimates in man-months for assumed engineering costs. The values shown for the single region separate New Data Network are reduced with respect to other single region networks since the network is considerably smaller. Cost per man-month including overhead and benefits is estimated at $4,000.

10.7 PERSONNEL COSTS

Regional switching facilities require supervisory, programming and computer operations personnel. This study assumes that each regional switcher facility requires one supervisor, two programmers and six computer operators. Two computer operators are provided per shift for safety reasons so that at no time during a 24-hour day the facility is manned by one person alone. Table 10-5 presents estimated salaries for the required personnel.

10.8 COST SUMMARY

Table 10-6 summarizes recurring and one-time installation costs developed in this section for convenient reference.

10.9 TEXAS NETWORK IMPLEMENTATION

The networks presented in this section are designed to meet TEXAS traffic requirements through the year 1985. A cost analysis on the feasibility of constructing an intermediate network to meet 1981 traffic level requirements, and then upgrading this network in 1981 to meet 1985 traffic level requirements, as opposed to building a single network to meet traffic requirements through 1985, was carried out. It was found that building a single network now to meet 1985 traffic requirements would not involve additional costs over intermediate phasing of network upgrades. A single exception to this rule occurs in the cases of networks where New Data Types are involved, (Options 4 and 5).

Growth in new data type traffic volumes from the present through 1985 is such that it is less costly to implement one network to handle traffic volumes up to 1980 and to then add to the network to meet traffic demands from 1981 through 1985.

Table 10-4. Engineering Cost Estimates (in man months)

Task	2, 3 and 4 Regions	1 Region New Data Types	1 Region Others
Final Functional Requirements	2	1	2
Switcher Design Spec/RFP	4	-	-
Network Design Spec/RFP	4	1	4
Switcher Facilities RFP	4	-	-
Switcher Procurement Monitor	6	-	-
Network Procurement Monitor	6	3	6
Facilities Procurement Monitor	6	-	-
Switcher Test Plan	2	-	-
Switcher Testing	2	-	-
Network Test Plan	2	1	2
Network Testing	2	1	2
Documentation	6	1	6
Supporting Analysis	6	2	6
User Operators Manual	6	2	6
Totals (Man Months)	58	12	34
Approximate Cost at $4K/MM ($K)	230	50	130

Table 10-5. Personnel Costs

Personnel	No. Required	($K) Annual Salary	($K) Annual Cost
Supervisor	1	20	20
Programmers	2	18	36
Operators	6	12	72
Total Personnel Annual Cost			$128K

Table 10-6. Cost Summary by Item

Item	Annual Recurring Cost Per Unit ($K)	One-Time Installation Cost Per Unit ($K)
Lines, Modems, Service Terminals	See Tariffs and Costs; Tables 4-2, 4-3, and 4-4	See Tariffs and Costs; Tables 4-2, 4-3, and 4-4
Terminals	1.260	8.847
Regional Switchers	18.0	350.0
Switcher Floor Space	4.8	30.0
Switcher Backup Power	6.0	20.0
Switcher Personnel	128.0	None
Engineering	None	50/130/230 See paragraph 11.6

For these reasons costs presented in Sections 13 and 14 are based on the construction in 1978 of networks that will accommodate predicted traffic levels through 1985 with the exception of networks involving new data types that are phased as indicated.

Thus, TEXAS Networks can be regarded as involving costs over a period of eight years. Therefore, total eight year costs including installation and recurring costs are used as a basis of network option cost comparisons.

SECTION XI

TEXAS NETWORK FUNCTIONAL REQUIREMENTS

SECTION XI

STACOM/TEXAS NETWORK FUNCTIONAL REQUIREMENTS

This section presents the Functional Requirements for the Texas State Criminal Justice Telecommunications (STACOM) Network as developed by the JPL/TEXAS STACOM Project Study.

The Functional Requirements document is the top level network specification and serves as a base for all lower level design specifications for the total network, including functional and design specifications of network elements. All subsequent documentation must be consistent with this specification.

This section provides a basic description of the Texas STACOM network, definition of network elements, and defines the required functions of the total network as well as the network elements. The description is intended to provide a succinct overview of network functions and requirements. Further details related to how the functional requirements shall shall be implemented shall be contained in later requests for proposals.

The use of the term STACOM Network refers to either a single network or a group of networks that meet the functional requirements outlined herein.

11.1 NETWORK PURPOSE

The purpose of the STACOM Network is to provide efficient telecommunications capable of transporting information between Texas state criminal justice agencies on a statewide scale and to and from specific interstate criminal justice agencies. Criminal justice agencies are agencies whose primary functions encompass law enforcement, prosecution, defense, adjudication, corrections and pardon and parole. The network shall be designed to handle communication requirements among these agencies projected through the year 1985.

11.2 STACOM USERS

The STACOM Network shall be comprised of one or more networks serving user requirements, to be determined during detailed network analysis and design phases of the STACOM Project. Users shall consist of the present and future users of the Texas Law Enforcement Telecommunications System, (TLETS), and other authorized criminal justice agencies within the Texas State Criminal Justice System.

11.3 NETWORK CONFIGURATION DEFINITIONS

The basic configuration of the STACOM Network is an array of network system terminations connected through Regional Switching Center, (RSC), facility(s) to data base facilities.

Each system termination on the STACOM Network shall be defined as one of three types:

a. individual terminals

b. groups of terminals in cities

c. interfaces to regional criminal justice systems

Any of the system terminations within a network shall be able to communicate with any other system termination. Each system termination shall not be routed through more than one RSC in gaining access to the Austin data bases, not including the Austin switching facility, during normal network operation.

11.4 MESSAGE CHARACTERISTICS

11.4.1 Digital Message Types

The STACOM Network shall handle the following six basic types of messages.

- Data File Interrogations/Updates

  These messages shall be inquiries, entries, modifiers, cancels, locates, clears and responses to and from a data file at the state or national level. The text is generally in fixed format.

- Administrative Messages

  These are messages between network users which do not involve data file access. The text is in a less restrictive format.

- Network Status

  These messages shall provide information at terminals initiating messages in the event that destination terminals or intermediate switchers or lines are unable to function or specific files or portions of files are not functional.

- Error Messages

  These messages shall contain information regarding the nature of errors detected in transmitted messages. Messages in which errors are detected are not automatically retransmitted on the network, but are resent at the users discretion.

- Diagnostic Messages

  Messages of a diagnostic nature shall be included with or shall accompany network status and error messages when feasible.

- Fingerprints

  Digitized representations of fingerprints shall be included on the STACOM Network.

11.4.2 Message Content

Criminal justice messages shall contain the following information in known locations:

- Internal TLETS messages shall contain
  - Message Origin
  - Message Type
- External TLETS messages shall contain
  - Message Type
  - Message Sequence Number
  - Message Origin

11.4.3 Message Lengths

Digital messages transmitted over the STACOM Network shall not exceed 500 characters in length. Actual messages exceeding 500 characters shall be blocked in message segments which shall not exceed 500 characters each. Multisegment messages shall have a single overall message number and distinct message segment numbers. Each segment shall be transmitted as a separate message. Personnel at destination terminal(s) must reassemble the overall message upon reception.

Multisegment fingerprint, multisegment file update messages, and other multisegment messages whose final destination is a computer, or data base file, shall be reassembled by software at the destination point.

11.5 NETWORK MESSAGE HANDLING

11.5.1 Message Routing

The STACOM Network shall provide communications routing for all messages between any of its system terminations.

The following specific routing capabilities shall be provided:

- Data base inquiry/update messages shall be routed from the originating terminal to the Austin data bases through no more than one intermediate Regional Switching Center, not including the Austin switcher, under normal network operation. Interface routing to NLETS and the NCIC shall be maintained as in the present Texas TLETS system.

- Administrative messages shall be routed from the originating terminal to the destination terminal through no more than two RSCs under normal network operation. Administrative messages shall also have a capability for ALL POINTS routing as currently employed by the Texas TLETS system.

- Digitized fingerprints data shall be routed from the originating terminal to the Identification and Criminal Records Division of DPS, Austin, through no more than two RSCs under normal network operation.

Message routing shall be accomplished by the regional switcher(s) utilizing the destination information in the message. Single messages destined for the same region in which they originate shall be switched to the appropriate system termination by the regional switcher servicing that region.

When more than one system termination is specified as the destination point, the message shall first be routed to appropriate STACOM Network Management who may exercise the option to grant message approval. The appropriate messages shall then be generated and transmitted.

11.5.2 Message Prioritization

Prioritization of messages shall be incorporated in the STACOM Network to the extent required to meet the message response time goals outlined in paragraph 11.5.3.

Messages shall be handled on a non-preemptive priority basis. In this scheme, messages or message segments in process of being transmitted shall not be interrupted, but allowed to complete before higher priority messages are honored.

Under the above conditions, the STACOM Network shall be capable of recognizing and handling message types in accordance with the following prioritization:

Priority 1: Items that may be directly related to officer safety, such as inquiries into TCIC, LIDR, MVD, and NCIC files and NLETS messages.

Priority 2: Administrative messages related to officer safety or tactical needs, and CCH Summaries.

Priority 3: Administrative messages not related to officer safety, fingerprints, SJIS, OBTS, CCH Rap Sheets, and other criminal justice data consisting of large numbers of message segments.

The assignment of message types by the STACOM Network to a given priority level shall be under computer software control so that such assignments may be altered by STACOM Network Management as needs arise.

11.5.3 Response Time Goals

Response time for the STACOM Network is defined as the time duration between the initiation of a request for service of an inquiry message by the network at a system termination and the time at which a response is completed at the inquiring system termination.

The response times shown below are maximum times for mean response times and for response times of messages 90% of the time. These response times represent maximum allowable goal values on the STACOM Network.

11.5.4 Line Protocol

The STACOM/TEXAS Network shall employ standard Bell 8A1 line protocol. All network equipment shall be capable of conversion to Bell 85A1 protocol.

- Half duplex
- The standard interface to system terminations shall be half duplex
- Full duplex

STACOM Response Time Goals Maximums

Message Priority	Mean Response Time	90% of Responses to Inquiries Received in Less Than
1	9 sec	20 sec
2	1 min	2.3 min
3	2 hrs	4.5 hrs

- Full duplex line discipline may only be used inter-regionally

11.5.5 Message Coding

All STACOM Network messages shall be coded using the American Standard Code for Information Interchange (ASCII), USAS X3.4-1968. Message coding for interaction with NCIC, and NLETS systems shall conform to existing practices of the Texas TLETS Network.

11.5.6 Error Detection

The STACOM Network regional switchers shall provide for bit error detection of erroneous messages. Error messages shall be transmitted to system terminations in accordance with present practices of the Texas TLETS Network. The computer shall detect format errors and transmission errors on incoming messages and notify the sending terminals appropriately. The computer shall also detect off-line or inoperative terminals.

Messages shall not be automatically retransmitted upon error detection. Messages may be retransmitted at the discretion of the user.

11.5.7 Network Status Messages

The STACOM Network shall provide for notification to system terminations of any conditions which prevent operation in the normal specified manner. System terminations shall receive such status message upon attempting to use the network when the network is in a degraded mode. Status messages shall include status on conditions of criminal justice files, portions of files, computer and line hardware difficulties and message queues, when appropriate.

11.6 SYSTEM TERMINATIONS

STACOM Network system terminations having interface capability of 1200 to 2400 BPS shall interface with the network using half duplex protocol. Terminals shall have the capability of off-line construction of input messages and for hard copy production of received messages. Terminal printers shall be capable of 1200 BPS operation.

All terminals shall be pollable, provide for parity error detection, and employ CRT display screens.

The number of system terminations per multidropped line shall not exceed 20.

11.7 REGIONAL SWITCHING CENTERS

The STACOM/TEXAS Network shall be comprised of one Regional Switching Center (RSC) with redundant data bases located in Austin and up to four additional RSCs without data bases. Regional Switching Centers shall determine for each message the:

- Message type
- Message destination
- Message number
- NCIC Identifiers of sending department
- Sending authority

The following further describes the capabilities of each type of RSC.

11.7.1 Switchers Without Data Bases

11.7.1.1 Communication Line Interfaces.

An input communication line interface shall convert incoming serial bit streams into assembled characters and furnish electrical interface for the modem and logic required for conditioning.

An output communication line interface shall convert characters into a bit stream. It shall also provide logic necessary to condition the modem for transmission and furnish the necessary electrical interface.

RSCs shall be designed to handle either full or half duplex line protocols on any line interface.

11.7.1.2 Message Assembly/Disassembly.

A message assembly unit shall assemble messages by deblocking the character stream.

A message disassembly unit shall segregate messages into logical blocks for output. It shall also disassemble the blocks into a character stream for presentation to the communication line interface.

11.7.1.3 Error Control.

The error control function shall provide error detection capability and initiate error messages in accordance with requirements outlined in Section 11.5.6. The error detection function is highly dispersed. Character parity is most efficiently checked during assembly of characters in the interface. Block parities are checked upon assembly of blocks. Additionally, all internal data transfers shall require a parity check.

11.7.1.4 Message Control and Routing.

The message control and routing function shall provide logic which examines the assembled messages, determines its priority, destination, and forms the appropriate pointers and places them in the proper queue, (the pointers are queued, not the messages).

Message routing shall be performed by RSCs in accordance with procedures outlined in Section 11.5.1.

In addition, this function shall maintain network status information for the purposes of determining availability of alternate communication paths in degraded modes of operation.

11.7.1.5 Queue Control.

This function shall provide buffer and queue storage used to assemble input messages, buffer them for output and to form space to queue the message pointers.

Regional switchers shall maintain necessary queues for each system termination they service and for interregional traffic. These queues shall hold messages that cannot be sent immediately due to line usage conflicts. However, the regional switchers shall not maintain a long term store and forward capability. In the event that queue space is full, the regional switcher shall not accept any more messages and shall notify the other switcher not to accept messages destined for the switcher in question.

This capability shall be provided through use of upper and lower queue thresholds specifiable by the regional switcher operator. All system terminations sending messages to the regional switcher which would demand queue space in excess of the upper threshold shall be sent negative acknowledgement responses. Once the upper threshold has been exceeded, the regional switcher shall enter the input control mode (i.e., the regional switcher shall output only). Any request for regional switcher service while it is in the input control mode shall result in a wait acknowledgement being sent to that system termination. The regional switcher shall stay in the input control mode until the lower threshold is attained.

Queue control procedures at the regional switchers shall be comprised of the following basic functions:

- Provide three independent queues for each system termination by priority as required.

- Dynamic queue management where a common core pool is made available for queueing on an as-needed basis.

- Queue overflow management as discussed above.
- Provide queue statistics for input to statistics gathering function, as discussed in Section 11.7.1.7.

11.7.1.6 Line Control.

The line control function shall provide the capability of controlling and ordering the flow of data between the various message switchers. It also determines which line discipline is to be used. Full-duplex, half-duplex, polled or contention line discipline capabilities shall be possible.

11.7.1.7 Network Statistics.

The STACOM Network shall be capable of collecting statistical data fundamental to the continued efficient use of traffic level prediction and network design tools developed by the STACOM Project.

The STACOM Network shall be capable of collecting the following statistical data:

- Number of messages by message type received from each system termination at State Data Bases.
- Number of messages by message type sent to each system termination from State Data Bases.
- Average message lengths by message type received at State Data Bases.
- Average message lengths by message type sent from State Data Bases.

The STACOM Network shall provide for periodic sampling of the following statistics:

- Origin-Destination message volumes by system termination.
- Percent of "HITS" and "NO-HITS" on each data base type.
- Average waiting times of input messages at switching and data base computers for CPU service.
- Average waiting times of output messages at switching and data base computers for output lines after CPU service.
- Average CPU service time per message at switching and data base computers.

- Total number of messages received each hour at the State Data Bases.

- Total response time for data base interrogations/updates of selected system terminations.

11.7.1.8 Operator Interface.

The regional switcher shall provide means of interfacing with the operator. This interface shall be used to control and monitor the regional switcher and its network. The following functions are to be provided:

- The regional switcher shall provide a set of commands for the purpose of communicating with the operator.

- The regional switcher shall provide means of outputting data to the operator at a rate of at least 30 characters per second.

- The regional switcher shall provide means of accepting operator control input.

- The regional switcher shall provide high speed data output capability. This data output capability shall not be less than 300 lines per minute. A line shall have 132 characters.

11.7.1.9 Fault Isolation.

Regional Switching facilities shall be equipped to rapidly isolate network component faults to the level of lines, modems, communication front ends and switching computers.

11.7.1.10 Switchers with Data Base.

RSCs with data base capability employ the additional function of providing file search and update capability. This function involves receiving messages from the switchers message control and routing function (see 11.5.1), and placing their pointers in queue by priority for access to data base files. Upon completion of data base access, messages are returned to the message control and routing function in preparation for output.

RCSs with data bases shall maintain redundant data base files, each of which is updated in parallel at the time of file update.

11.8 NETWORK AVAILABILITY GOAL

The availability goal for the STACOM Network shall be 0.9722 for the worst case Origin-Destination, (O-D), pair of system terminations on the network. The worst case O-D pair is defined as that link from system termination to data base computer that employs the largest number of system components in its path, or the one that is most vulnerable to failure.

Availability of 0.9722 implies an average outage of less than or equal to 40.0 minutes per day for the worst case path. Planned system outage shall be in addition to outages specified here. It shall be a design goal to allocate a minimum of 20 minutes outage per day, (Availability = 0.9861), to data base computers and the remaining maximum of 20 minutes outage per day to terminals, lines, modems and RSCs.

11.9 TRAFFIC VOLUMES

The STACOM Network shall be designed to handle traffic projections through the year 1986. These projections shall include traffic estimates plus design margins for peak vs. average loading. The total network throughput projected from 1977 to 1986 is as follows:

Total STACOM Network Throughput Average Messages/Day (in 1000s)

Year	TLETS	New Data Types
1977	138	8
1981	247	24
1985	311	86

11.10 CONSTRAINTS AND BOUNDARIES

11.10.1 Data Handling Constraints

All data transmission shall be digital.

No unscrambling or decryption shall be performed within the STACOM Network. (Some modems perform scrambling in the normal course of their operation but this scrambling is transparent to the user.)

Traffic loading by network users in excess of the traffic safety margins for which their system terminations are designed could result in degraded message response time.

11.10.2 Data Rate Constraints

The minimum service goal for the STACOM/TEXAS Network shall be 1200 Baud half duplex lines. All available line capacity services above this rate shall be eligible for consideration in a cost/performance effective manner.

11.10.3 Security and Privacy Constraints

The STACOM Network shall be configured to allow management control by an authorized criminal justice agency or group of such agencies. Only STACOM Network operating personnel who have been authorized by STACOM Network Management shall have physical access to the network equipment. These personnel shall have been thoroughly screened. It shall be the responsibility of the STACOM Network Management to institute and maintain security measures and procedures consistent with applicable regulations.

It shall be the responsibility of the STACOM Network Management to ensure that unauthorized personnel are not allowed access by system terminations and that authorized personnel do not employ the network facilities for any purpose other than those for which the STACOM Network is specifically intended.

STACOM Network design shall assist in the realization of adequate security to the extent that engineering considerations can contribute. The STACOM Network shall consider in its design methods to prevent any alterations of the content of messages once they have been routed over the network. All of the equipment comprising the STACOM Network, except for the communication lines, shall provide adequate physical security to protect them against any unauthorized personnel gaining access to the STACOM Network. The computers and other network accessing equipment comprising the STACOM Network shall be located in controlled facilities. Redundant elements should be configured such that a single act of sabotage will not disable both redundant elements.

SECTION XII

ANALYSIS OF EXISTING NETWORKS IN TEXAS

SECTION XII

ANALYSIS OF EXISTING NETWORKS IN TEXAS

The purpose of this section is to compare the performance of the existing Texas Law Enforcement Telecommunications Network, (TLETS), with network specifications contained in the STACOM Functional Requirements for the State of Texas presented in Section 11.

This section begins with an overview of the present TLETS system. Section 12.2 summarizes areas in which the present system fails to meet stated Functional Requirements, and presents a detailed analysis of the present system in these specific deficient areas.

12.1 THE PRESENT TLETS NETWORK

The analysis of the present Texas Law Enforcement Telecommunications Network, (TLETS), presented here considers service to 431 law enforcement agencies throughout the state consisting of police departments, sheriffs offices and State Department of Public Safety, (DPS), offices. The network is managed by the DPS.

The TLETS network is topologically distributed from three regional switching centers located in Garland, Austin, and San Antonio. Terminals on the network are served from these switchers by 75, 110, or 1200 Baud multidropped lines.

Network users have access through the Austin switcher to state data bases located in Austin consisting of the Texas Crime Information Center, (TCIC), a drivers record system, (LIDR), and the Motor Vehicle Department, (MVD), records.

Figure 12-1 presents a simplified diagram of the TLETS system. Detailed TLETS line layouts for 75, 110, 1200, and 2400 Baud lines are shown in Figures 12-2 and 12-3.

In general, multidropped lines are organized such that terminals on a given drop are clustered in areas under the jurisdiction of a single Council of Government, (COG). There are approximately 23 such COGs in the state of Texas as depicted in Figure 12-4. Figure 12-5 presents a composite of Figures 12-2 and 12-3 showing the complete TLETS terminal network.

The Garland and Austin switchers communicate through two 2400 Baud lines and the San Antonio Switcher is connected to the Austin switcher through a single 2400 Baud line.

The Austin switcher also provides for TLETS communication with the NLETS switcher in Phoenix through a 2400 Baud line and with the NCIC through a 2400 Baud line.

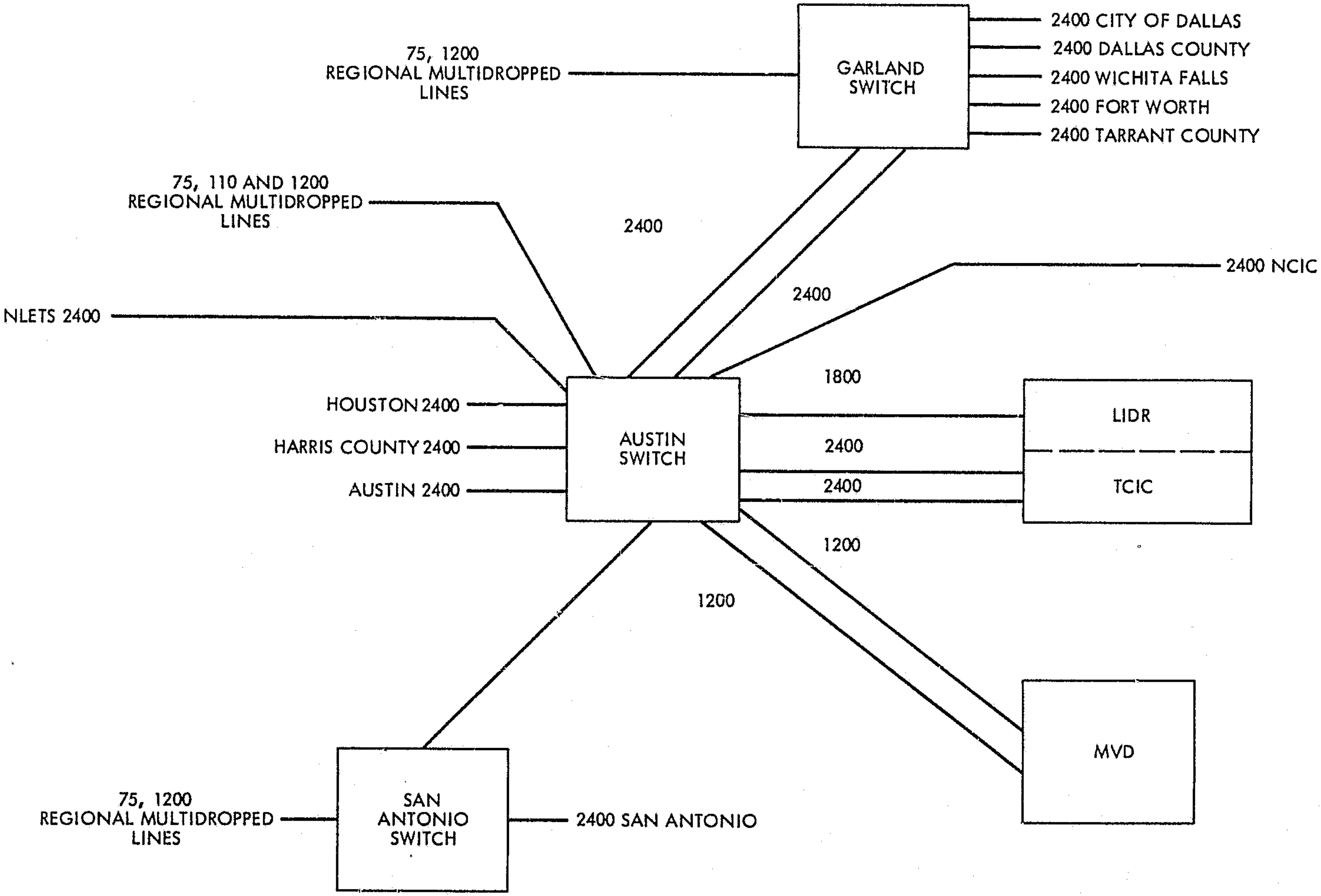


Figure 12-1. Simplified TLETS Diagram

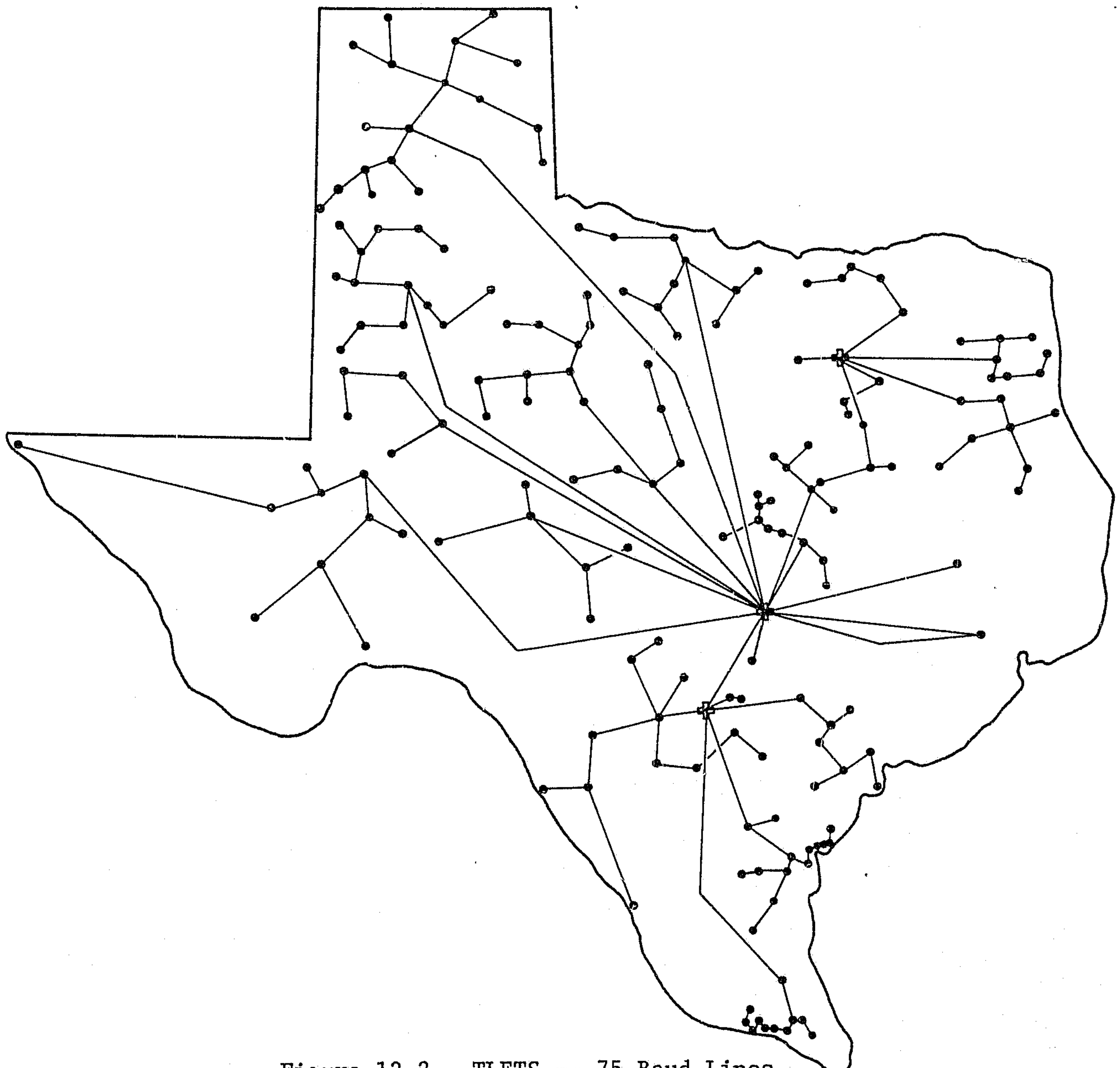


Figure 12-2. TLETS -- 75 Baud Lines

503-99

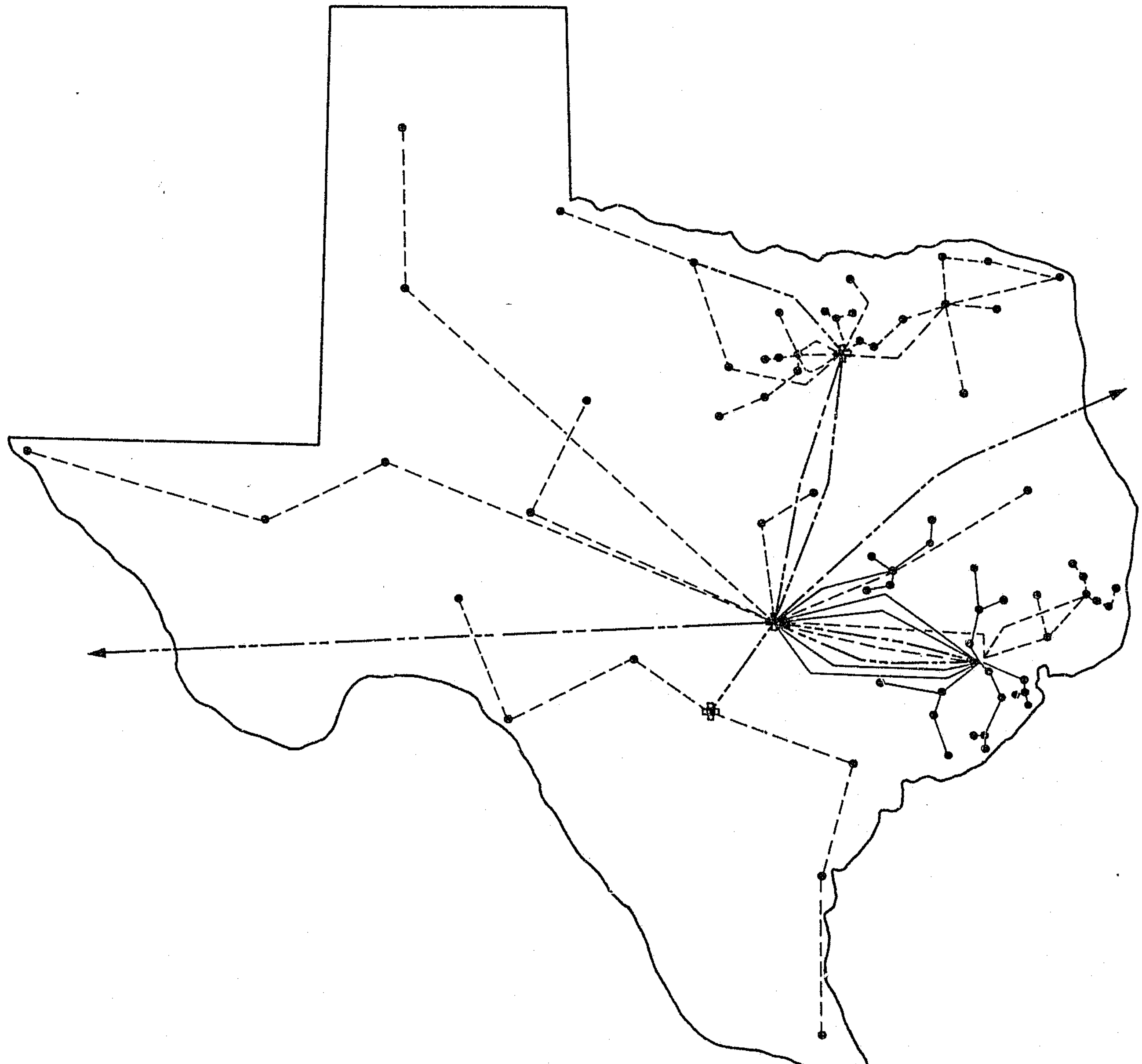


Figure 12-3. TLETS 110, 1200, 2400 Baud Lines

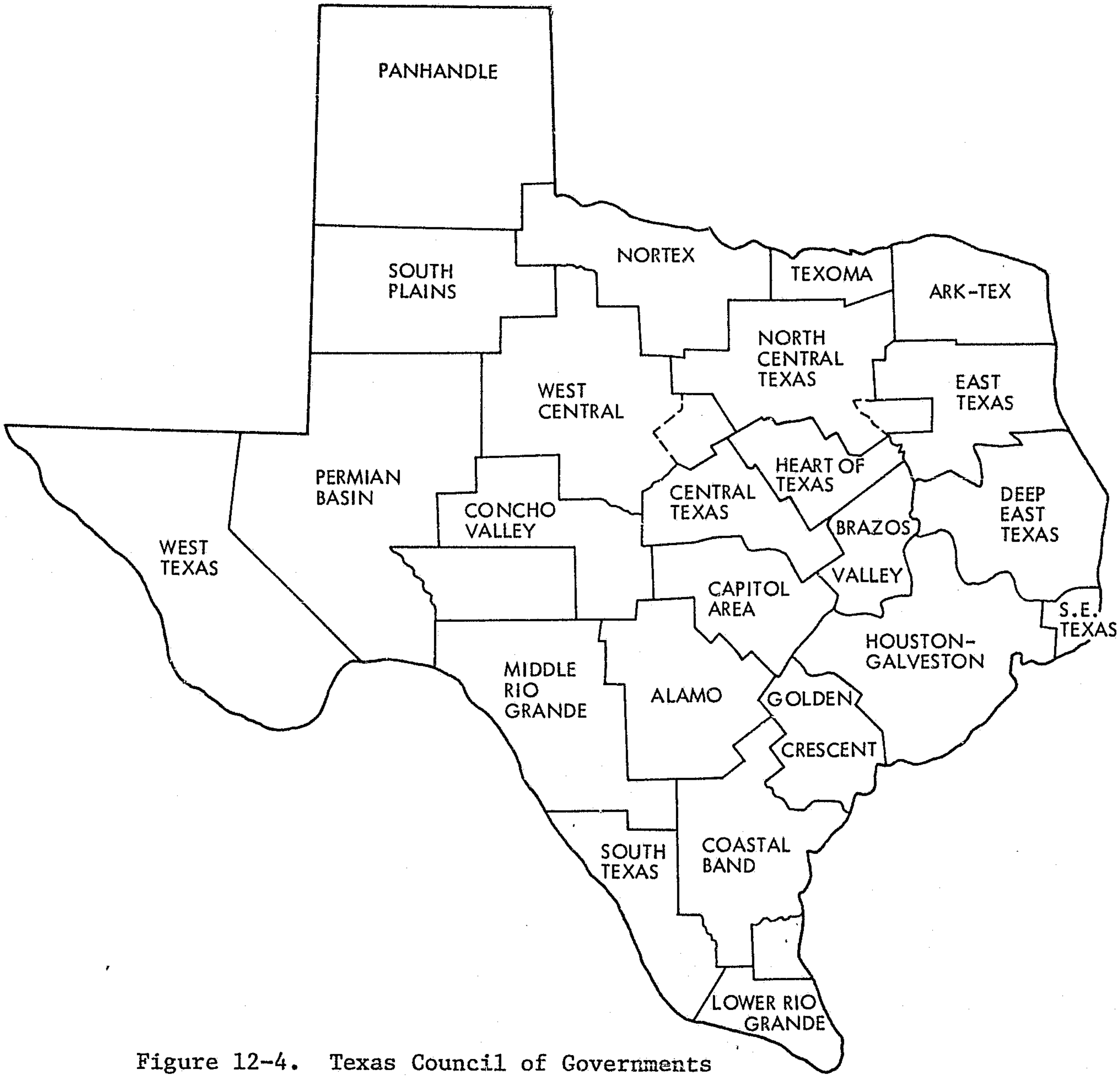


Figure 12-4. Texas Council of Governments

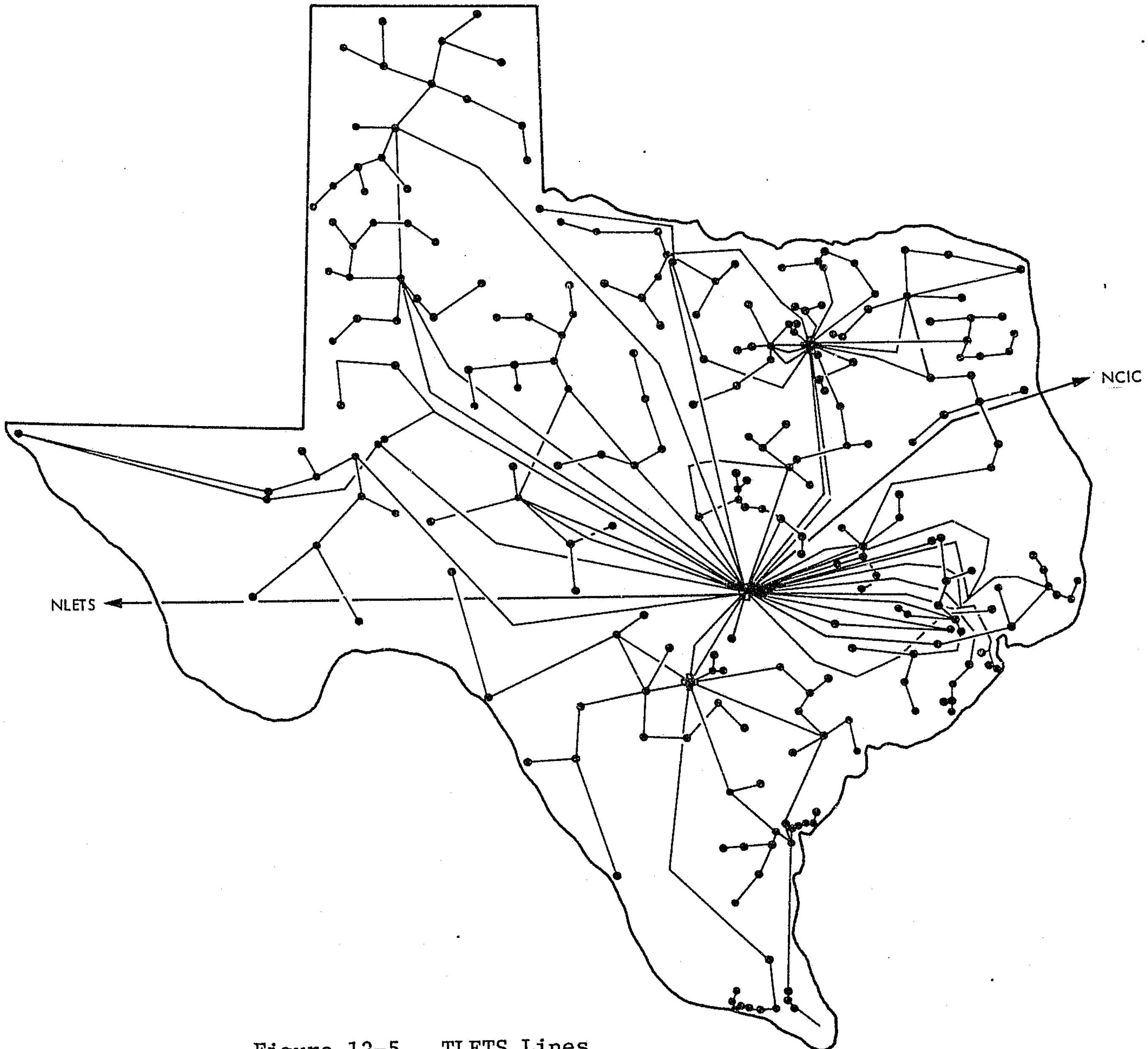


Figure 12-5. TLETS Lines

The Austin switcher is connected to the TCIC data base through two 2400 Baud lines, to the LIDR data base through a single 1800 Baud line and to the MVD data base through two 1200 Baud lines. In the present system, the data base lines are held once an inquiry is initiated from the Austin switch until the response is returned over the same line.

The TCIC data base computer is an IBM 370/155 and the MVD employs two 370/155's. The three TLETS switchers are supplied by Action Communication Systems of Dallas, Texas.

The total cost of TLETS lines, modems, service terminal arrangements and drop charges is $320,000 per year. These costs include charges to central COG points and charges incurred within COG's.

It is anticipated that total network costs for lines, modems, service terminals and drop charges for the present network with a minimum line service of 1200 Baud would cost approximately $495,000 year.

12.2 COMPARISONS OF EXISTING NETWORK WITH STACOM/TEXAS FUNCTIONAL REQUIREMENTS

Table 12-1 summarizes conformity to STACOM/TEXAS Functional Requirements by the existing TLETS Network.

The two principal areas for discrepancies shown are Network Response Times and Network Availability. The following sections discuss these deviations in detail.

12.2.1 Response Times

Response time for the STACOM Network is defined as the time duration between the initiation of a request for service for an inquiry message at a network system termination and the time at which a response is completed at the inquiring system termination.

The response time goal for the STACOM Network for law enforcement traffic is to achieve a mean response time less than or equal to 9 seconds, which insures that 90% of the time, responses to inquiries shall be received in less than 20 seconds.

Response times at given terminals on the TLETS Network depend on the number of switchers that messages must pass through to and from the data bases, and on the line speed servicing the terminal on a multidrop.

Representative circuits at each multidrop line speed, (75, 110, and 1200 Baud), that carry relatively heavy loads of traffic were selected for analysis. Circuits selected for analysis were the Garland circuit 4 at 75 Baud, the Austin circuit 27 at 110 Baud and the Garland circuit 15 at 1200 Baud. Normally, in a worst case analysis, circuits would be selected that pass through the maximum number of switchers - in the Texas case, two. Austin circuit 27 was selected at 110 Baud because there are

CONTINUED

3 OF 4

Table 12-1. Conformity Summary of Existing Network to STACOM Functional Requirements

Requirement	Section X Requirements Met	Section X Requirements Not Met
Message Characteristics	All	-
Network Message Handling	Routing, Protocol, Coding, Error Detection, Status Messages	Response Time on 75, 110 Baud Lines
System Terminations	All	-
Regional Switching Centers	Dallas, San Antonio	Austin Switch Mean Service Time
Network Availability Goal	-	TCIC/LIDR Data Base Availability
Traffic Volumes	Average Traffic Levels	Peak Traffic Levels
Constraints and Boundaries	Data Handling	Data Rates

no 110 Baud lines in the present system served by the Garland or San Antonio Switchers. Garland circuits 4 and 15 were selected for analysis because their traffic loads are higher than any 75 or 1200 Baud lines served through the San Antonio switcher. These circuits, then, are representative of worst case performance for 75, 110, and 1200 Baud multidrops on the network.

Response times at terminals presented here are estimated mean values derived from queueing equations presented in Section II of this report.

The solid line in Figure 12-6 presents mean response time for the Garland circuit 15. At a 1977 average daily traffic level taken to be 116,000 transactions per day through the Austin switcher, the system performs adequately with a mean response time of 8.6 seconds. However, at system peak loads, estimated at twice the daily average, response time becomes excessive. Queueing analysis indicates that the principal contributor to this excessive response time at user terminals is the buildup of queues at the Austin switcher. This component of total response time is shown by the dotted line in Figure 12-6. With the present mean service time per transaction estimated at 400 ms for the Austin switch, computer utilization of 0.7 is reached at a transaction level of 151,000 per day, as shown in Figure 12-6. In general, telecommunication systems should be designed such that switcher utilizations do not exceed 0.70.

Figure 12-7 presents system queue times for circuit 15 at selected system traffic levels. It can be seen that the Austin switch

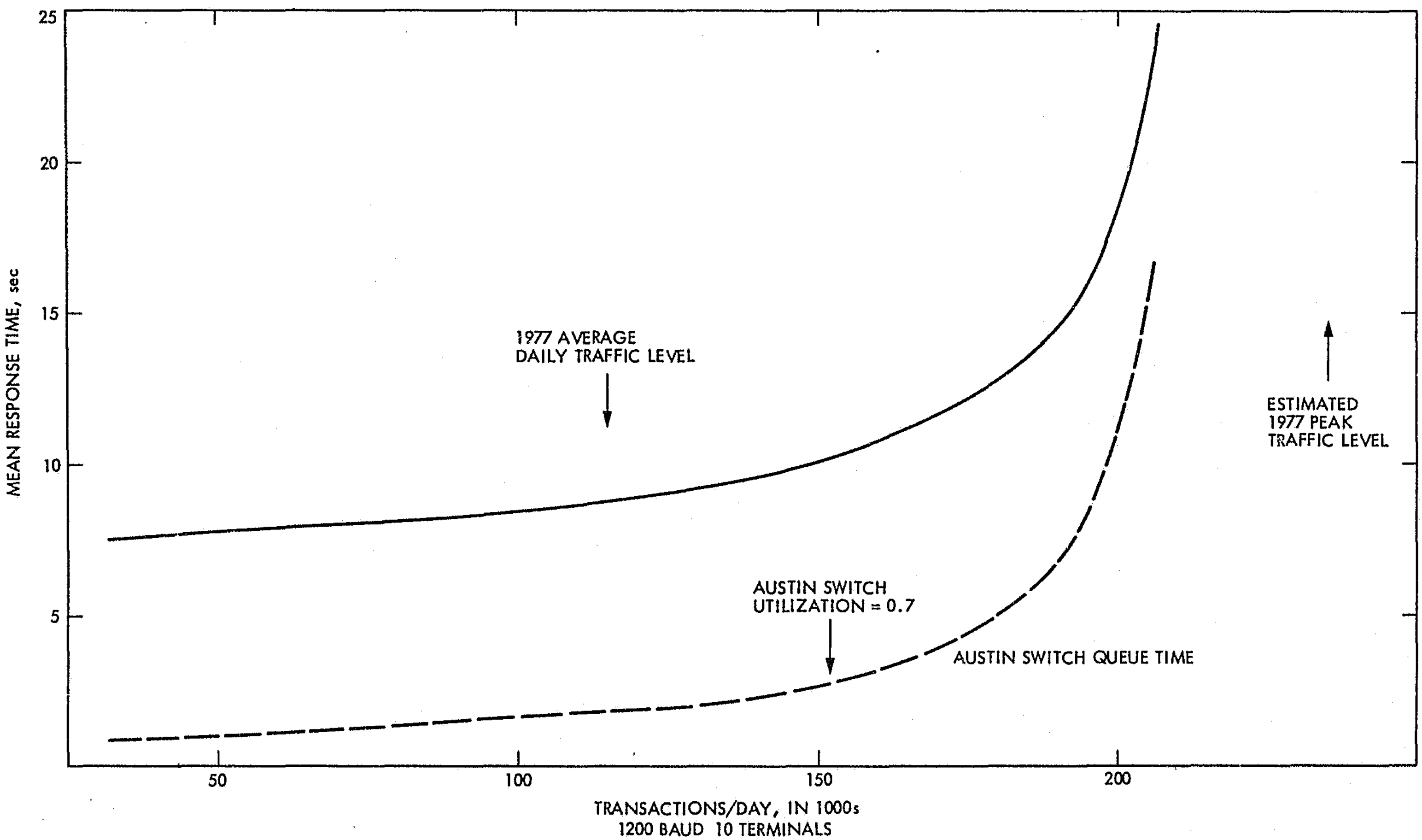
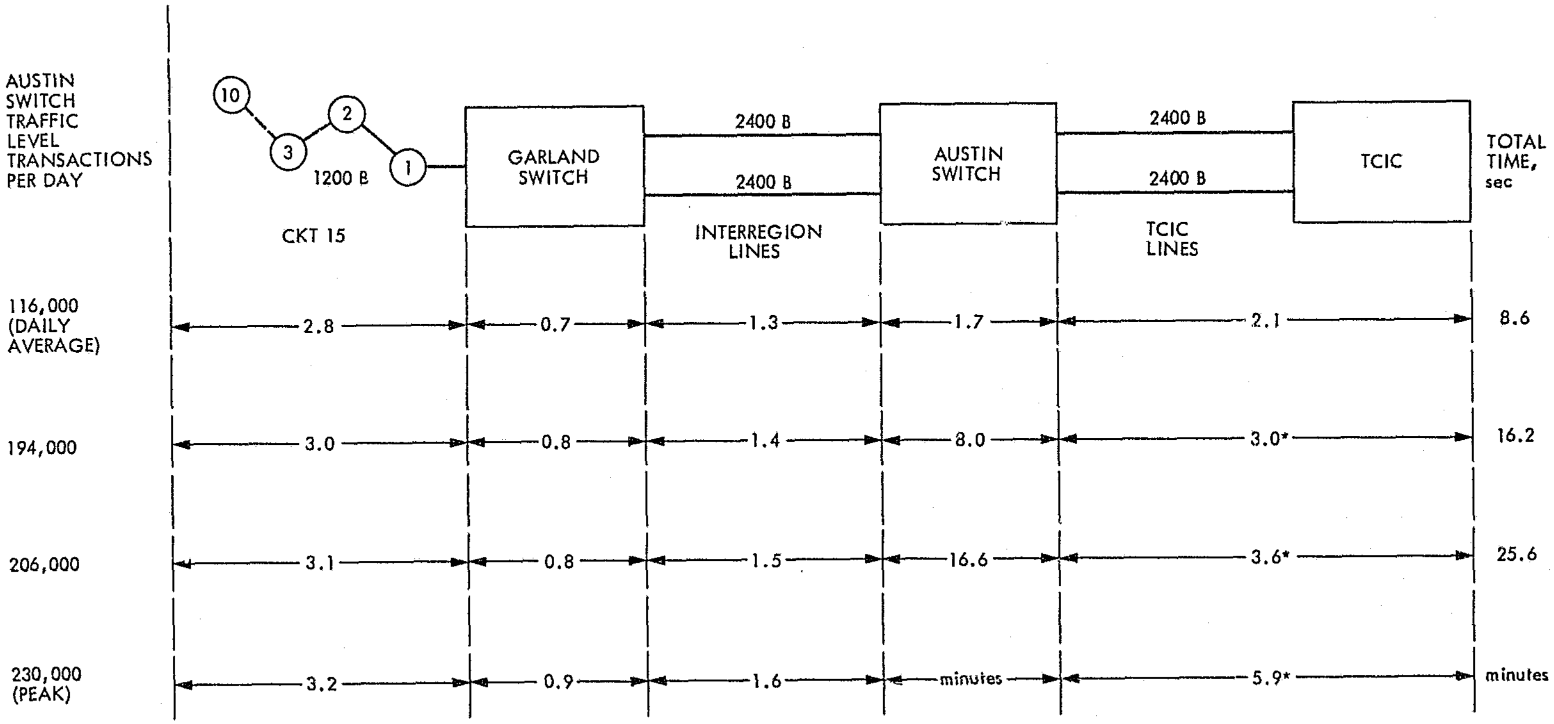


Figure 12-6. Mean Response Time to TCIC Garland CKT 15



*RESPONSE TIME AT IN-HOUSE DPS DATA ENTRY TERMINALS DEGRADED.

Figure 12-7. Time Spent in Seconds in System Components as a Function of Traffic Levels for TCIC

5030-99

component becomes excessive as traffic progresses from average levels to peak levels, whereas the remaining components consisting of the multidrop line, the Garland switch, interregion lines and the TCIC do not increase as dramatically.

Figures 12-8 and 12-9 present mean response times at terminals on Garland circuit 4, (75 Baud) and Austin circuit 27 (110 Baud). The major component of times in these cases is spent in transmitting over the low speed multidropped lines. It is interesting to note that the 110 Baud line out of Austin actually has a longer response time at terminals than the 75 Baud line out of Garland, even though the latter passes through an additional switcher. There are four principal reasons for this - (1) 110 and 75 Baud lines have the same character rates*, (2) the 110 Baud line protocol involves more line turnarounds per message, (3) the traffic level on circuit 27 is higher than on circuit 4, and (4) there are 15 terminals on circuit 27 and only 10 on circuit 4.

In any case, low speed lines exhibit response times on the order of one minute during average network transaction levels and of minutes to tens of minutes during network peak transaction levels. The low speed lines themselves are major contributors to response time at low traffic levels and the Austin switch is the limiting factor at higher levels.

It is also of interest to consider the effect of peak traffic levels on the TCIC/LIDR and MVD computers. In the case of the TCIC/LIDR 370/155, an exact analysis is made more difficult because traffic levels from DPS in-house data entry terminals, (DPS traffic), must be estimated during TLETS average and peak traffic levels. On any given day DPS traffic peaks may not fluctuate as much as TLETS inquiries to the TCIC and LIDR, however, over a period of years DPS traffic can be expected to grow at approximately 4% per year. The analysis presented here assumes an increase in DPS traffic as TLETS traffic fluctuates, and, in that sense is conservative.

Increases in DPS traffic, of course, affect the TCIC/LIDR computer utilization. The effect of high computer utilization on TLETS inquiries, however, is minimized since these inquiries are given priority over DPS interaction. Thus TCIC/LIDR computer utilizations of up to 0.8 to 0.9 have fairly small effects on TLETS response time, but do have a significant effect on in-house DPS terminal operations, (see Figure 12-7).

Total queue times for an inquiry passing through the Austin switch to the TCIC/LIDR computer and back out through the Austin switch were analyzed as a function of network traffic load. A similar exercise was carried out for the MVD computer. Figure 12-10 shows queueing times for the three data bases including the Austin switch. TCIC is seen to provide the best service and LIDR the longest. The curves are driven

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*110 Baud lines have 11 bits per character and 75 Baud lines have 7.5 bits per character; thus both lines transmit 10 characters per second.

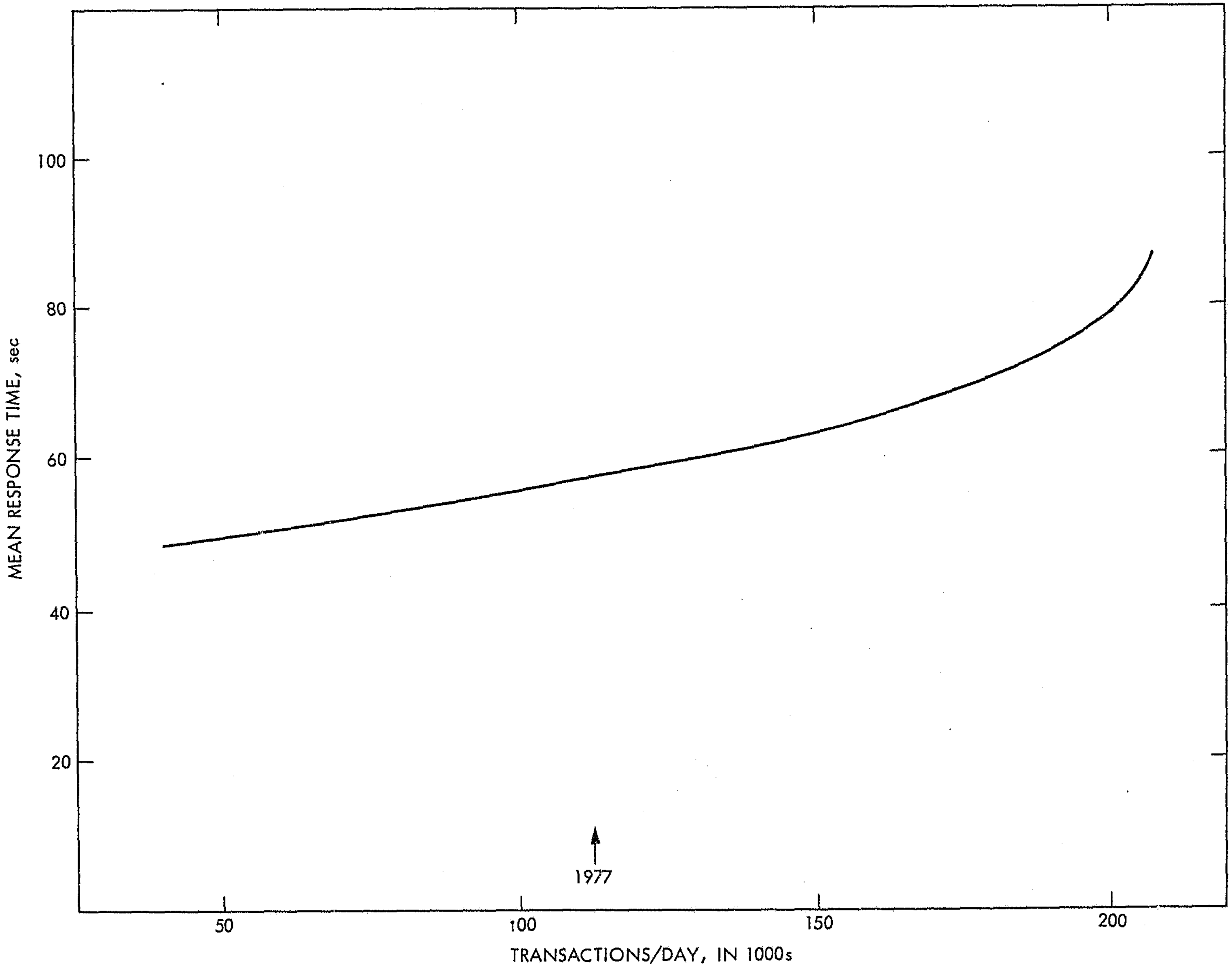

Figure 12-8. TLETS Mean Response Time - 75 Baud Lines

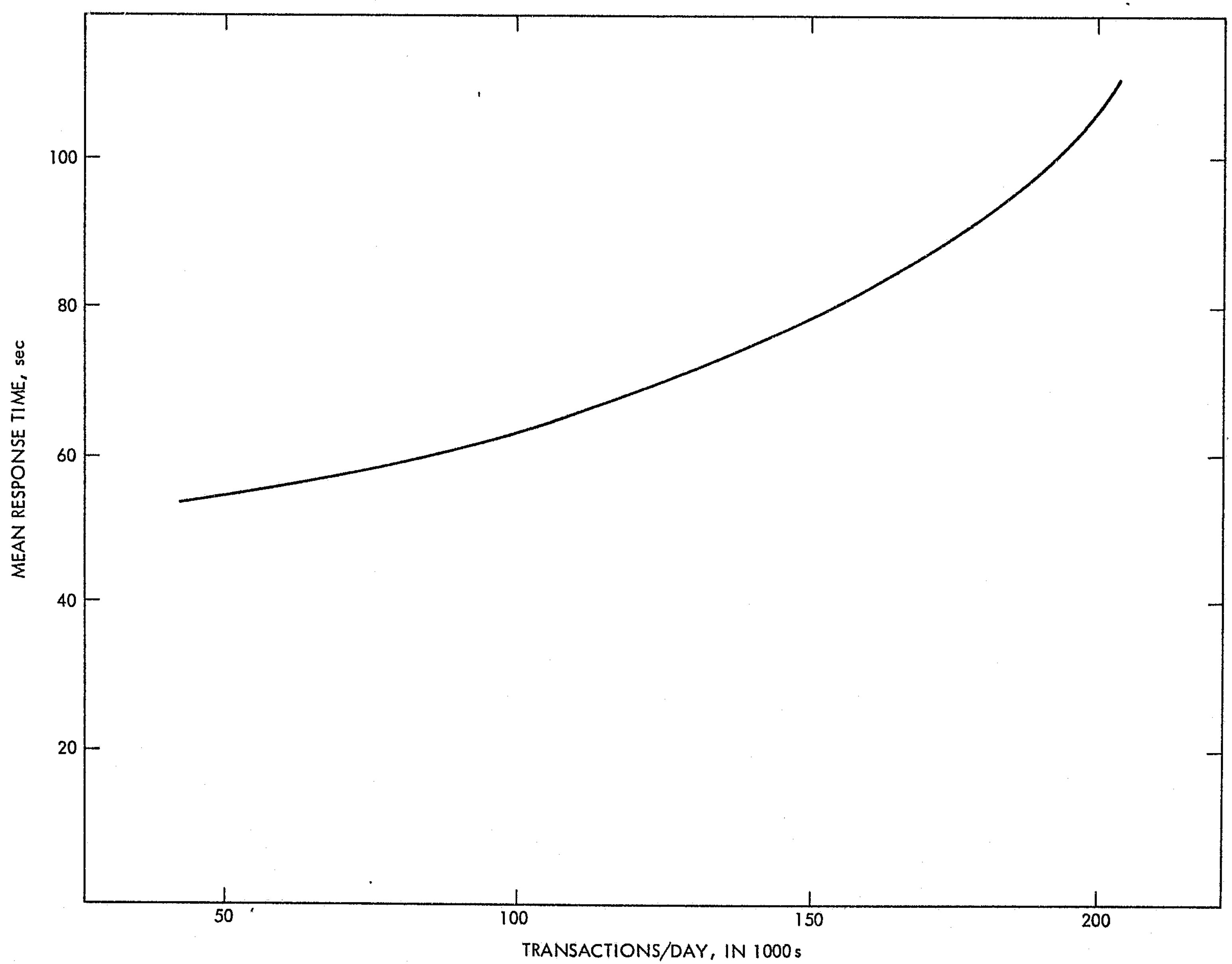

Figure 12-9. TLETS Mean Response Time - 110 Baud Lines

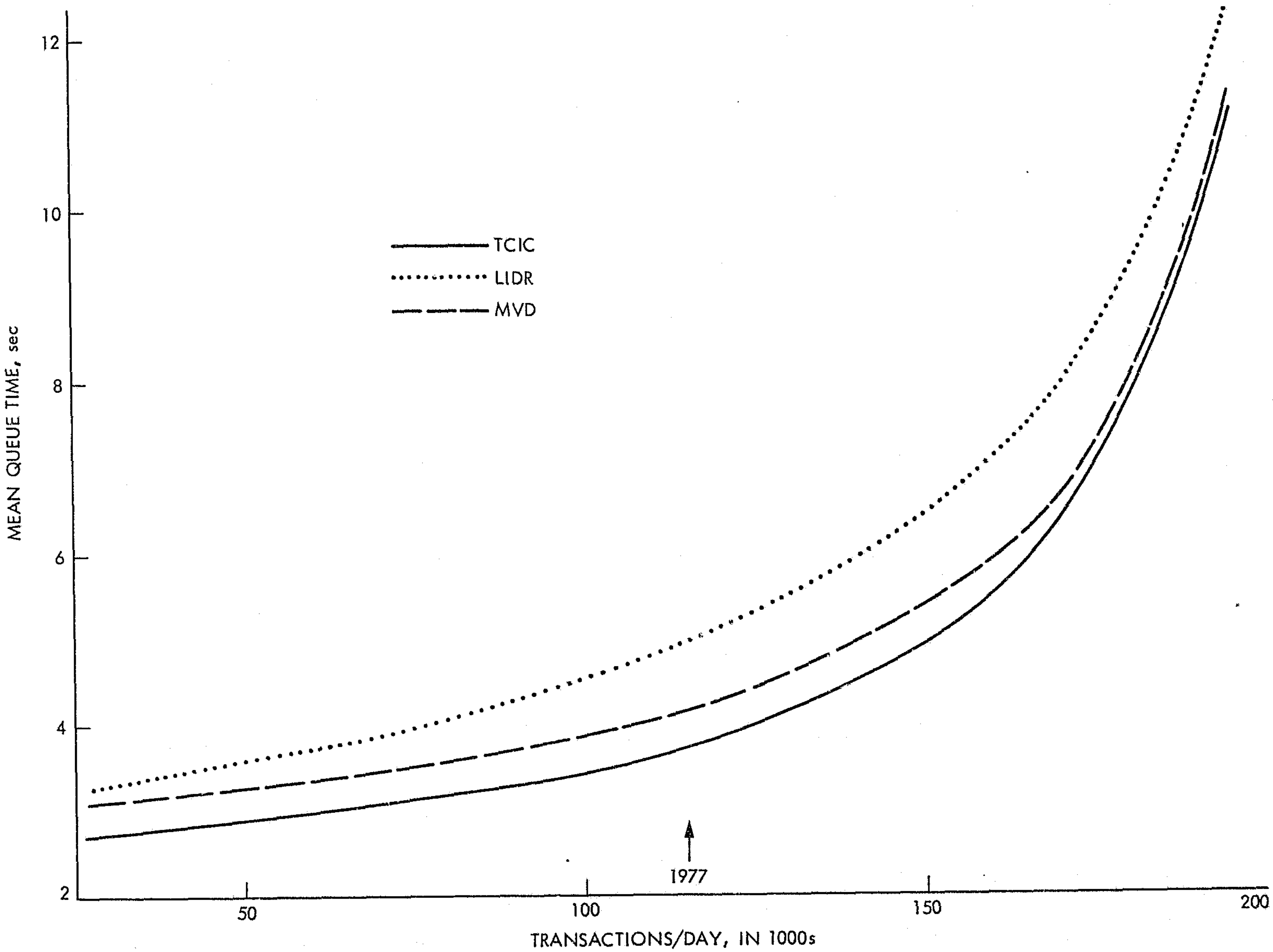

Figure 12-10. Present Data Base System Including Austin Switch

5030-99

upward as TLETS traffic levels increase because of large queueing in the Austin switch, (high computer utilization).

It is also of interest to estimate the present system performance of the data base systems alone without the effects of the Austin switch. This is shown in Figure 12-11 where data base queue times are presented as they appear to the Austin switch. The TCIC and MVD systems provide better data base turnaround times due to the fact that they provide service over two lines. However, it is also noted that these systems begin to degrade rapidly at TLETS peak traffic levels which adds to response time degradation at DPS terminals under our conservative assumption.

From the standpoint of network response time at user terminals, then, we can conclude the following with respect to the present TLETS system.

75 and 110 Baud lines do not meet functional requirements due to their inherent low data rates.

1200 Baud line service mean response time is less than or equal to 9 sec., (the functional requirements goal), for traffic levels of under 130,000 transactions per day at the Austin switcher, (see Figure 12-6).

Network response time limitations encountered above 130,000 transactions per day are due principally to high utilization of the Austin switch.

The TCIC/LIDR computer also experiences utilizations near 0.9 at network peak traffic levels.

During peak traffic loads on the present TLETS system, the magnitude of user response times at terminals is measured in minutes to tens of minutes.

Section 13 of this report treats specific network and computer upgrades required to meet the STACOM/TEXAS Functional Requirements of Section 11.

12.2.2 Network Availability

In Paragraph 2-2 of this report, sample calculations are carried out which derive system reliability and availability for the present TLETS System. These calculations show that the system availability for a terminal connected through the Dallas regional switcher is 0.915. This value implies an average daily outage of the network to any terminal connected to the Dallas switcher of 122 minutes.

A similar calculation carried out in Paragraph 2-2 for terminals connected through the San Antonio switcher results in an availability of 0.915 which implies an average daily outage of 134 minutes.

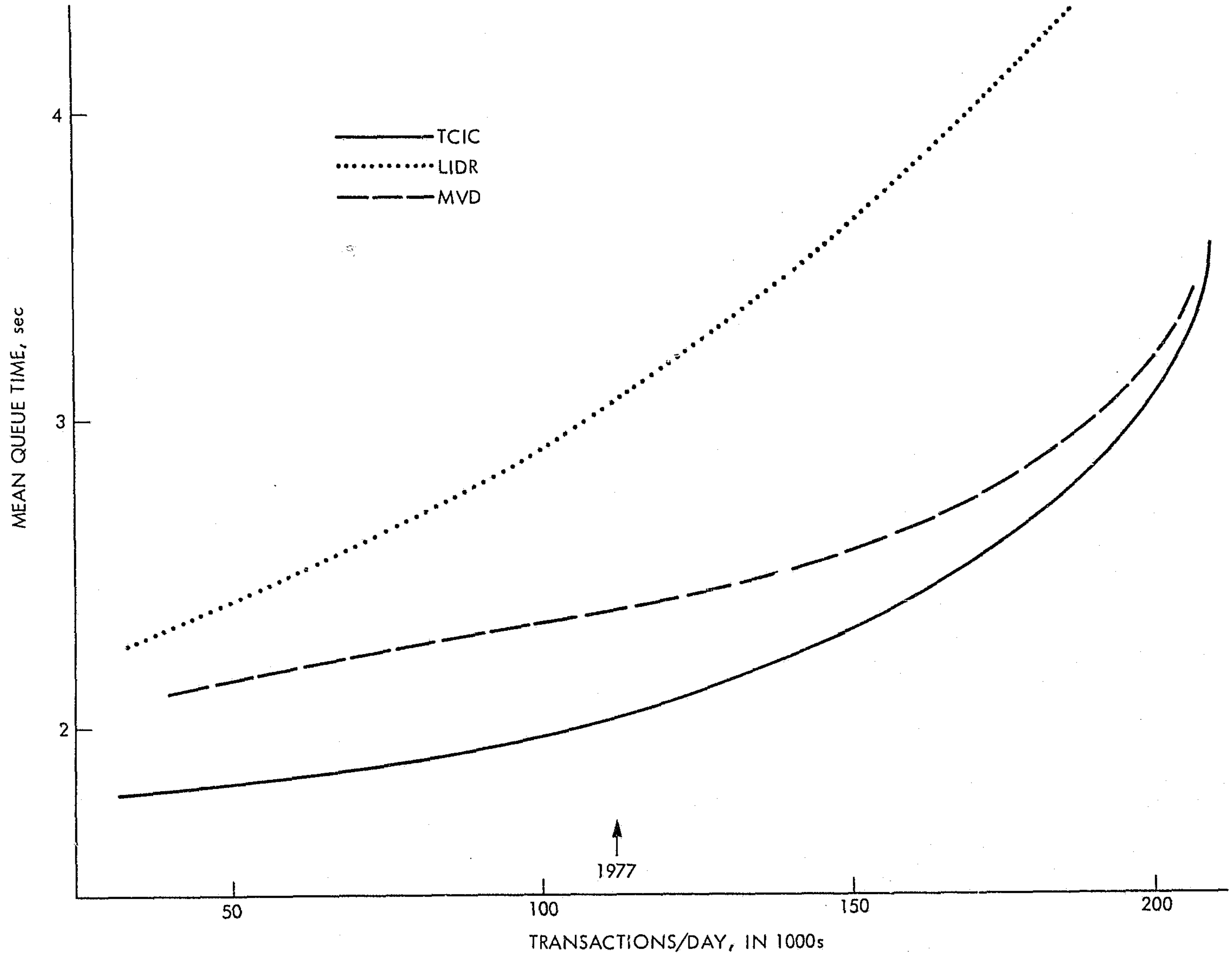

Figure 12-11. Present Data Base System As It Appears to the Austin Switch

The Functional Requirements for the State of Texas set an availability goal of 0.9722 which corresponds to an average daily outage of 40 minutes. Thus, the present network does not conform to availability goals. Specific upgrades required for conformity are discussed in Section 13.

SECTION XIII

NEW OR IMPROVED TEXAS NETWORKS

SECTION XIII

NEW OR IMPROVED STACOM/TEXAS NETWORKS

This section presents detailed topology, cost, and performance data for each of the network options outlined in Section 4. Section 14 of this report presents a comparative discussion of cost and performance data for the options considered.

13.1 COMPUTER PERFORMANCE REQUIREMENTS

13.1.1 Mean Service Time Upgraded

STACOM/TEXAS networks are designed to meet response time functional requirements for all network options at peak network traffic loads. To this end, computer mean service times per transaction at peak traffic loads have been assumed such that switcher and data base computer utilizations do not exceed values in the neighborhood of .700. It is important to realize that increasing network multidropped line speeds does not appreciably decrease network response times when computer utilization becomes high, i.e., increasing line speeds is not an effective solution for alleviating computer queueing pressure. Thus, it is of crucial importance to maintain computer utilizations at less than approximately 0.700 at all times.

The networks presented in this section assume similar data base line and computer configurations as exist now in Austin, with certain specific upgrades.

Specifically, the Austin Switcher serves the TCIC through two lines, the LIDR through one line and the MVD through two lines as in the present system. The line "holding" procedures in present use with the TCIC and MVD are maintained.

Table 13-1 summarizes traffic loads on the Austin Switcher, the TCIC/LIDR data base and the MVD data base in terms of computer transactions in 1981 and 1985. Also included are transaction requirements for handling new data types. The following comments discuss the origins of values entered in the table.

Values shown for transactions at the Austin Switch include the total of existing TLETS traffic types plus CCH, new data types and fingerprint traffic. The TCIC and LIDR entries show predicted levels for these data bases. The TCIC levels include CCH traffic. That is, it is assumed that CCH in Texas will continue to be implemented at the TCIC/LIDR data base.

Values shown for in-house data processing traffic on the TCIC/LIDR computer assume a growth of 4% per year from 1977 levels through 1985.

Table 13-1. Traffic Loads on Computers by Year

	1981			1985		
	Av Trans Per Day (1000)	Av Trans Per Sec	Peak Trans Per Sec	Av Trans Per Day (1000)	Av Trans Per Sec	Peak Trans Per Sec
Austin Switch	230	2.66	5.32	315	3.6	7.2
TCIC	43	0.5	1.0	47	0.55	1.1
LIDR	10	0.12	0.23	13	0.15	0.3
In House DP Terminals	65	0.75	1.5	74	0.86	1.75
MVD from Austin Switch	24	0.28	0.56	30	0.35	0.70
MVD other Processing	7	0.08	0.16	8	0.09	0.18
New Data Computer	15	0.17	0.35	25	0.29	0.58

Traffic shown between the Austin Switch and the MVD computer is taken from STACOM/TEXAS MVD traffic predictions. The MVD computer also handles traffic from sources other than the Austin Switch. This traffic is assumed to amount to 25% of the Austin Switcher MVD traffic level.

Finally, it is assumed, and recommended, that new data types be integrated onto a single separate computer facility located in Austin. These data types include systems used by ICR, OBSCIS, SJIS, fingerprints, TYC, Pardons and Paroles, and Corrections.

Table 13-2. Computer Mean Service Time and Data Base Line Requirements for Peak Loading

Years	Line Requirements in Baud - Austin Switch to Data Base			Required Mean Service Time per Transaction (ms)			
	TCIC	LIDR	MVD	Austin Switcher	TCIC/LIDR	MVD	New Data Computer
1977 to 1980	4800 (2)	4800 (1)	4800 (2)	130	250	400	2000
1981 to 1985	4800 (2)	4800 (1)	4800 (2)	100	200	400	1500

The traffic levels shown in Table 13-1 were run through data base queuing models discussed in Section 2 of this report in order to size data base line and computer mean service time requirements. Table 13-2 summarizes the results of that analysis.

It is recommended that all data base lines be immediately upgraded to 4800 Baud lines. This upgrade will be sufficient to meet line requirements from the present through 1985. An investigation into the merits of "holding" or not holding TCIC/LIDR and MVD lines was carried out. It was found that holding the lines, as is the present practice, is a bad practice only when line utilizations become excessive. Since data base lines need to be upgraded to 4800 Baud in any case, the penalty for continuing the present practice is minimized to an extent that response time functional requirements can still easily be met.

Computer upgrade requirements in terms of mean service time per transaction is also indicated in Table 13-2. To function properly, the Austin switcher should immediately be upgraded to perform with a mean service time of 130 ms, and, in 1981, should exhibit a mean service time of 100 ms. As an example, the Action Model 200 system with the Nova Model 840 and Century Discs could meet these requirements.

The TCIC/LIDR computer should immediately be upgraded to provide a mean service time of 250 ms, and in 1981, provide a mean service of 200 ms. The 250 ms goal may be approached by considering the use of an IBM 370/158 machine and 3350 Discs with a reduction of mean disc accesses per transaction from 8 to 6. The 200 ms goal may require a mixed use of totally fixed head discs and semi-fixed head discs. At this point, improvements in CPU time per transaction will not appreciably reduce total mean service time per transaction.

The MVD computer need not be upgraded through 1985. A mean service time of 400 ms will continue to serve that data base adequately.

The networks presented in this section assume that the data base line and computer upgrades outlined above will be carried out as indicated.

13.1.2 System Availability Upgrade Requirements

The principal component which causes non-conformity to STACOM/TEXAS Functional Requirements for system availability is the TCIC/LIDR data base computer. If the availability of this facility is upgraded to 0.9814, system availability requirements can be met for the single region case. The following characteristics provide an example as to how this might be achieved:

- MTBF — 145 hours
- MTTR — 1.7 hours
- Failure Rate (X 10-3) — 6.88
- Availability — 0.9814

If these conditions are met, the resulting availability of the single region TLETS Network would be 0.974 which implies an average daily system outage from any terminal on the network of 37.4 minutes. The STACOM/TEXAS goal for availability implies an average daily average outage of 40.0 minutes.

For multiple region configurations, upgrades are also required at regional switching sites to improve system availability. In multiple region configurations, availability of regional switchers should be 0.997 in addition to the above mentioned data base improvement. By way of example, this goal could be achieved with;

- MTBF — 333 hours
- MTTR — 1 hour
- Failure Rate (X 10-3) — 3.0
- Availability — 0.997

These improvements will yield a network system availability of 0.973 which corresponds to an average daily system outage of 39 minutes.

13.2 OPTION 1 - SINGLE REGION TLETS

13.2.1 Topology

The STACOM/TEXAS single region TLETS network layout is shown in Figure 13-1. The network consists of a single regional switcher facility located in Austin connected to the TCIC/LIDR and MVD Data Bases. There are 35 multidropped lines serving system terminations. All network lines are 1200 Baud lines with the exception of one 2400 Baud line and one 4800 Baud line. Table 13-3 presents the detailed terminal assignments for each of the 35 multidrops. Reading from left to right, the Table shows the line number, (1 to 35), the total number of terminals on the drop, the alphabetic code name for the first terminal on the drop, and the remaining code names for terminals on the drop in order.

13.2.2 Costs

Total eight-year costs for the single region TLETS system are presented in Table 13-4. Total costs based on costing assumptions outlined in Section XI amount to $15,800,000. About 68% of this total cost is due to terminal recurring and purchase costs. Lines, modems and service terminals amount to approximately 31% of total costs. Engineering costs make up the remainder. Regional switchers in addition to the Austin Switcher are not required in this option.

13.2.3 Line Performance

Table 13-5 summarizes performance characteristics by line for the single region TLETS Network. Reading from left to right, the table presents the line number, the code name for the first terminal on the drop, the total number of terminals on the drop, the line capacity in Bauds, the peak line utilization value, total mileage on the drop, and the mean response time for any single terminal on the drop.

Mean response times on the single region network run between 2.5 seconds to a worst case value of 8.7 seconds depending on the specific multidrop line. Of the 35 lines in the network, 33 have mean response times of less than 5 seconds.

13.2.4 Network Availability

The availability of the data bases to any terminal on the network is 0.974 calculated in accordance with the procedure outlined in Section 2.2, and assuming data base upgrades called for in Section 13.1.2 are implemented. This availability implies an average network daily outage at any terminal on the network of 37 minutes.

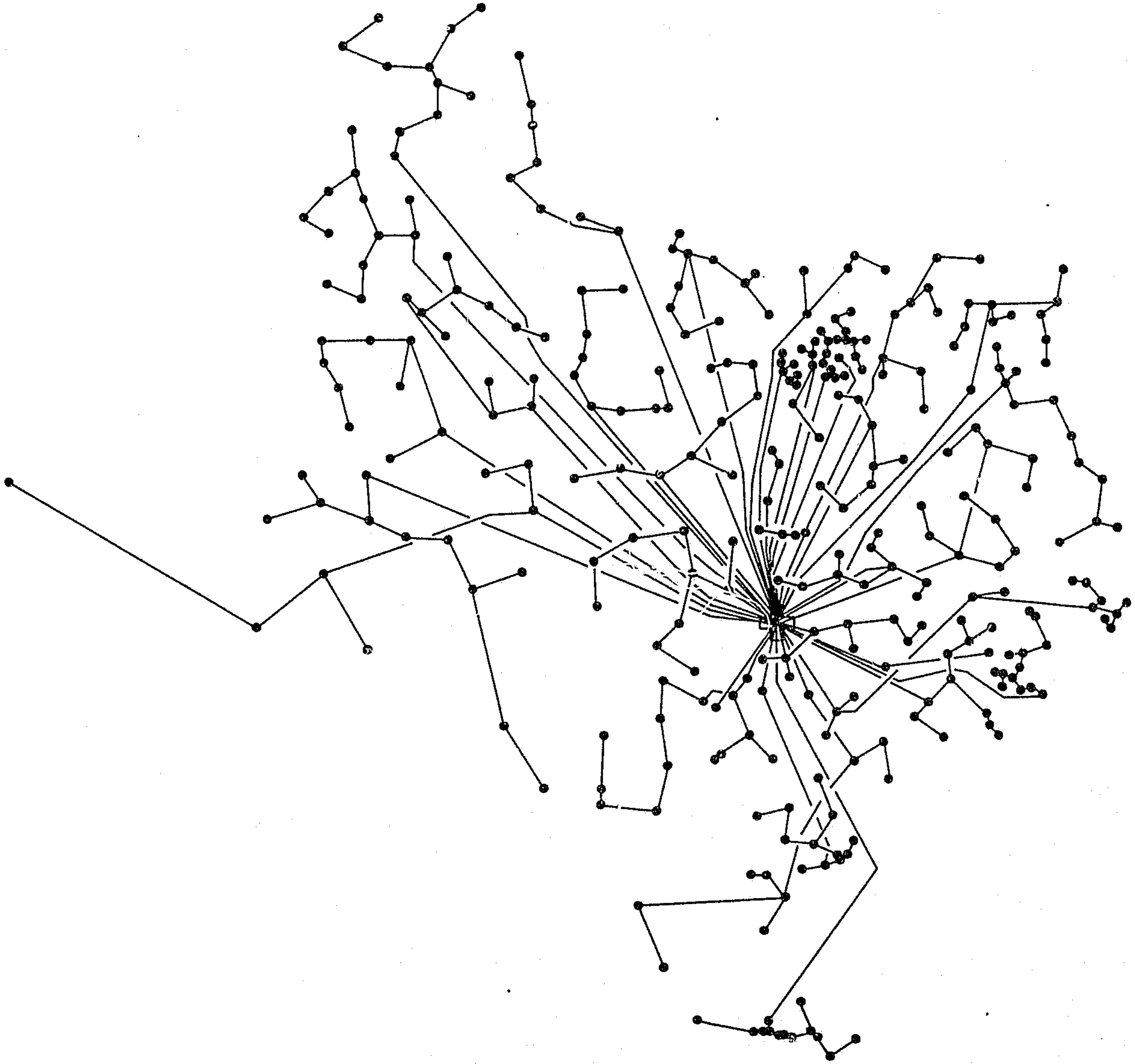

Figure 13-1. Single Region TLETS Network

Table 13-3. Terminal Assignments

NETWORK OPTION: TLETS/AUSTIN

NUMBER OF REGIONS: 1

REGION	LINE NO.	TOTAL NO.	TERMINALS STARTING	TERMINALS REMAINING
1				
	1	10	SXLP	SXFS,S ,SXRJ,SXAY,AZZD,SXQS,SXYA,SXYB,SXQW,
	2	20	AZID	AZIC,AZAV,AUB ,AUH ,AZAV,AZCS,AZFH,AZFW,AZFL,AZZH, AZHN,AZIB,AZTY,AZFK,AZYN,AZSE,AZUJ,AZUK,AZPB,
	3	18	SXQQ	NABD,SXPR,SXSQ,SXKC,NAAD,SXSN,SXLE,NAAF,SXQX,SXRB, NABT,NACW,NARK,SXCC,NAFC,SXQZ,NAEK,
	4	17	AZFI	AZFJ,AU+S,AZFZ,AZHC,AZLZ,AZAW,AZFD,AZIA,AZAN,AZYP, AZFB,AZFE,AZAU,AZIU,AZIU,AZYQ,
	5	19	SXKA	NABX,SXGV,SXDJ,SXDK,SXBQ,SXBP,SXRC,SXRD,NAFB,SXBN, NACS,SXSD,SXBR,NAAK,SXDS,NACN,SXDL,SXDN,
	6	20	SXQP	NACA,SXGC,SXBK,SXBJ,SXBL,SXRT,SXBS,SXYF,NADX,NADN, SXAD,NADW,SXBI,NAAH,SXWT,SXIT,SXBW,NAAC,SXRZ,
	7	20	SXRK	SXRL,SXYJ,NACE,SXDA,SXRS,SHGH,SXRX,SXRN,SXRP,SXUL, SXYK,NAEU,SXRW,SXCD,SXHI,SXRR,SXRQ,NADZ,NAEA,
	8	20	SXDP	AZUE,AZUD,AZBT,AZBU,AZDU,NADE,AZJU,AZKU,NACQ,NACR, AZFU,AZCU,NADF,AZEU,AZLU,AZUC,SXDF,SXDI,NABJ,
	9	17	AZTE	AZQI,AZAC,AZBC,AZXY,AZNS,AZAX,AZAB,AZTD,AZAA,AZQJ, AZUP,AZJL,AZQL,AZTS,AZQK,AZRI,
	10	18	AZUN	NAEQ,AZAS,AZUA,NABU,AZAD,AZFA,AZAH,AZLS,AZFF,AZKY, AZJY,AZYL,AZHU,AZGP,NAEP,AZIP,AZIE,
	11	13	NAAN	NAAP,NAAG,NACX,AZYI,NAEO,NACE,AZIZ,AZFR,NABR,AZON, NACC,NAAO,
	12	11	AZUS	AZUS,AZNA,AZRK,AZUZ,AZZC,AZZA,AZZP,AZUQ,AZCN,AZXL,
	13	17	AZUX	DQJH,DQIY,NACL,DQCW,DQJY,DQNU,DQNH,NADM,NABI,DQGS, DQKH,NACI,DQEA,DQEJ,NACD,DQAC,
	14	14	AZBN	AZAE,AZAI,NAAI,AZAJ,AZZB,NAEX,NAEV,NAEW,AZUW,AZAZ, NADO,NABZ,AZBX,
	15	20	DQHT	DQHP,DQCF,DQHN,DQIT,DQHQ,DQHR,DQAD,DQFT,DQET,DQDT, DQHJ,DQIH,NADP,DQHW,DQHS,DQHY,NABC,NABH,DQBY,
	16	1	DTJ	
	17	16	DTL	DQMJ,DQTR,DQTW,DQBD,DQGD,DQCS,DQRS,DQNA,DQCT,DQHL, DQHI,DQBT,DQRK,DQSU,DQHZ,

Table 13-3. Terminal Assignments (Continuation 1)

18	10	DQHU	DQHX,DQGB,DQNB,DQBE,DQLX,DQCA,NABQ,DQLZ,NABF,
19	17	DQEK	DQED,DQEL,DQEI,NADP,DQDX,NADI,NADY,NADT,NADS,NACO, NACP,NAEI,NADO,DQDQ,DQUT,NAEJ,
20	16	AZXJ	AZDA,AZXN,NACY,AZAF,AZXQ,AZXP,AZXW,AZGW,AZXS,AZXR, AZXI,AZXK,DQCE,DQDC,DQHK,
21	21	DQGY	DQEE,DQDZ,DQKY,NAEG,NAAU,DQGX,DQLH,DQLY,DQER,DQPF, DQEC,DQEW,NABS,DQGS,DQKH,NACI,NAEZ,NAAR,NAAS,DQEZ,
22	12	DQJT	DQBH,NACT,AZUI,NACF,DQRD,DQHC,DQHE,DQHF,DQEY,DQVI, DQSL,
23	18	DQKT	DQCY,DTQ ,DQNW,DQLT,DQHA,DQHD,DQHT,DQHH,DQHB,DTC , DQZY,NAEF,NAED,DQBZ,DQCH,NAEE,DQDH,
24	19	AZUF	AZXH,AZYC,NAAW,NAAX,DQEN,DQDR,AZGN,DQEF,DQDW,DQEP, NAAA,AZRZ,AZAR,NADU,NADK,NAER,NACJ,NACK,
25	17	AZPW	NAAL,AZPS,NABE,AZAZ,DQAY,NABP,NACH,DQDY,DQGJ,DQGJ, NADG,NADH,AZPX,NABH,AZPZ,NADQ,
26	17	AZIJ	AZIK,AZJP,AZJA,AZZN,SZGF,SXGR,NAEL,NAEM,SXRA,NADA, AZZJ,AZIL,NAEN,AZGO,AZIN,NAEY,
27	19	AZLA	AZLB,AZTI,AZLC,AZKA,AZLD,NACG,AZKK,AZWR,NAAV,AZWN, AZWP,AZWQ,AZWX,AZLI,NAAE,AZZK,AZWS,NAEC,
28	17	AZIS	AZIW,AZGM,AZIF,AZII,AZLJ,AZKS,AZIX,AZJK,AZLE,AZLF, AZFA,AZLN,AZIR,NABV,AZIQ,NAAB,
29	17	AZPN	AZPP,AZPL,AZPI,AZGL,AZLK,AZLL,AZLR,NARG,AZKW,AZPC, AZYE,AZXZ,AZLQ,AZPJ,AZPK,AZRB,
30	18	AZWL	NADL,AZAM,AZWJ,AZWK,NAAT,AZWE,AZWF,NARY,NACM,AZSP, AZWB,AZWA,AZSZ,AZWD,NADC,AZWC,AZSX,
31	13	AZGA	AZQB,AZQC,NAAQ,NABM,AZGF,AZPE,NAER,AZQE,AZPD,AZQD, AZPA,AZKD,
32	18	AZAG	AZQA,AZAG,AZJQ,NADJ,AZJE,NAAJ,AZMJ,AZGE,AZBI,AZJF, AZJI,AZKJ,AZJD,NABO,AZLR,AZZI,AZZF,
33	15	DTF	DQGI,AZJR,AZJS,AZKK,AZKP,AZKR,AZJW,AZKQ,NABA,AZKN, DQEH,AZKL,NAES,AZKF,
34	11	AZBF	NAET,DQGZ,NAAY,NAAZ,NACB,AZWI,AZWW,NAER,AZZL,AZJZ,
35	16	NAAM	AZGG,AZUR,NACV,NACZ,SXQR,NABW,SXGK,SXRF,NACU,SXBE, NADV,AZZR,NADB,AZZW,AZZX,

Table 13-4. Network Option Costs in Thousands of Dollars

Network: TLETS   Number of Regions: 1
Remarks: Single Region - Austin

		Recurring Costs			One Time Installation Costs		Total
Item	No. Reqd.	Annual Cost Each	Total Annual Cost	Eight Year Cost	Unit Cost	Total Purchase Cost	Eight Year Cost by Item
Lines, Modems Service Terminals	-	-	611	4,888	-	37	4,925
Terminals	564	1,260	711	5,700	8.847	5,000	10,700
Regional Switchers	0						
Switcher Floor Space							
Switcher Back up Power	0						
Switcher Personnel	0						
Engineering					-	130	130
Subtotals				10,588		5,167	15,755
			Total Eight Year Cost:				15,800

Table 13-5. Network Line Characteristics

Network: TLETS Number of Regions: 1
Remarks: Austin as Regional Center

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	SXLP	10	1200	0.643	73	8.7
2	AZIO	20	2400	0.611	154	4.6
3	SXQQ	19	1200	0.068	374	3.8
4	AZFI	17	1200	0.157	313	4.1
5	SXKA	19	1200	0.145	469	4.1
6	SXQP	20	1200	0.181	356	4.2
7	SXRK	19	1200	0.169	433	4.2
8	SXDP	20	1200	0.213	415	4.4
9	AZTE	17	1200	0.243	0	4.1
10	AZUN	18	1200	0.101	304	4.0
11	NAAN	13	1200	0.037	218	3.6
12	AZUS	11	1200	0.083	143	3.7
13	AZUX	17	1200	0.115	396	3.9
14	AZBN	14	1200	0.064	255	3.7
15	DQHT	20	1200	0.310	297	4.9
16	DTJ	11	4800	0.445	181	2.6
17	DTL	16	1200	0.556	181	2.5
18	OQHU	10	1200	0.095	309	3.7
19	DQEK	17	1200	0.076	441	3.8
20	AZXJ	16	1200	0.145	286	4.0
21	DQGY	19	1200	0.137	451	4.1
22	DQJT	12	1200	0.123	254	3.9
23	DQKT	19	1200	0.319	213	5.0
24	AZUF	19	1200	0.095	449	4.0
25	AZPW	17	1200	0.065	356	3.8
26	AZIJ	19	1200	0.124	698	4.0
27	AZLA	19	1200	0.054	623	3.8
28	AZIS	17	1200	0.083	523	3.8
29	AZPN	17	1200	0.130	550	4.0
30	AZWL	18	1200	0.172	661	4.2
31	AZGA	14	1200	0.083	386	3.8
32	AZAG	18	1200	0.247	706	4.5
33	DTF	15	1200	0.080	446	3.8
34	AZBF	11	1200	0.025	489	3.5
35	NAAM	16	1200	0.051	317	3.7

13.3 OPTION 2 - TWO REGION TLETS

13.3.1 Topology

For the STACOM/TEXAS two region case, four possible networks were studied. Each of the four networks consists of one region served by the Austin Switcher. Candidates for a second region in the network included, Dallas, Amarillo, Lubbock, and Midland.

The least cost configuration of these four possibilities is the Austin-Dallas network shown in Figure 13-2. The Austin region consists of 16 1200 Baud lines and one 2400 Baud line for a total of 17 lines. The Dallas region is comprised of 18 1200 Baud lines and one 2400 Baud line for a total of 19 lines. A single 4800 Baud line connects the two regional computers. Table 13-6 details the terminal assignments by line for the two region case.

13.3.2 Costs

Total eight-year costs for the two region Austin-Dallas network are shown in Table 13-7. There is no purchase cost shown for the Dallas regional switcher or for an uninterruptable power supply since these facilities presently exist. The total cost is $17,000,000 over eight years. Note that the annual line cost of $602,000 is reduced from the $611,000 annual cost in the single region case. Total costs are increased, however, despite the fact that the second switcher need not be purchased due to additional switcher, facility and personnel recurring costs.

Tables 13-8, 13-9, and 13-10 show costing results of considering Lubbock, Midland and Amarillo as locations for a second switcher respectively instead of Dallas. Note that annual line costs are very similar in all two region cases. However, non-existent switching facilities are required in the Western locations.

13.3.3 Line Performance

Table 13-11 presents line performance characteristics for the two region case with switchers in Austin and Dallas. Mean response times vary between 2.2 seconds and 8.7 seconds depending on the particular multidropped line. Of the total of 36 lines for both regions, 34 show mean response times of less than 5 seconds.

13.3.4 Network Availability

If data base and switcher upgrades called for in Section 13.1.2 are implemented, the system availability for the two region case is 0.973. This implies an average daily network outage for terminals connected to the Dallas switcher of 39.0 minutes.

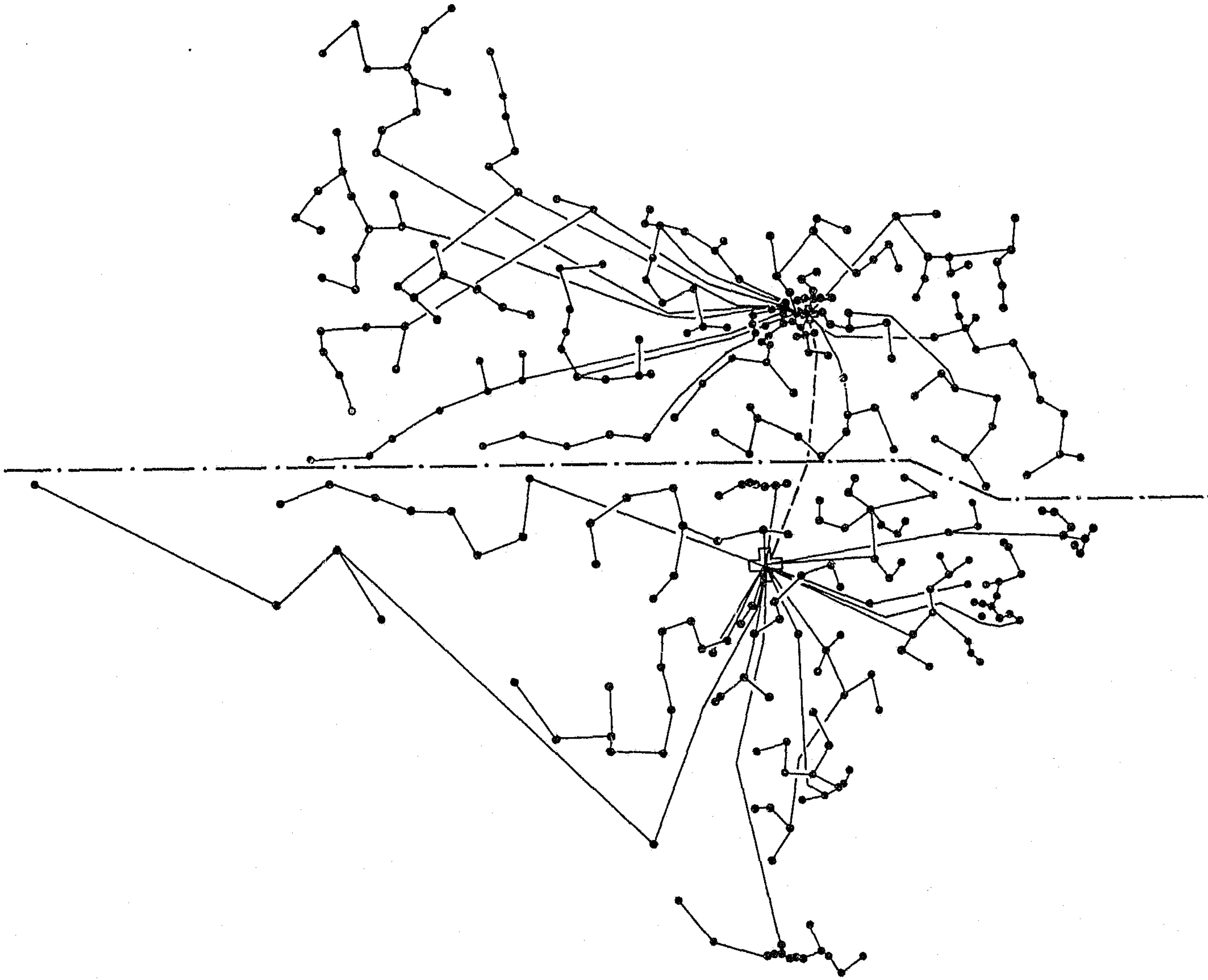

Figure 13-2. Two Region TLETS -- Switches in Austin and Dallas

Table 13-6. Terminal Assignments

WORK OPTION: TLETS/AUSTIN-DALLAS

NUMBER OF REGIONS: 2

Austin REGION	LINE NO.	TOTAL NO.	TERMINALS STARTING	TERMINALS REMAINING
1	1	20	AZID	AZIC,AZAV,AUB ,AUH ,AZAV,AZCS,AZFH,AZFW,AZFL,AZZH, AZHN,AZIB,AZTY,AZFK,AZYN,AZSE,AZUJ,AZUK,AZPB,
	2	16	AZFI	AZFJ,AO+S,AZHC,AZLZ,AZAW,AZFD,AZIA,AZAN,AZYP,AZFB, AZFE,AZAU,AZIU,AZIU,AZYQ,
	3	20	SXKA	NABX,SXGC,SXBK,SXBJ,SXBL,SXRT,SXRS,SXYF,NADX,NADN, SXAD,NADW,SXBI,NAAH,SXWT,SXIT,SXRW,NAAC,SXRZ,
	4	12	SXOP	NACA,NAAO,NAAN,NAAP,MAAG,NACX,NABR,SXSQ,SXKC,NAAD, SXSN,
	5	21	SXRK	SXRL,SXYJ,NACE,SXDA,SXRS,SHGH,SXRX,SXRN,SXRP,SXUL, SXYK,NAEU,SXRW,SXCD,SXHI,SXPR,SXRO,NADZ,NAEA,NAFB,
	6	18	SXDP	SXGV,SXDJ,SXDK,SXBO,SXBP,SXBN,NACS,SXSU,SXBR,NAAK, SXDS,NACN,SXDL,SXDN,SXDF,SXDI,NABJ,
	7	17	AZUE	AZUD,AZBT,AZBU,AZDU,NADE,AZJU,AZKU,NACQ,NACR,AZFU, AZCU,NADF,AZEU,AZLU,AZUC,NADU,
	8	20	AZYI	NAEO,AZBN,AZAE,AZAI,NAAI,AZUF,AZXH,AZYC,AZRZ,AZAJ, AZZB,AZUW,AZAZ,NADO,NACE,AZBX,NABZ,AZIZ,AZFR,
	9	17	AZUN	NAEQ,AZAS,AZUA,NABU,AZAD,AZFA,AZAR,AZFF,AZKY,AZJY, AZYL,AZHU,AZGP,NAEP,AZIP,AZIE,
	10	12	AZUS	AZUS,AZUX,NACJ,NACK,AZNA,AZRK,AZUZ,AZZC,AZGG,AZUR, NACV,
	11	10	SXLP	SXFS,S ,SXRJ,SXAY,AZZD,SXQS,SXYA,SXYB,SXQW,
	12	19	SXPR	SXLE,SXBE,NAAF,SXQX,SXRP,NART,NACW,NABK,NABL,SXCC, NAFC,SXQZ,NAEK,SXRA,NADA,SXGR,NAEL,NAEM,
	13	4	AZQN	NACC,SXQQ,NABD,
	14	11	AZAG	AZQA,AZAG,AZZJ,SXGF,AZZN,AZJA,AZJP,AZTL,NAEN,AZGO,
	15	17	AZTE	AZQI,AZAC,AZBC,AZXY,AZNS,AZAX,AZAR,AZTD,AZAA,AZQJ, AZUP,AZJL,AZQL,AZTS,AZQK,AZRI,
	16	15	SXRC	SXRD,AZJQ,NADJ,AZJE,NAAJ,AZMJ,AZGE,AZBI,AZJF,AZJI, AZKJ,AZJD,NABO,AZJH,
	17	14	NAEJ	NAAM,NACZ,SXQR,NABW,SXGK,SXRF,NACU,NADV,AZZR,NADB, AZZW,AZZX,NAEX,

Table 13-6. Terminal Assignments (Continuation 1)

DALLAS

REGION

1	1	DTJ	
2	18	DTL	DQMJ,DQTR,DQTW,DQBD,DQGD,DQCS,DQRS,DQNA,DQCT,DQHL, DQHI,DQBT,DQRK,DQSU,DQHZ,DQDT,DQHJ,
3	9	DQHQ	DQIT,DQHN,DQHP,DQCF,DQHT,DQDC,DQHK,DQCE,
4	19	DQFT	DQET,DQIH,NADP,DQAD,DQHR,NABH,DQBY,DQVI,DQSL,DQRD, DQHC,DQHE,DQHF,DQEY,DQHW,DQHS,DQHY,NABC,
5	17	DQHU	DQHX,DQGB,DQNB,DQBE,DQIY,NACL,DQCW,NABI,DQGS,DQKH, NACI,DQLX,DQCA,NABQ,DQLZ,NABF,
6	16	DQJH	NAAW,NAAX,DQEN,DQDR,AZGN,DQEF,NAEH,NADK,DQDW,DQEP, NAAA,DQAC,DQEA,DQEJ,NACD,
7	22	DQJY	DQNU,DQKY,NAEG,NAAU,DQGX,DQLH,DQLY,DQEK,DQFF,DQEC, DQEW,NABS,DQGS,DQKH,NACI,NAEZ,NAAR,NAAS,DQEZ,DQNH, NADM,
8	20	AZXJ	AZDA,AZXN,AZXK,AZAR,NACY,AZAF,AZXQ,AZXP,AZXW,AZGW, AZXS,AZXR,AZXI,AZCN,AZXL,AZZP,AZUQ,AZWZ,AZZA,
9	20	DQGY	DQEE,DQDZ,DQEK,DQED,DQEL,DQDQ,DQUT,NAEJ,DQEI,NADR, DQDX,NADI,NADY,NADT,NADS,NACO,NACP,NAEI,NADD,
10	13	DQJT	NAEE,DQBZ,DQCH,DQBH,NACT,AZUI,NACF,NACH,DQAY,NABP, AZPS,NABE,
11	16	DQKT	DQCY,DTQ ,DQNW,DQLT,DQHA,DQHD,DQHT,DQHH,DQHR,DTC , DQZY,NAEF,NAED,DQDH,DQDD,
12	8	AZPW	NAAL,AZPX,NABB,AZPZ,NADQ,AZZI,AZZF,
13	18	DQGZ	NAAY,NAAZ,AZGL,AZLK,AZLL,AZLR,NABG,AZKW,AZPC,AZYE, AZXZ,AZLQ,NACR,AZWI,AZWW,NAER,AZZL,
14	19	AZLA	AZLB,AZWS,NAEC,AZTI,AZLC,AZKA,AZLD,NACG,AZKK,AZWR, NAAV,AZWN,AZWP,AZZK,AZWQ,AZWX,AZLI,NAAE,
15	16	AZPN	AZPP,AZPL,AZPI,AZIS,AZIW,AZGM,AZIF,AZTI,AZIJ,AZIK, AZIN,NAEY,AZPJ,AZPK,AZRB,
16	18	AZWL	NADL,AZAM,AZWJ,AZWK,NAAT,AZWE,AZWF,NARY,NACM,AZSP, AZWB,AZWA,AZSZ,AZWD,NADC,AZSX,AZWC,
17	14	AZGA	AZQB,AZQC,NAAQ,NAAM,AZPE,NAEB,AZQF,NAPN,AZQE,AZPD, AZQD,AZPA,AZKD,
18	20	DTF	DQGI,AZJR,AZJS,AZKK,AZKP,AZKR,AZJW,AZKQ,DQGJ,DQGJ, NADG,DQDJ,NADH,NABA,AZKN,DQEH,AZKI,NRES,AZKF,
19	15	AZRF	NAET,AZLJ,AZKS,AZIX,AZJK,AZLE,AZLF,NAFA,AZLN,AZIR, NABV,AZIQ,NAAB,AZJZ,

Table 13-7. Network Option Costs in Thousands of Dollars

Network: TLETS　　　　Number of Regions: 2
Remarks: Austin - Dallas

Item	No. Reqd.	Recurring Costs: Annual Cost Each	Recurring Costs: Total Annual Cost	Recurring Costs: Eight Year Cost	One Time Installation Costs: Unit Cost	One Time Installation Costs: Total Purchase Cost	Total Eight Year Cost by Item
Lines, Modems Service Terminals	-	-	602	4,816	-	38	4,854
Terminals	564	1,260	711	5,700	8,847	5,000	10,700
Regional Switchers	1	18	18	144	0*	0*	144
Switcher Floor Space	1	4.8	4.8	38	-	-	38
Switcher Back Up Power	1	6.0	6.0	48	0*	0*	48
Switcher Personnel	1 Set	128	128	1,024	-	-	1,024
Engineering						230	230
Subtotals				11,770		5,268	17,038

Total Eight Year Cost: 17,000

*Regional Switch Installation Not Required

Table 13-8. Network Option Costs in Thousands of Dollars

Network: TLETS
Remarks: Austin - Lubbock

Number of Regions: 2

Item	No. Reqd.	Recurring Costs: Annual Cost Each	Recurring Costs: Total Annual Cost	Recurring Costs: Eight Year Cost	One Time Installation Costs: Unit Cost	One Time Installation Costs: Total Purchase Cost	Total Eight Year Cost by Item
Lines, Modems Service Terminals	-	-	606	4,848	-	38	4,886
Terminals	564	1,260	711	5,700	8,847	5,000	10,700
Regional Switchers	1	18	18	144	350	350	494
Switcher Floor Space	1	4.8	4.8	38	30	30	68
Switcher Back Up Power	1	6.0	6.0	48	20	20	68
Switcher Personnel	1 Set	128	128	1,024	-	-	1,024
Engineering						230	230
Subtotals				11,802		5,668	17,470
					Total Eight Year Cost:		17,500

Table 13-9. Network Option Costs in Thousands of Dollars

Network: TLETS   Number of Regions: 2
Remarks: Austin - Midland

Item	No. Reqd.	Recurring Costs: Annual Cost Each	Recurring Costs: Total Annual Cost	Recurring Costs: Eight Year Cost	One Time Installation Costs: Unit Cost	One Time Installation Costs: Total Purchase Cost	Total Eight Year Cost by Item
Lines, Modems Service Terminals	-	-	609	4,872	-	38	4,910
Terminals	564	1,260	711	5,700	8,847	5,000	10,700
Regional Switchers	1	18	18	144	350	350	494
Switcher Floor Space	1	4.8	4.8	38	30	30	68
Switcher Back Up Power	1	6.0	6.0	48	20	20	68
Switcher Personnel	1 Set	128	128	1,024	-	-	1,024
Engineering						230	230
Subtotals				11,826		5,668	17,494
						Total Eight Year Cost:	17,500

Table 13-10. Network Option Costs in Thousands of Dollars

Network: TLETS
Remarks: Austin - Amarillo

Number of Regions: 2

Item	No. Reqd.	Recurring Costs: Annual Cost Each	Recurring Costs: Total Annual Cost	Recurring Costs: Eight Year Cost	One Time Installation Costs: Unit Cost	One Time Installation Costs: Total Purchase Cost	Total Eight Year Cost by Item
Lines, Modems Service Terminals	-	-	612	4,896	-	38	4,934
Terminals	564	1,250	711	5,700	8,847	5,000	10,700
Regional Switchers	1	18	18	144	350	350	494
Switcher Floor Space	1	4.8	4.8	38	30	30	68
Switcher Back Up Power	1	6.0	6.0	48	20	20	68
Switcher Personnel	1 Set	128	128	1,024	-	-	1,024
Engineering						230	230
Subtotals				11,850		5,668	17,518
						Total Eight Year Cost:	17,500

Table 13-11. Network Line Characteristics

Network: TLETS Number of Regions: 2
Remarks: Austin Region

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	AZID	20	2400	0.611	154	4.6
2	AZFI	17	1200	0.157	313	4.1
3	SXKA	20	1200	0.177	352	4.2
4	SXQP	12	1200	0.035	240	3.6
5	SXRK	20	1200	0.170	479	4.2
6	SXDP	18	1200	0.112	356	3.9
7	AZUE	17	1200	0.204	338	4.3
8	AZYI	20	1200	0.087	352	3.9
9	AZUN	18	1200	0.101	304	3.9
10	AZUS	12	1200	0.097	224	3.8
11	SXLP	10	1200	0.643	73	8.7
12	SXPR	19	1200	0.077	395	3.9
13	AZQN	4	1200	0.023	46	3.4
14	AZAG	13	1200	0.095	428	3.8
15	AZTE	17	1200	0.243	0	4.1
16	SXRC	15	1200	0.228	841	4.3
17	NAEV	15	1200	0.047	293	3.7

Network: TLETS Number of Regions: 2
Remarks: Dallas Region

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	DTJ	1	2400	0.472	0	2.2
2	DTL	18	1200	0.325	22	5.0
3	DQHQ	9	1200	0.110	69	3.8
4	DQFT	19	1200	0.242	106	4.5
5	DQHU	17	1200	0.135	231	4.1
6	DQSH	16	1200	0.099	335	3.9
7	DQJY	20	1200	0.105	363	4.0
8	AZXJ	20	1200	0.156	316	4.1
9	DQGY	20	1200	0.129	336	4.1
10	DQJT	13	1200	0.082	172	3.7
11	DQKT	16	1200	0.308	52	4.8
12	AZPW	8	1200	0.020	272	3.5
13	DQGZ	18	1200	0.125	622	4.0
14	AZLA	19	1200	0.054	567	3.8
15	AZPN	16	1200	0.120	424	4.0
16	AZWL	18	1200	0.172	588	4.2
17	AZGA	14	1200	0.083	368	3.8
18	DTF	20	1200	0.116	378	4.0
19	AZBF	15	1200	0.044	517	3.7

13.4 OPTION 3 - THREE REGION TLETS

13.4.1 Topology

For the STACOM/TEXAS three region case, five possible configurations were studied. Each of the five networks consists of a switcher facility in Austin and Dallas. Candidate locations for a third switcher were San Antonio, Houston, Midland, Amarillo and Lubbock.

The least cost configuration of these five is the network shown in Figure 13-3 employing Austin, Dallas and San Antonio as switcher locations, (see Paragraph 13.4.2). The Austin region consists of ten 1200 Baud lines and two 2400 Baud lines.

The Dallas region services 19 lines, all of which are 1200 Baud lines with the exception of one 4800 Baud line. The San Antonio switcher has six 1200 Baud lines and one 2400 Baud line. A single 4800 Baud line connects the Austin switch to Dallas and a single 4800 Baud line also provides communication from Austin to San Antonio. Table 13-12 provides line topology details for this three region case.

13.4.2 Cost

Tables 13-13 through 13-17 show eight-year cost breakdowns for the five three region cases considered. The Austin-Dallas-San Antonio case exhibits the highest annual line cost of any of the five alternatives considered ($639,000). The overall eight-year cost, however, is less by some $200,000 only because required switching facilities are already in place.

The remaining four cases indicate virtually identical costs when totals are rounded off, although the Austin-Dallas-Houston configuration exhibits the lowest annual line cost of all alternatives, ($597,000).

As in the two-region case, the location of switchers in the Western part of the state appear to be least favorable by slight margins only.

13.4.3 Line Performance

Line performance characteristics for the three region Austin-Dallas-San Antonio configuration are shown in Table 13-18. Mean response times vary from 2.2 seconds to a worst case of 5.0 seconds. Of the total of 38 lines in the network, 22 have mean response times of less than or equal to 4.0 seconds.

13.4.4 Network Availability

If the data base and switcher upgrades called for in Section 13.1.2 are implemented, the three region network will have an availability of 0.973, which implies an average daily system outage for any terminal connected to the Dallas or San Antonio switchers of 39.0 minutes.

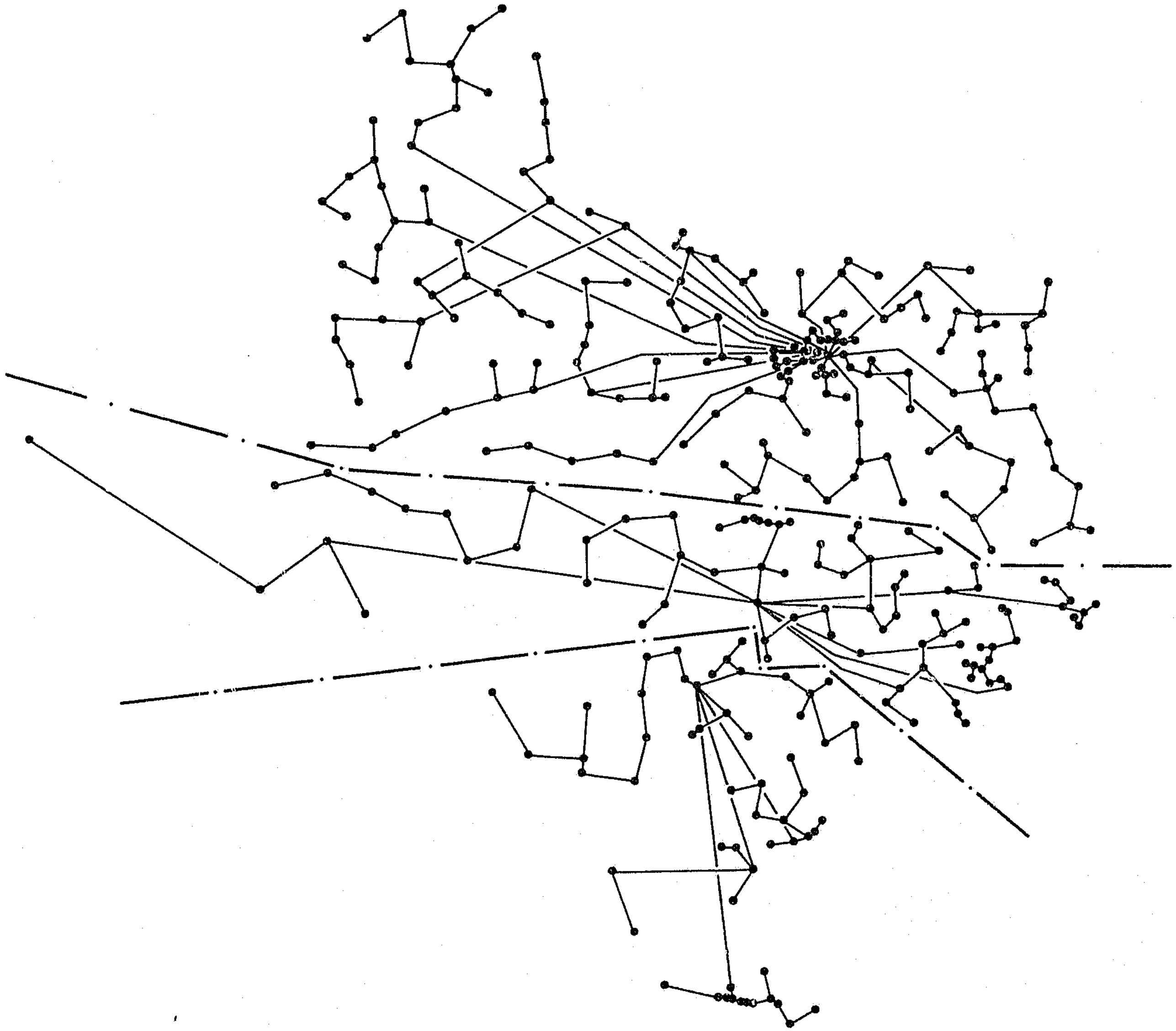

Figure 13-3. Three Region TLETS with Switchers in Austin, Dallas and San Antonio (1985)

Table 13-12. Terminal Assignments

NETWORK OPTION: TLFTS/A-D-SA

NUMBER OF REGIONS: 3

REGION	LINE NO.	TOTAL NO.	TERMINALS STARTING	TERMINALS REMAINING
1	1	20	AZID	AZIC,AZAV,AUB ,AUH ,AZAV,AZCS,AZFH,AZFW,AZFL,AZZH, AZHN,AZIB,AZTY,AZFK,AZYN,AZSE,AZUJ,AZUK,AZPB,
	2	17	AZFI	AZFJ,A0+S,AZFZ,AZHC,AZLZ,AZAW,AZFD,AZIA,AZAN,AZYP, AZFB,AZFE,AZAU,AZIU,AZIU,AZYQ,
	3	17	AZUE	AZUD,AZBT,AZBU,AZDU,NADE,AZJU,AZKU,NACQ,NACR,AZFU, AZCU,NADF,AZEU,AZLU,AZUC,NADU,
	4	19	AZYI	NAEO,AZBN,AZAE,AZAI,NAAI,AZUF,AZXH,AZYC,AZRZ,AZAJ, AZZB,AZUW,AZAZ,NADO,AZIZ,AZFR,AZBX,NARZ,
	5	18	AZUN	NAEQ,AZAS,AZUA,NABU,AZAD,AZFA,AZAH,AZLS,AZFF,AZKY, AZJY,AZYL,AZHU,AZGP,NAEP,AZIP,AZIE,
	6	6	NAAN	NAAP,NAAG,NACX,NABR,NAAO,
	7	10	AZUS	AZUS,AZUX,AZNA,AZRK,AZUZ,AZZC,AZGG,AZUR,NACV,
	8	13	AZJQ	NADJ,AZJE,NAAJ,AZMJ,AZGE,AZBI,AZJF,AZJI,AZKJ,AZJD, NABO,AZJB,
	9	13	AZAG	AZQA,AZAG,AZZJ,SXGF,AZZN,AZJA,AZJP,AZIL,NAEN,AZGQ, AZJC,AZJJ,
	10	17	AZTE	AZQI,AZAC,AZBC,AZXY,AZNS,AZAX,AZAB,AZTD,AZAA,AZQJ, AZUP,AZJL,AZQL,AZTS,AZQK,AZRI,
	11	15	NAEV	NAEW,NAAM,NACZ,SXQR,NABW,SXGK,SXRF,NACU,NADV,AZZR, NADB,AZZW,AZZX,NAEX,
2	1	17	DTJ	DTL ,DQMJ,DQTR,DQTW,DQBD,DQGD,DQCS,DQRS,DQNA,DQCT, DQHL,DQHI,DQBT,DQRK,DQSU,DQHZ,
	2	3	DTL	DQDT,DQHJ,
	3	9	DQHQ	DQIT,DQHN,DQHP,DQCF,DGHT,DQDC,DQHK,DQCE,
	4	19	DQFT	DQET,DQIH,NADP,DQAD,DQHR,NABH,DQBY,DQVI,DQSL,DQRD, DQHC,DQHE,DQHF,DQEY,DQHW,DQHS,DQHY,NABC,
	5	17	DQHU	DQHX,DQGB,DQNB,DQBE,DQIY,NACL,DQCW,NABI,DQGS,DQKH, NACI,DQLX,DQCA,NABQ,DQLZ,NABF,
	6	16	DQJH	NAAW,NAAX,DQEN,DQDR,AZGN,DQEF,NAEH,NADK,DQDW,DQEP, NAAA,DQAC,DQEA,DQEJ,NACD,

Table 13-12 Terminal Assignments (Continuation 1)

	7	21	DQJY	DQNU,DQKY,NAEG,NAAU,DQGX,DQLH,DQLY,DQFR,DQEC,DQEW; NABS,DQGS,DQKH,NACI,NAEZ,NAAR,NAAS,DQEZ,DQNH,NADM,
	8	20	AZXJ	AZDA,AZXN,AZXK,AZAR,NACY,AZAF,AZXQ,AZXP,AZXW,AZGW, AZXS,AZXR,AZXI,AZCN,AZXL,AZZP,AZUQ,AZWZ,AZZA,
	9	20	DQGY	DQEE,DQDZ,DQEK,DQED,DQEL,DQDQ,DQUT,NAEJ,DQEI,NADR, DQDX,NADI,NADY,NADT,NADS,NACO,NACP,NAEI,NADD,
	10	13	DQJT	NAEE,DQBZ,DQCH,DQRH,NACT,AZUI,NACF,NACH,DQAY,NARP; AZPS,NABE,
	11	16	DQKT	DQCY,DTQ ,DQNW,DQLT,DQHA,DQHD,DQHT,DQHH,DQHB,DTC ; DQZY,NAEF,NAED,DQDH,DQDD,
	12	8	AZPW	NAAL,AZPX,NABB,AZPZ,NADQ,AZZI,AZZF,
	13	18	DQGZ	NAAY,NAAZ,AZGL,AZLK,AZLL,AZLR,NABG,AZKW,AZPC,AZYE; AZXZ,AZLQ,NACB,AZWI,AZWW,NAER,AZZL,
	14	19	AZLA	AZLB,AZWS,NAEC,AZTI,AZLC,AZKA,AZLD,NACG,AZKK,AZWR; NAAV,AZWN,AZWP,AZZK,AZWQ,AZWX,AZLI,NAAE,
	15	16	AZPN	AZPP,AZPL,AZPI,AZIS,AZIW,AZGM,AZIF,AZII,AZIJ,AZIK; AZIN,NAEY,AZPJ,AZPK,AZRR,
	16	18	AZWL	NADL,AZAM,AZWJ,AZWK,NAAT,AZWE,AZWF,NARY,NACM,AZSP, AZWB,AZWA,AZSZ,AZWD,NADC,AZSX,AZWC,
	17	14	AZGA	AZQB,AZQC,NAAQ,NABM,AZPE,NAEB,AZQF,NARN,AZQE,AZPD; AZQD,AZPA,AZKD,
	18	20	DTF	DQGI,AZJR,AZJS,AZKK,AZKP,AZKR,AZJW,AZKQ,DQGJ,DQGJ; NADG,DQDY,NADH,NABA,AZKN,DQEH,AZKL,NAES,AZKF,
	19	15	AZBF	NAET,AZLJ,AZKS,AZIX,AZJK,AZLE,AZLF,NAFA,AZLN,AZIR; NARV,AZIQ,NAAB,AZJZ,
3				
	1	10	SXLP	SXFS,S ,SXRJ,SXAY,AZZD,SXQS,SXYA,SXYB,SXQW,
	2	18	SXLE	SXBE,NAAF,SXQX,SXRB,NABT,NACW,NABK,NABL,SXCC,NAFC; SXQZ,NAEK,SXRA,NADA,SXGR,NAEL,NAEM,
	3	20	SXQP	NACA,SXKA,NABX,SXDP,SXGV,SXDJ,SXDK,SXDS,NACN,SXDL; SXDN,SXDI,NABJ,SXDF,SXQQ,NABD,SXPR,AZQN,NACC,
	4	20	SXRK	SXRL,SXYJ,NACE,SXDA,SXRS,SHGH,SXRX,SXRN,SXRP,SXUL; SXYK,NAEU,SXRW,SXCD,SXHI,SXRR,SXRQ,NADZ,NAEA,
	5	10	SXBQ	SXBP,SXRC,SXRD,NAFB,SXBN,NACS,SXSD,SXBR,NAAK,
	6	18	SXGC	SXBK,SXBJ,SXBL,SXRT,SXBS,SXYF,NADX,NADW,SXBI,NAAH; SXWT,NADN,SXAD,SXIT,SXBW,NAAC,SXRZ,
	7	4	SXSQ	NAAD,SXSN,SXKC,

Table 13-13. Network Option Costs in Thousands of Dollars

Network: TLETS　　　　Number of Regions: 3
Remarks: Austin - Dallas - San Antonio

Item	No. Reqd.	Recurring Costs: Annual Cost Each	Recurring Costs: Total Annual Cost	Recurring Costs: Eight Year Cost	One Time Installation Costs: Unit Cost	One Time Installation Costs: Total Purchase Cost	Total Eight Year Cost by Item
Lines, Modems Service Terminals	-	-	639	5,112	-	40	5,152
Terminals	564	1,260	711	5,760	8,847	5,000	10,700
Regional Switchers	2	18	36	288	0*	0*	288
Switcher Floor Space	2	4.8	9.6	77	0*	0*	77
Switcher Back Up Power	2	6	12	96	0*	0*	96
Switcher Personnel	2 Sets	128	256	2,048	-	-	2,048
Engineering						130	130
Subtotals				13,321		5,170	18,491
				Total Eight Year Cost:			18,500

*Switches exist in Dallas and San Antonio

Table 13-14. Network Option Costs in Thousands of Dollars

Network: TLETS Number of Regions: 3
Remarks: Austin - Dallas - Houston

Item	No. Reqd.	Recurring Costs: Annual Cost Each	Recurring Costs: Total Annual Cost	Recurring Costs: Eight Year Cost	One Time Installation Costs: Unit Cost	One Time Installation Costs: Total Purchase Cost	Total Eight Year Cost by Item
Lines, Modems Service Terminals	-	-	597	4,776	-	38	4,814
Terminals	564	1,260	711	5,700	8,847	5,000	10,700
Regional Switchers	2	18	36	288	350	350*	638
Switcher Floor Space	2	4.8	9.6	77	30	30*	107
Switcher Back Up Power	2	6.0	12.0	96	20	20	116
Switcher Personnel	2 Sets	128	256	2,048	-	-	2,048
Engineering						230	230
Subtotals				12,985		5,668	18,653
					Total Eight Year Cost:		18,700

*New facility required in Houston only

Table 13-15. Network Option Costs in Thousands of Dollars

Network: TLETS Number of Regions: 3
Remarks: Austin - Dallas - Midland

		Recurring Costs			One Time Installation Costs		
Item	No. Reqd.	Annual Cost Each	Total Annual Cost	Eight Year Cost	Unit Cost	Total Purchase Cost	Total Eight Year Cost by Item
Lines, Modems Service Terminals	-	-	604	4,832	-	38	4,870
Terminals	564	1,260	711	5,700	8,847	5,000	10,700
Regional Switchers	2	18	36	288	350	350	638
Switcher Floor Space	2	4.8	9.6	77	30	30*	107
Switcher Back Up Power	2	6.0	12.0	96	20	20	116
Switcher Personnel	2 Sets	128	256	2,048	-	-	2,048
Engineering						230	230
Subtotals				13,041		5,668	18,709
						Total Eight Year Cost:	18,700

*New facility required in Midland only

Table 13-16. Network Option Costs in Thousands of Dollars

Network: TLETS Number of Regions: 3
Remarks: Austin - Dallas - Amarillo

Item	No. Reqd.	Recurring Costs: Annual Cost Each	Recurring Costs: Total Annual Cost	Recurring Costs: Eight Year Cost	One Time Installation Costs: Unit Cost	One Time Installation Costs: Total Purchase Cost	Total Eight Year Cost by Item
Lines, Modems Service Terminals	-	-	607	4,856	-	38	4,894
Terminals	564	1,260	711	5,700	8,847	5,000	10,700
Regional Switchers	2	18	36	288	350	350	638
Switcher Floor Space	2	4.8	9.6	77	30	30*	107
Switcher Back Up Power	2	6.0	12.0	96	20	20	116
Switcher Personnel	2 Sets	128	256	2,048	-	-	2,048
Engineering						230	230
Subtotals				13,065		5,668	18,733
					Total Eight Year Cost:		18,700

*New facility required in Amarillo only

Table 13-17. Network Option Costs in Thousands of Dollars

Network: TLETS
Remarks: Austin - Dallas - Lubbock

Number of Regions: 3

Item	No. Reqd.	Recurring Costs: Annual Cost Each	Recurring Costs: Total Annual Cost	Recurring Costs: Eight Year Cost	One Time Installation Costs: Unit Cost	One Time Installation Costs: Total Purchase Cost	Total Eight Year Cost by Item
Lines, Modems Service Terminals	-	-	602	4,816		38	4,854
Terminals	564	1,260	711	5,700	8,847	5,000	10,700
Regional Switchers	2	18	36	288	350	350	638
Switcher Floor Space	2	4.8	9.6	77	30	30*	107
Switcher Back Up Power	2	6.0	12.0	96	20	20	116
Switching Personnel	2 Sets	128	256	2,048	-	-	2,048
Engineering						230	230
Subtotals				13,025		5,668	18,693
						Total Eight Year Cost:	18,700

*New facility required in Lubbock only

Table 13-18. Network Line Characteristics

Network: TLETS Number of Regions: 3
Remarks: Austin Region

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	AZID	20	2400	0.611	154	4.6
2	AZFI	17	1200	0.157	313	4.1
3	AZUF	20	1200	0.220	373	4.4
4	AZYI	15	1200	0.067	269	3.7
5	AZUN	18	1200	0.101	304	3.9
6	NAAN	6	1200	0.012	111	3.4
7	AZBN	18	1200	0.141	372	4.1
8	AZID	20	2400	0.611	154	4.6
9	AZFI	17	1200	0.157	313	4.1
10	AZBT	20	1200	0.186	437	4.3
11	AZUN	18	1200	0.101	304	4.0
12	NAAG	9	1200	0.021	165	3.5

Network: TLETS Number of Regions: 3
Remarks: Dallas Region

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	DTJ	1	4800	0.472	0	2.2
2	DTL	18	1200	0.325	22	5.0
3	DQHQ	9	1200	0.110	69	3.8
4	DQFT	19	1200	0.242	106	4.5
5	DQHU	17	1200	0.135	231	4.1
6	DQJH	16	1200	0.099	335	3.9
7	DQJY	20	1200	0.105	363	4.0
8	AZXJ	20	1200	0.156	316	4.2
9	DQGY	20	1200	0.129	336	4.1
10	DQJT	13	1200	0.082	172	3.8
11	DQKT	16	1200	0.308	52	4.8
12	AZPW	8	1200	0.020	272	3.5
13	DQGZ	18	1200	0.125	622	4.0
14	AZLA	19	1200	0.054	567	3.8
15	AZPN	16	1200	0.120	424	4.0
16	AZWL	18	1200	0.172	588	4.2
17	AZGA	14	1200	0.083	368	3.8
18	DTF	20	1200	0.116	378	4.0
19	AZBF	15	1200	0.044	517	3.7

Table 13-18. Network Line Characteristics (Continuation 1)

Network: TLETS Number of Regions: 3
Remarks: San Antonio Region

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	SXLP	10	2400	0.324	0	2.7
2	SXLE	12	1200	0.037	220	3.5
3	SXQP	19	1200	0.095	319	3.8
4	SXRK	19	1200	0.169	376	4.1
5	SXBQ	10	1200	0.090	341	3.6
6	SXGC	18	1200	0.172	310	4.1
7	SXSQ	4	1200	0.015	82	3.3

13.5 OPTION 4 - SEPARATE TLETS AND NEW DATA NETWORKS

13.5.1 Topology

Growth of new data types in Texas is such that communication facilities for these data types should be implemented in two phases. An initial network to handle traffic requirements through 1980 is shown in Figure 13-4. A complete network sufficient to handle predicted new traffic volumes from 1981 through 1985 is shown in Figure 13-5. Both networks are basically starred networks to provide desired response times at terminals.

Table 13-19 lists cities included in the network which functions through 1980 and Table 13-20 shows terminals to be added to make up the final new data network which functions from 1981 through 1985. The first network employs 14 terminals. In the second network 18 locations are added for a total of 32.

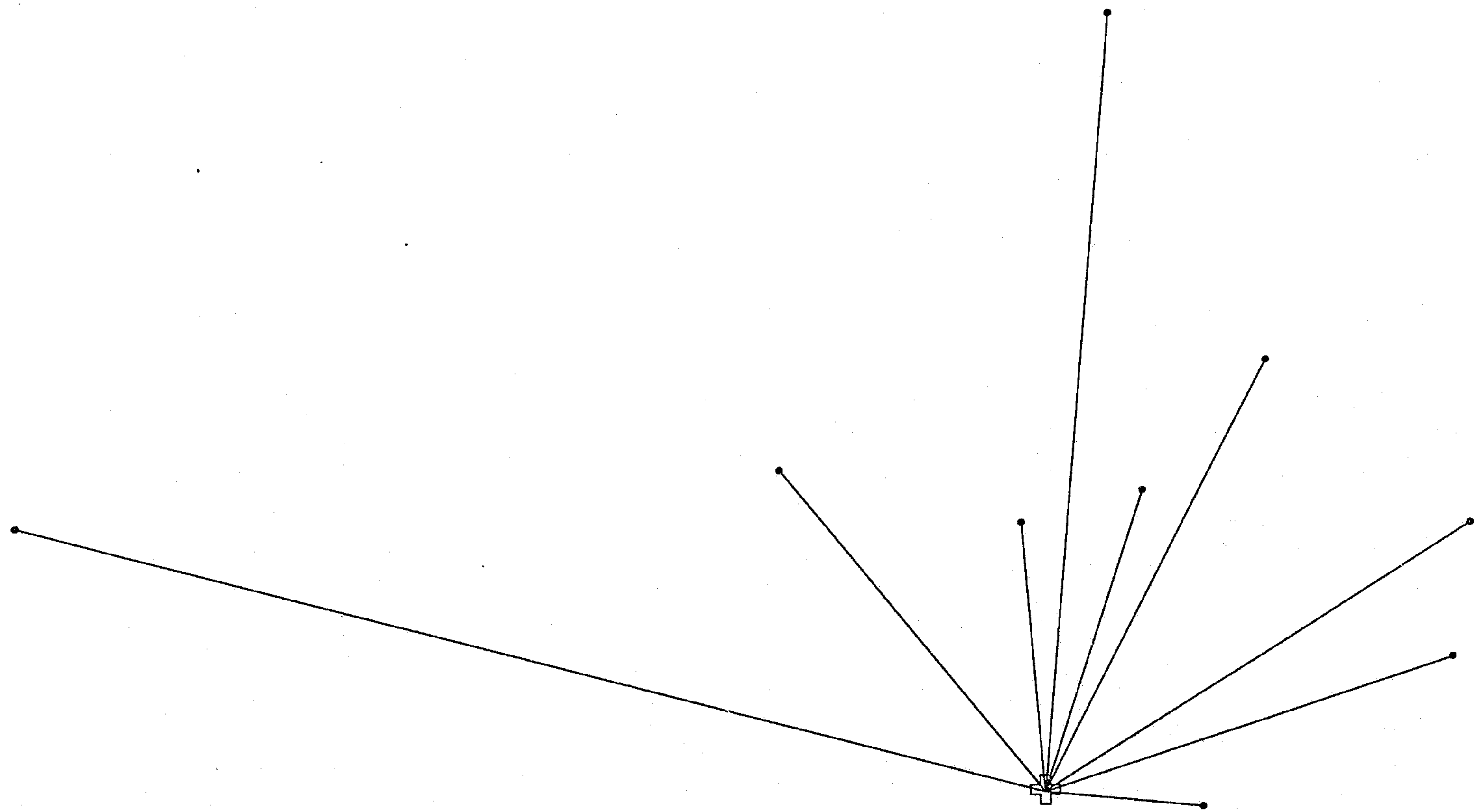

Figure 13-4. Texas Separate New Data Network
Through 1980

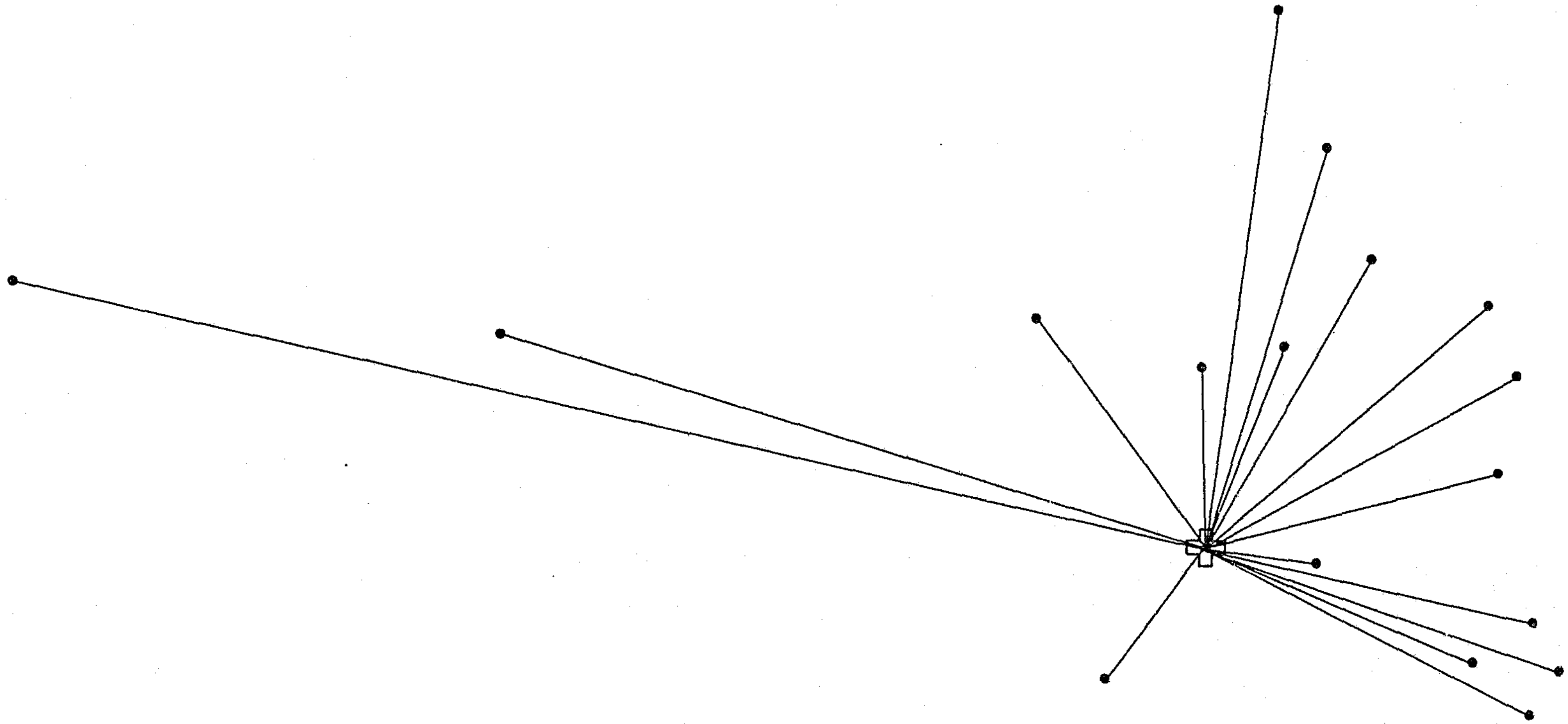

Figure 13-5. Texas Separate New Data Network
1981 Through 1985

Table 13-19. Separate New Data Terminals Through 1980

Code Name	Terminal Location
ICRA	ICR Data Conversion, Austin
TDCA*	TDC H.Q., Huntsville
BPPA*	BPP H.Q., Austin
TYCA	TYC H.Q., Austin
TYCB	Gatesville TYC, Coryel
TYCC	Gainesville TYC, Cooke
TYCD	Giddings TYC, Lee
TYCE	Brownwood TYC, Brown
TYCF	Corsicana TYC, Navarro
TYCG	Pyote TYC, Ward
TYCH	Waco TYC, McLennan
TYCI	Crockett TYC, Houston

*2 terminals, 1 each for CCH and OBSCIS

Table 13-20. Separate New Data Terminals to be Added to Those of Table 14.19 to Make up 1981 Through 1985 Network

Code Name	Terminal Location
CTAD	El Paso Courts
TDCC	Eastham CCH, Fodice
TDCG	Ramsey I CCH, Angleton
TDCI	Ramsey II CCH, Angleton
TDCK	Jester CCH, Stafford
TDCO	Goree CCH, Huntsville
CTAA	Dallas-Ft. Worth Courts
CTAE	Austin Courts
TDCD	Ellis CCH, Riverside
TDCH	Clemens CCH, Brazoria
TDCL	Retrieve CCH, Angleton
TDCP	Mt View CCH, Coryell
CTAB	Houston Courts
TDCE	Ferguson CCH, Weldon
TDCM	Central CCH, Stafford
CTAC	San Antonio Courts
TDCB	Coffield CCH, Palestine
TDCF	Wynne CCH, Huntsville
TDCJ	Darrington CCH, Alvin
TDCN	Huntsville Diag. CCH

13.5.2 Cost

Total eight-year costs for the separate new data network amount to $1,350,000 as shown in Table 13-21. Costs for lines, modems, service terminals and network terminals are broken down for required network phasing. It is assumed that the first network is built in 1978 and the second in 1981. As in previous costing, new terminals for the network are purchased.

It is assumed that new data type files, with the exception of CCH files, will be implemented at a new single computer facility in Austin. That is, functions of the TDC, BPP, TYC, OBSCIS and SJIS will be integrated on a single computer. Required mean service times for this computer are indicated in Table 13-22.

The costing of this computer is not included in the cost comparisons for Options 4 and 5. This does not invalidate the cost comparisons carried out here, since the comparative issue is network integration with TLETS lines versus separate new data network construction. In either case, a separate computer facility from the TCIC/LIDR and MVD facilities is called for.

13.5.3 Line Performance

Line performance characteristics for the 1981 through 1985 new data network are shown in Table 13-22. Mean response times vary between 11.9 seconds and 17.7 seconds for the lines. These response times are in keeping with functional requirements for these data types.

13.5.4 Network Availability

The network availability for the separate new data network is calculated at 0.974 which implies an average outage per day of 37.0 minutes. This assumes similar performance as in the single region TLETS Network.

13.6 OPTION 5 - AN INTEGRATED TLETS AND NEW DATA NETWORK

13.6.1 Topology

Integration of new data type terminals into the TLETS network involves a two-step implementation procedure as new data terminals are added to the network in the same manner that the separate new data network implementation is carried out. The network consists of a single region TLETS network with new data terminals added at appropriate points. Table 13-23 lists terminals assigned to the 43 lines called for in the integrated network of 1981-85. Six of the new data terminals remain connected in a star configuration and the remainder of the new data terminals are integrated into multidropped lines with law enforcement agencies.

Table 13-21. Network Option Costs in Thousands of Dollars

Network: New Data — Number of Regions: 1
Remarks: Separate New Data Network

Item	Recurring Costs					One Time Installation Costs			
	No. Reqd.	Annual Cost Each	Total Annual Cost To 1980	Total Annual Cost 1981-1985	Eight Year Cost	Unit Cost	Total Purchase Cost 1978	Total Purchase Cost 1981	Eight Year Cost by Item
Lines, Modems Service Terminals	-	-	51	121	758	-	1.8	2.6	762.4
Terminals	14/32*	1260	18	40	254	8.847	124	159*	537
Regional Switchers									
Switcher Floor Space									
Switcher Back Up Power									
Switcher Personnel									
Engineering							40	10	50
Subtotals					1,012		165.8	171.6	1,349.4
			Total Eight Year Cost:						1,350

*18 additional units

Table 13-22. Network Line Characteristics

Network: New Data Type   Number of Regions: 1
Remarks: Austin as Regional Center

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	ICRA	1	2400	0.512	0	14.6
2	CTAA	1	4800	0.611	181	11.9
3	CTAB	1	4800	0.544	147	11.3
4	CTAC	1	2400	0.473	73	13.7
5	CTAD	1	1200	0.364	530	17.7
6	CTAE	1	1200	0.362	0	17.7
7	TDCA	1	2400	0.367	134	13.2
8	TDCB	1	1200	0.180	162	16.0
9	TDCC	1	1200	0.180	154	16.0
10	TDCD	1	1200	0.163	134	15.8
11	TDCE	1	1200	0.150	154	15.6
12	TDCF	1	1200	0.140	134	15.5
13	TDCG	1	1200	0.128	159	15.4
14	TDCH	1	1200	0.088	159	15.1
15	TDCI	1	1200	0.077	159	15.0
16	TDCJ	1	1200	0.066	161	15.0
17	TDCK	1	1200	0.066	126	15.0
18	TDCL	1	1200	0.060	159	14.9
19	TDCM	1	1200	0.060	126	14.9
20	TDCN	1	1200	0.052	134	14.8
21	TDCO	1	1200	0.038	134	14.7
22	TDCP	1	1200	0.027	80	14.6
23	BPPA	1	2400	0.382	0	13.2
24	TYCA	1	1200	0.082	0	15.0
25	TYCB	1	1200	0.059	80	14.9
26	TYCC	1	1200	0.027	233	14.6
27	TYCD	1	1200	0.027	49	14.6
28	TYCE	1	1200	0.082	124	15.0
29	TYCF	1	1200	0.014	145	14.5
30	TYCG	1	1200	0.014	320	14.5
31	TYCH	1	1200	0.014	95	14.5
32	TYCI	1	1200	0.014	154	14.5

13.6.2 Costs

Total eight-year costs for the integrated TLETS New Data Type Network are $16,300,000 as shown in Table 13-24. The phasing for line reconfiguration and addition of 18 new terminals in 1981 is indicated.

13.6.3 Line Performance

Line performance for the integrated TLETS New Data Type Network is tabulated in Table 13-25. Response times vary from 2.5 seconds to 8.2 seconds. Line configurations are such that prioritization of law enforcement message types is not required.

13.6.4 Network Availability

Assuming data base upgrades called for in Section 13.1.2 are implemented, the availability of data bases to any terminal on the network is 0.974. This availability implies an average network daily outage at any terminal on the network of 37.0 minutes.

13.7 COMPILATION OF COST AND PERFORMANCE DATA - OPTIONS 1 THROUGH 5

Table 13-26 compiles cost and performance data presented in this section for each of the five STACOM/TEXAS Network options.

The next Section discusses these findings and also presents results of additional network studies carried out in Texas.

Table 13-23. Terminal Assignments

NETWORK OPTION: TLETS WITH NEW DATA TYPE

NUMBER OF REGIONS: 1

REGION	LINE NO.	TOTAL NO.	TERMINALS STARTING	TERMINALS REMAINING
1				
	1	10	SXLP	SXFS,S ,SXRJ,SXAY,AZZD,SXQS,SXYA,SXYB,SXQW,
	2	19	SXKA	NABX,SXGV,SXDJ,SXDK,SXBQ,SXBP,SXRC,SXRD,NAFB,SXBN, NACS,SXSD,SXBR,NAAK,SXDS,NACN,SXDL,SXDN,
	3	20	SXQP	NACA,SXGC,SXBK,SXBJ,SXBL,SXRT,SXBS,SXYF,NADX,NADN, SXAD,NADW,SXBI,NAAH,SXWT,SXIT,SXBW,NAAC,SXRZ,
	4	20	SXRK	SXRL,SXYJ,NACE,SXDA,SXRS,SHGH,SXRX,SXRN,SXRP,SXUL, SXYK,NAEU,SXRW,SXCO,SXHI,SXRR,SXRQ,NADZ,NAEA,
	5	19	SXDP	AZUN,NAEQ,TDCL,TDCI,TDCH,TDCG,AZAD,AZFA,AZAH,AZLS, AZFF,AZGP,NAEP,AZIP,AZIF,SXDF,SXDI,NABJ,
	6	16	AZUE	AZUD,AZBT,AZBU,AZDU,NADE,AZJU,AZKU,NACQ,NACR,AZFU, AZCU,NADF,AZEU,AZLU,AZUL,
	7	17	AZTE	AZQI,AZAC,AZBC,AZXY,AZNS,AZAX,AZAB,AZTD,AZAA,AZQJ, AZUP,AZJL,AZQL,AZTS,AZQK,AZPI,
	8	18	AZYI	NAEO,TDCM,AZAS,AZUA,NABU,AZKY,AZJY,AZYL,AZHU,NACE, AZIZ,AZID,NABR,TYCD,NAAG,NACX,AZFR,
	9	5	NAAN	NAAP,AZQN,NACC,NAAO,
	10	1	ICRA	
	11	1	CTAB	
	12	1	CTAC	
	13	20	CTAE	SXQQ,NABD,SXPR,SXSQ,SXKC,NAAD,SXSN,SXLE,NAAF,SXQX, SXRB,NABT,NACW,NABK,NABL,SXCC,NAFC,SXQZ,NAEK,
	14	20	TDCK	AZIC,AZAV,AUB ,AUH ,AZAV,AZCS,AZFH,AZFW,AZFL,AZZH, AZHN,AZIB,AZTY,AZFK,AZYN,AZSE,AZUJ,AZUK,AZPB,
	15	1	BPPA	
	16	18	TYCA	AZFI,AZFJ,AO+S,AZHC,AZLZ,AZAW,AZFD,AZIA,TDCJ,AZAN, AZYP,AZFB,AZFE,AZAU,AZIU,AZIU,AZYQ,
	17	13	AZUS	AZUS,AZNA,AZRK,AZUZ,AZZC,AZZA,TYCB,AZCN,AZXL,TDCP, AZZP,AZUQ,
	18	13	AZUX	TYCH,AZAF,AZXQ,NACY,AZXN,AZXK,AZXP,AZXW,AZGW,AZXS, AZXR,AZXI,

Table 13-23 Terminal Assignments (Continuation 1)

19	14	AZBN	AZAE,AZAI,NAAI,AZAJ,AZZB,NAEX,NAEV,NAEW,AZUW,AZAZ, NADO,NABZ,AZBX,
20	20	DQHT	DQHP,DQCF,DQHN,DQIT,DQHQ,DQHR,DQAD,DQFT,DQFT,DQDT, DQHJ,DQIH,NADP,DQHW,DQHS,DQHY,NABC,NABH,DQBY,
21	1	DTJ	
22	16	DTL	DQMJ,DQTR,DQTW,DQBD,DQGD,DQCS,DQRS,DQNA,DQCT,DQHL, DQHI,DQBT,DQRK,DQSU,DQHZ,
23	16	DQJH	DQIY,NACL,DQCW,DQJY,DQNU,DQNH,NADM,NABI,DQGS,DQKH, NACI,DQEA,DQEJ,NACD,DQAC,
24	21	DQGY	DQEE,DQDZ,DQKY,NAEG,NAAU,DQGX,DQLH,DQLY,DQER,DQPF, DQEC,DQEW,NABS,DQGS,DQKH,NACI,NAEZ,NAAK,NAAS,DQEZ,
25	12	DQJT	DQBH,NACT,AZUI,NACF,DQRD,DQHC,DQHE,DQHF,DQEY,DQVI, DQSL,
26	19	DQKT	DQCY,DTQ ,DQNW,DQLT,DQHA,DQHD,DQHT,DQHH,DQHB,DTC , DQZY,NAEF,NAED,DQBZ,DQCH,NAEE,DQDH,DQDU,
27	10	NAAN	NAAP,DQEN,DQDR,AZGN,DQEF,DQDW,TDCB,DQEP,NAAA,
28	1	CTAA	
29	1	TDCA	
30	14	TDCN	AZUF,AZXH,AZYC,AZRZ,AZAR,NADU,NADK,NAEH,TYCI,TDCE, TDCC,NACJ,NACK,
31	20	TDCO	DQEK,DQED,DQEL,DQEI,NADR,DQDX,NADT,NADY,NADT,NADS, NACO,NACP,NAEI,NADU,DQDQ,DQUT,NAEJ,TDCF,TDCD,
32	17	TYCF	DQHU,DQHX,DQGB,DQNB,DQBE,DQLX,DQCA,NABQ,TYCC,DQLZ, NABF,AZXJ,AZDA,DQCE,DQDC,DQHK,
33	10	AZJE	NAAJ,AZMJ,AZGE,AZBI,AZJF,AZJI,AZKJ,AZJD,NABO,
34	17	AZPW	NAAL,AZPS,NABE,AZWZ,DQAY,NABP,NACH,DQDY,DQGJ,DQGJ, NADG,NADH,AZPX,NABB,AZPZ,NADQ,
35	20	AZIJ	AZIK,AZJP,AZJA,AZZN,SXGF,SXGR,NAEL,NAEM,SXRA,NADA, AZZJ,TYCG,AZGQ,AZJC,AZJJ,AZIN,NAEY,AZIL,NAEN,
36	17	AZIS	AZIW,AZGM,AZIF,AZII,AZLJ,AZKS,AZIX,AZJK,AZLE,AZLF, NAFA,AZLN,AZIR,NABV,AZIQ,NAAB,
37	17	AZPN	AZPP,AZPL,AZPI,AZGL,AZLK,AZLL,AZLR,NABG,AZKW,AZPC, AZYE,AZXZ,AZLQ,AZPJ,AZPK,AZRB,
38	17	AZWL	NADL,AZAM,AZWJ,AZWK,NAAT,AZWE,AZWF,NABY,NACM,AZSP, AZWB,AZWA,AZSZ,AZND,AZWC,AZSX,
39	14	AZGA	AZQB,AZQC,NAAQ,NABM,AZQF,NABN,AZPF,NAFB,AZQE,AZPD,

Table 13-23. Terminal Assignments (Continuation 2)

			AZQD,AZPA,AZKD,
40	20	AZAG	AZQA,AZAG,AZBF,NAET,DQGZ,NAAY,NAAZ,NACB,AZWI,AZWW,NAER,AZZL,AZJZ,AZJO,NADJ,CTAD,AZJP,AZZI,AZZF,
41	15	DTF	DQGI,AZJR,AZJS,AZKK,AZKP,AZKR,AZJW,AZKQ,NARA,AZKN,DQEH,AZKL,NAES,AZKF,
42	16	NAAM	AZGG,AZUR,NACV,NACZ,SXQR,NARW,SXGK,SXRF,NACU,SXBE;NADV,AZZR,NADB,AZZW,AZZX,
43	20	TYCE	AZLA,AZLB,AZTI,AZLC,AZKA,AZLD,NACG,AZKK,AZWR,NAAV;AZWN,AZWP,AZWQ,AZWX,AZLI,NAAE,AZZK,AZWS,NAEC,

Table 13-24. Network Option Costs in Thousands of Dollars

Network: TLETS Network with New Data — Number of Regions: 1
Remarks: A Single Integrated Network

Item	Recurring Costs					One Time Installation Costs			
	No. Reqd.	Annual Cost Each	Total Annual Cost To 1980	Total Annual Cost 1981-1985	Eight Year Cost	Unit Cost	Total Purchase Cost 1978	Total Purchase Cost 1981	Total Eight Year Cost by Item
Lines, Modems Service Terminals	-	-	620	634	5,030		38	2	5,070
Terminals	578/596	1,260	729	751	5,942	8,847	5,100	159*	11,201
Regional Switchers									
Switcher Floor Space									
Switcher Back up Power									
Switcher Personnel									
Engineering									
Subtotals					10,972		5,138	161	16,271
Total Eight Year Cost									16,300

*18 Additional Units

Table 13-25. Network Line Characteristics

Network Remarks	TLETS with New Data Type Austin as Regional Center	Number of Regions	1

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	SXLP	10	1200	0.637	73	8.2
2	SXKA	19	1200	0.144	469	4.7
3	SXQP	20	1200	0.179	356	4.8
4	SXRK	19	1200	0.167	433	4.8
5	SXDP	19	1200	0.431	269	6.7
6	AZUE	16	1200	0.201	320	4.9
7	AZTE	17	1200	0.241	0	4.8
8	AZYI	18	1200	0.140	352	4.6
9	NAAN	5	1200	0.020	59	3.9
10	ICRA	1	2400	0.524	0	3.9
11	CTAB	1	2400	0.595	147	2.5
12	CTAC	1	2400	0.486	73	3.4
13	CTAE	20	1200	0.437	374	6.3
14	TDCK	20	2400	0.638	156	5.7
15	BPPA	1	2400	0.390	0	3.2
16	TYCA	19	1200	0.305	313	5.6
17	AZUS	13	1200	0.168	143	4.6
18	AZUX	13	1200	0.153	176	4.6
19	AZBN	14	1200	0.063	255	4.2
20	DQHT	20	1200	0.308	297	5.6
21	DTJ	1	4800	0.472	181	2.2
22	DQSU	16	1200	0.296	181	4.8
23	DQJH	16	1200	0.090	394	4.4
24	DQGY	19	1200	0.136	451	4.6
25	DQJT	12	1200	0.122	254	4.4
26	DQKT	19	1200	0.316	213	5.6
27	NAAW	10	1200	0.250	278	5.0
28	CTAA	1	4800	0.668	181	2.9
29	TDCA	1	2400	0.375	134	3.2
30	TDCN	14	1200	0.427	279	6.5
31	TDCO	20	1200	0.421	473	6.6
32	TYCF	17	1200	0.161	369	4.7
33	AZJE	10	1200	0.185	549	4.7
34	AZPW	17	1200	0.065	356	4.3
35	AZIJ	20	1200	0.136	698	4.7
36	AZIS	17	1200	0.082	523	4.4
37	AZPN	17	1200	0.129	550	4.6

Table 13-25. Network Line Characteristics
(Continuation 1)

Network TLETS with New Data Type — Number of Regions 1
Remarks Austin as Regional Center

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
38	AZWL	18	1200	0.170	661	4.8
39	AZGA	14	1200	0.082	386	4.3
40	AZAG	20	1200	0.457	1078	6.5
41	DTF	15	1200	0.080	446	4.3
42	NAAM	16	1200	0.051	317	4.2
43	TYCE	20	1200	0.135	623	4.6

Table 13-26. Compilation of Cost and Performance Data
for Texas Options 1 Through 5

	Option	1	2	3	4	5
	Network	1 Region	2 Region	3 Region	Separate TLETS, New Data	TLETS plus New Data
Item	Parameter					
1	One Time Cost ($K)	5.2	5.3	5.2	5.6	5.2
2	Eight Year Recurring Cost ($K)	10.6	11.8	13.3	11.6	11.0
3	Response Time (sec)	5.0	5.0	5.0	5.0/ 15.0*	6.7
4	Availability	0.979	0.973	0.973	0.979	0.979

*15.0 on separate New Data Network

SECTION XIV

STACOM/TEXAS NETWORK COMPARISONS

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STACOM/TEXAS NETWORK COMPARISONS

This section provides a comparative overview of the five STACOM/TEXAS Network Options and also presents results of three additional studies. One additional study assesses the impact on network costs of reducing response time at terminals to less than the 9 seconds called for in the STACOM/TEXAS Functional Requirements. A second study deals with impacts on the TLETS network due to inclusion of classified fingerprint data. The third additional study investigates the potential for line savings if network multidropping is carried out without the restriction of serving C.O.G. agencies on separate lines.

14.1 COMPARISON OF THE THREE TLETS OPTIONS

Each of the three TLETS options, Options 1 through 3 involving the use of 0 to 2 regional switchers, in addition to the existing Austin Switcher, have been designed to meet or exceed STACOM/TEXAS Functional Requirements. The principal issue of comparison between networks thus becomes cost. Costs presented here, and in the previous Section 13, are based upon total eight-year installation and recurring costs for the year 1978 through 1985 as developed in Section 10.

Figure 14-1 presents total eight-year costs for Options 1, 2 and 3. The single region TLETS network is the least expensive. The best two region case with switchers in Austin and Dallas, and the best three region case with switchers in Austin, Dallas and San Antonio follow with increasing total costs.

The network with the least recurring line costs is the three region Austin, Dallas, Houston configuration (see Section 13). The network with the greatest recurring line cost is found in the three region Austin, Dallas, San Antonio case. However, the latter case exhibits lowest overall costs for three regions, since the eight-year difference in line costs does not justify the movement of switchers.

In any case, the single region network is the least cost network. These results show that line savings due to the use of regional switchers located throughout the state do not offset the additional costs incurred for regional switcher hardware, sites, personnel, interregion lines and increased engineering costs encountered in a more complex network.

Since all networks meet functional requirements, the conclusion is that the STACOM/TEXAS single region network is the most cost-effective option of the first three options.

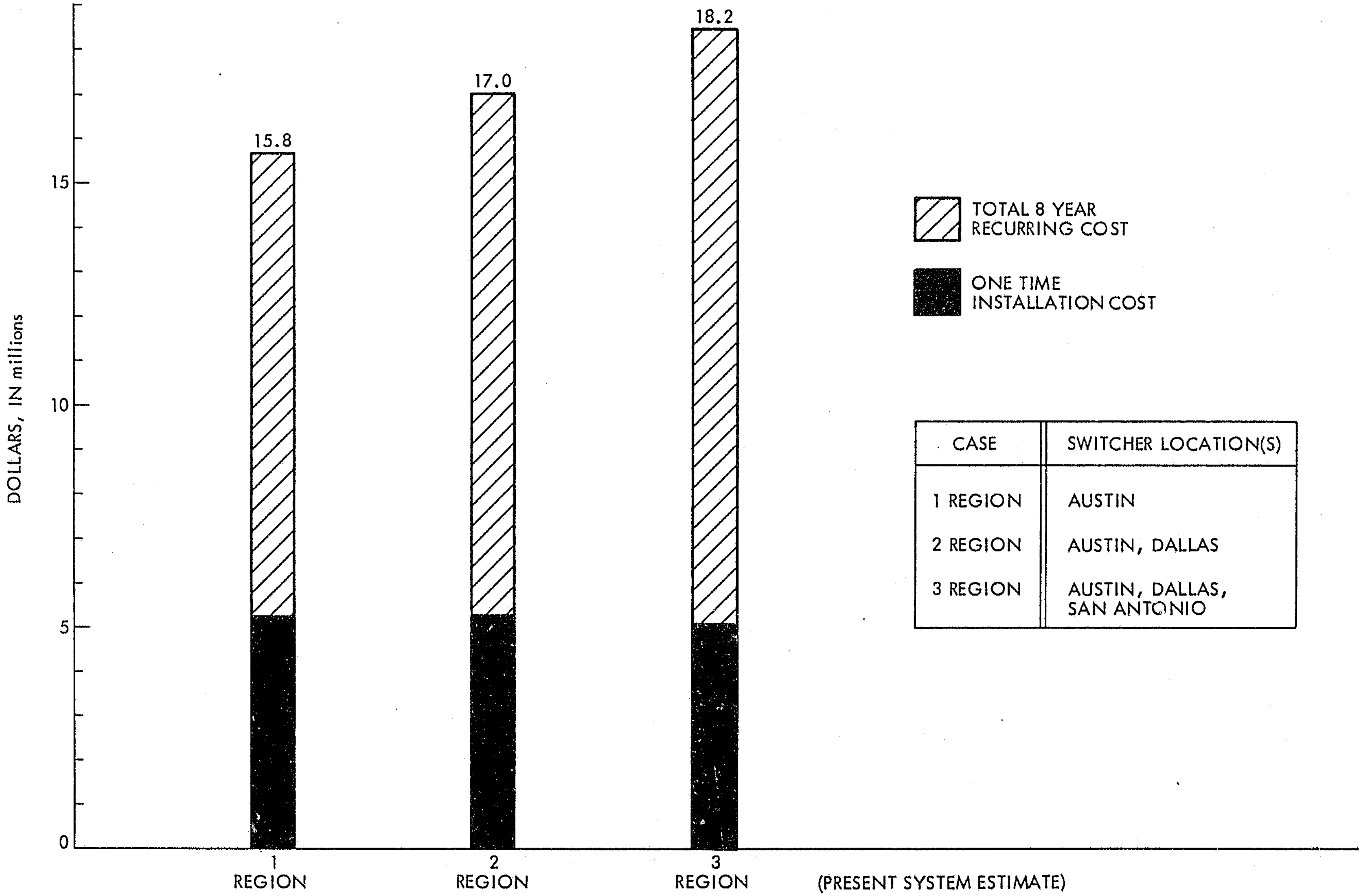

Figure 14-1. Total Comparative Cost 1978 Through 1985
Options 1 Through 3

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14.2 SEPARATE VS INTEGRATED TLETS/NEW DATA NETWORK(S)

Whether integrated with the TLETS Network or not, the estimated growth of new data types from the present until 1985 calls for the implementation of 14 terminals through 1980 and the addition of 18 more terminals in 1981, for a total of 32 operational terminals from 1981 through 1985. This means that in either case there is an additional one-time installation cost incurred in 1981.

When installation and recurring costs are totaled over an eight-year period for the separate and integrated configuration, the costs are as shown in Figure 14-2.

If the TLETS and New Data networks were to be implemented as two separate networks, the total eight-year comparative cost is $17,150,000, or approximately 17.2 million as shown. If network lines are integrated in accordance with Option 5, the total cost is $16,300,000. The eightyear estimated difference is $850,000.

The monetary benefits of integration over an eight-year period are significant enough to come under consideration in the management decision to implement Options 4 or 5.

Mean response time requirements are met in the integrated network without a need for message prioritization.

14.3 NETWORK COST SENSITIVITY TO RESPONSE TIME

The effect of reducing network response time on annual recurring costs for lines, modems and service terminals in the single region TLETS case, (Option 1), was investigated. Network optimization computer runs were carried out at a number of points where the required response time was set at less than 9 seconds. The program then found the required networks and produced costs for each run.

Figure 14-3 shows the results of this analysis, which was carried out with the same mean service times for the Austin Switcher and Data Base Computers used in Option 1 runs to clarify the effect on network costs. The figure shows that for the STACOM/TEXAS single region TLETS network, there is virtually no cost penalty for specifying a response time down to approximately 7.0 seconds. Stating the case alternatively, a network that meets a 9.0 second response time requirement also meets a 7.0 second requirement.

A slight increase in cost begins to appear at 6.0 seconds, due primarily to the reduction of the number of multidropped terminals on some of the lines. This reduction is required to meet the lower response time goal.

A substantial increase in cost of about 10% is required to realize a reduction in response time from 6.0 to 5.0 seconds. Reductions in mean response time requirements below 5.0 seconds begin to result in rapidly increasing costs.

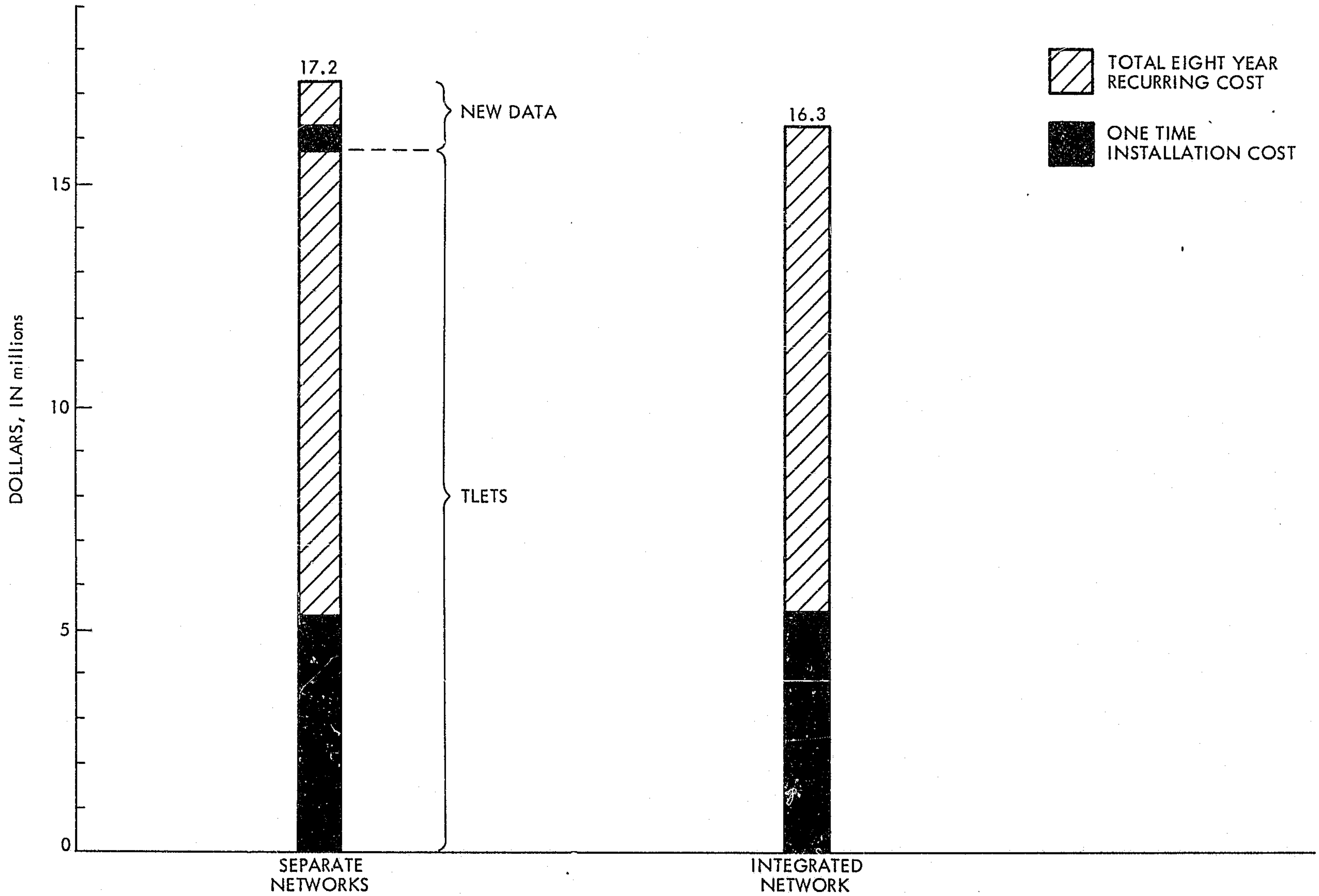

Figure 14-2. Eight Year Comparative Costs Separate and Integrated TLETS/New Data Networks

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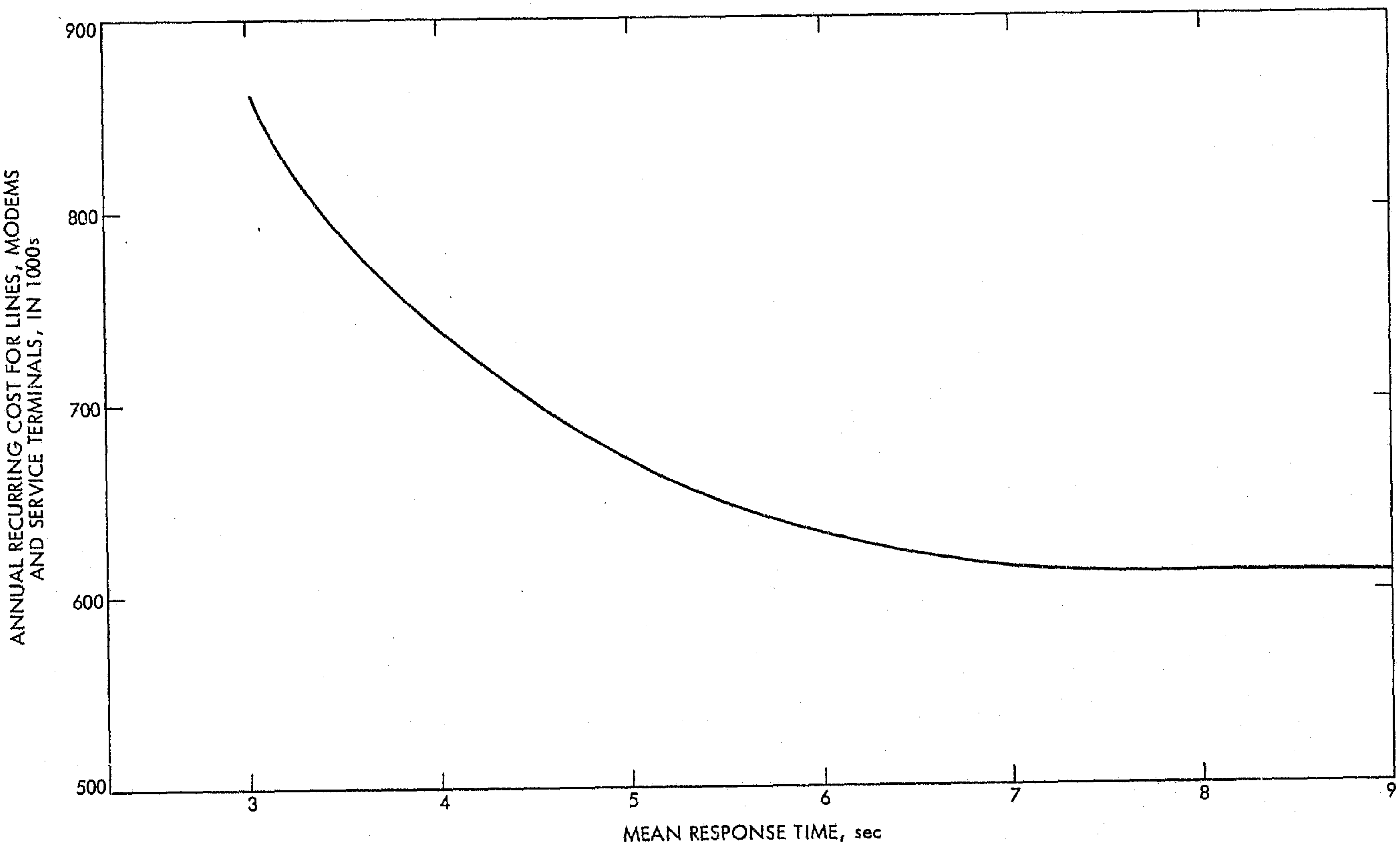

Figure 14-3. Recurring Annual Line Costs vs Mean Response Time -- TLETS Single Region

14.4 IMPACT OF FINGERPRINT DATA ON LEADS NETWORK

14.4.1 Topology

Predicted growth of fingerprint data types is contingent on the development and use of digitizer and classifying equipment located in major Texas cities. The STACOM Study implementation schedule calls for a first digitizer/classifier to be located in the Dallas-Ft. Worth area in 1981 and three more to be added to the system in 1983 at Houston, San Antonio and El Paso. The incorporation of these facilities involves a slight modification to the topology of the single region TLETS case, (see section 13.2). The TLETS Network with fingerprint data added as specified requires a total of 36 multidropped lines. These lines, and their principal characteristics, are summarized in Table 14-1.

14.4.2 Costs

Total eight-year costs for a TLETS Network which handles fingerprint data are broken down in Table 14-2. Costs for the LEADS System from 1978 to 1985 are shown separately. In 1981, the incremental costs for the first terminal in Dallas are shown. These costs are incurred through 1985. The three-year costs for the addition of the final three terminals in 1983 through 1985 are also listed.

Total eight-year costs are $16,537. Costs for lines, modems, and service terminals, (listed as LINES in Table 14-2), account for about 8% of the eight-year cost increase over the single region LEADS without fingerprints and the costs for fingerprint processing equipment accounts for 92% of the additional cost.

As indicated in Table 14-2, the purchase cost for a single fingerprint digitizer-classifier is estimated at $200,000 per unit. Annual maintenance is assumed to run at $12,000.

14.4.3 Performance

The principal performance question of interest when considering the addition of messages with long average message lengths, such as fingerprint data, to the TLETS Network is the potential degrading effect on response times for higher "priority" type messages involving officer safety.

An analysis of the mean and standard deviation of message service times on the TLETS Network with fingerprint data added, indicates that mean response time goals specified in the STACOM/TEXAS Functional Requirements will be met satisfactorily without the necessity of message prioritization by the computer.

This result stems from two considerations. First, the classification of fingerprint data allows for substantial reductions in the actual amount of data characters transmitted for each fingerprint (1852 characters). Second, while this message length is still

Table 14-1. Network Line Characteristics

Network TLETS with Fingerprint — Number of Regions 1
Remarks Austin as Regional Center

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	SXLP	10	1200	0.640	73	9.0
2	AZID	20	2400	0.608	154	5.0
3	AZFI	17	1200	0.156	313	4.4
4	SXKA	19	1200	0.144	469	4.4
5	SXQP	19	1200	0.069	344	4.1
6	SXRK	19	1200	0.168	433	4.5
7	AZUE	16	1200	0.202	320	4.6
8	SXGC	18	1200	0.121	350	4.5
9	AZTE	20	1200	0.247	70	4.9
10	AZUN	18	1200	0.100	304	4.2
11	FPAB	1	2400	0.545	147	3.5
12	FPAC	17	1200	0.528	375	6.4
13	AZUS	11	1200	0.083	143	4.0
14	AZUX	17	1200	0.114	396	4.2
15	AZBN	14	1200	0.064	255	4.0
16	DQHT	20	1200	0.309	297	5.2
17	DTJ	17	4800	0.549	181	2.7
18	DQHU	10	1200	0.094	309	4.0
19	DQEK	17	1200	0.076	441	4.1
20	AZXJ	16	1200	0.145	286	4.3
21	DQGY	19	1200	0.136	451	4.4
22	DQJT	12	1200	0.123	254	4.2
23	DQKT	19	1200	0.318	213	5.3
24	AZUF	19	1200	0.095	449	4.2
25	FPAA	1	2400	0.626	181	3.9
26	AZPW	17	1200	0.065	356	4.1
27	AZIJ	19	1200	0.124	698	4.3
28	AZLA	19	1200	0.053	623	4.1
29	AZIS	17	1200	0.083	523	4.1
30	AZPN	17	1200	0.136	550	4.3
31	AZWL	18	1200	0.171	661	4.5
32	AZGA	14	1200	0.083	386	4.1
33	AZAG	9	1200	0.437	706	6.0
34	DTF	15	1200	0.080	446	4.1
35	AZBF	11	1200	0.025	489	3.8
36	NAAM	16	1200	0.051	317	4.0

Table 14-2. Cost Summary by Year for TLETS Network with Fingerprint Data

Year(s)	Item	Number Required	Annual Cost Each	Total Annual Cost	Eight-Year Recurring Cost	Unit Cost	Total Purchase Cost
1978-1985	Lines	-	-	615	4,928	-	37
	TLETS Terminals	564	1,260	711	5,700	8.847	5,000
1981-1985	Lines*	-	-	3.2	16	-	.22
	Fingerprint* Terminals	1	12	12	60	200	200
1983-1985	Lines*	-	-	5	15	-	1
	Fingerprint* Terminals	3	12	36	108	200	600
					10,827		5,838
				Total Eight Year Cost			16,665

*Added Costs in Years Shown

comparatively long with respect to the normal TLETS message types, the occurrence of fingerprint messages on the network accounts for only about 1% of the total traffic predicted for 1985.

For these reasons, the mean response time goal of less than, or equal to 9 seconds is met for the network topology presented above.

14.5 LINE SERVICE TO COUNCIL OF GOVERNMENTS

In the present TLETS system, multidropped lines providing service to agencies throughout the state are organized such that single multidrop lines service agencies in jurisdictions of a single Council of Governments (COG).

A study was carried out to compare costs of the single region TLETS network, (Option 1), in which multidropped lines were not restricted to servicing single C.O.G. areas only, and costs for a single region TLETS network in which multidropped lines were organized to service single COGs.

The resulting COG-oriented network is shown in Figure 14-4. Annual recurring line costs for this network amount of $617,000 as compared with $611,000 for he unrestricted multidropping Option 1 case. Since all other network costs are comparable, the difference of $6,000 per annum over eight years amounts to $48,000. This difference is not considered significant when compared to overall network costs. The result is that significant cost savings are not to be realized in the abandonment of a COG oriented approach.

Performance characteristics for the network pictured in Figure 14-4 are presented in Table 14-3.

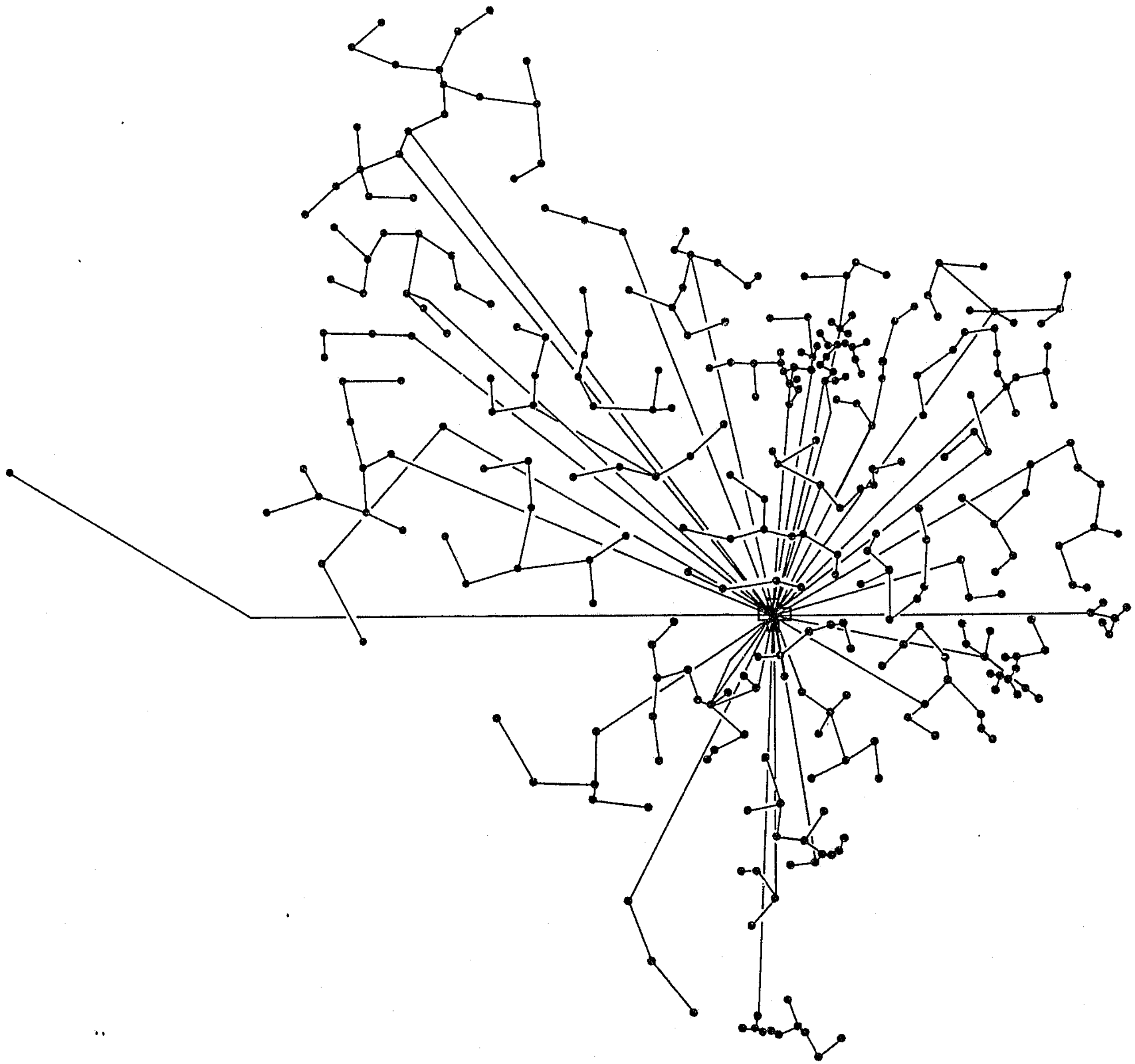

Figure 14-4. TLETS Single Region COG Oriented Network

Table 14-3. Network Line Characteristics

Network TLETS Under COG Structure — Number of Regions 1
Remarks Austin as Regional Center

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
1	S	1	2400	0.302	73	2.6
2	AZZD	20	1200	0.102	305	3.9
3	NACA	8	1200	0.030	96	3.5
4	NAEG	17	1200	0.095	491	3.9
5	NAEO	13	1200	0.059	261	3.7
6	AZRI	17	1200	0.243	0	4.5
7	NAAP	8	1200	0.025	128	3.5
8	NAEW	5	1200	0.011	107	3.4
9	AZUS	17	1200	0.119	245	4.0
10	SXBP	7	1200	0.052	247	3.5
11	SXBJ	18	1200	0.173	358	4.2
12	AZAG	12	1200	0.074	469	3.7
13	DQDR	18	1200	0.083	506	3.9
14	DQEK	20	1200	0.104	448	4.0
15	NAAX	8	1200	0.077	264	3.6
16	NABX	14	1200	0.067	224	3.7
17	AZXR	15	1200	0.127	249	3.9
18	AUB	1	2400	0.495	147	3.4
19	AZHN	20	1200	0.241	196	4.5
20	AZIB	18	1200	0.157	308	4.1
21	AZYC	6	1200	0.053	185	3.5
22	NAEQ	18	1200	0.098	317	3.9
23	SXRL	18	1200	0.163	399	4.1
24	NAEK	12	1200	0.048	323	3.6
25	DQHT	28	1200	0.310	297	4.9
26	DTJ	1	2400	0.472	181	2.2
27	DQSU	16	1200	0.296	181	4.7
28	AZDA	10	1200	0.061	280	3.6
29	DQJT	18	1200	0.243	261	4.5
30	DTQ	20	1200	0.266	298	4.6
31	AZJS	15	1200	0.081	453	3.8
32	NAET	6	1200	0.017	365	3.4
33	AZWJ	20	1200	0.104	789	4.0
34	NADL	12	1200	0.098	579	3.8
36	AZIW	5	1200	0.024	444	3.4
37	AZII	20	1200	0.130	561	4.1
38	AZDU	11	1200	0.156	270	4.0
39	AZLL	18	1200	0.138	617	4.1

Table 14-3. Network Line Characteristics
(Continuation 1)

Network Remarks: TLETS Under COG Structure, Austin as Regional Center — Number of Regions: 1

Line No.	First Node	No. of Terminals	Line Type (Baud)	Line Utilization	Total Mileage (mi)	Mean Response Time (sec)
40	AZKS	6	1200	0.017	388	3.4
41	SXRD	5	1200	0.047	307	3.5
42	DQBE	8	1200	0.060	304	3.6
43	AZPW	18	1200	0.050	462	3.8
44	NAAL	14	1200	0.082	355	3.8
45	NAAV	10	1200	0.187	549	4.1

END