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Total Network Data System:

Environment and Objectives

By A. L. BARRESE,* D. E. PARKER,† T. E. ROBBINS,* and L. M. STEELE*

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Planning for computer-based tools to help in the measurement and analysis of network traffic data began in the late 1960s. During this same period, the rapid introduction of computer technology was changing the character of the network. The network was becoming more efficient and economical but, at the same time, more sophisticated and complex. This intensified the need to provide timely and complete information to those responsible for the management, administration, engineering, and planning of the network. The computer-based systems that were developed to meet this need are collectively called the Total Network Data System (TNDS). This paper discusses the operating environments of the network and telephone company, and provides a framework for the remainder of the papers in this issue.

I. INTRODUCTION

Managing, engineering, and planning the telecommunications network are essential tasks for the future health and vitality of the network. These complex tasks cannot be performed effectively without detailed data about network traffic. The Bell System has mechanized the collection and processing of such data with a family of computer-based systems collectively called the Total Network Data System

* Bell Laboratories. † AT&T.

(TNDS). This paper provides an overview of the telecommunications network environment, introduces the need for network traffic data in the operating environment of the telephone company, and briefly discusses the primary mechanization objectives for collecting and processing the network traffic data through the TNDS.

II. THE TELECOMMUNICATIONS ENVIRONMENT

To appreciate the need for network traffic data, it is necessary to have a general understanding of the telecommunications network.

2.1 Network description

In the most general sense, a network can be defined as a set of nodes interconnected with links. We can further define the telecommunications network (hereafter referred to as "the network") both on the basis of its function and its physical characteristics. From a functional standpoint, the network carries a variety of telecommunications traffic (e.g., voice, data) between a number of stations that can be connected on demand, or that are permanently connected. From the physical standpoint, the network consists of switching systems (nodes), transmission facilities (links), and stations (sources and receptors of traffic) that are connected together in an organized and controlled manner. These two views are complementary and together provide a framework for understanding aspects of telephone engineering and operations.[1]

Let us examine the physical elements of the network more closely. To construct a telecommunications network that would allow complete, direct interconnection of all stations would be both impractical and cost prohibitive. Therefore, every large communications network is based on the principle of shared facilities, whereby facilities that can be shared among different elements of traffic are utilized extensively when designing and building the network. Central offices are entities built to provide switchable interconnection of customer stations. A central office allows each of its customers, with a single pair of wires connected to the office (i.e., the customer's loop facilities), to talk to any other customer served by that office. Such a central office, having customer station equipment directly connected to it, is said to serve "local" traffic from those stations.

In general, however, customer stations being connected are served by different central offices. Therefore, central offices are connected to one another by transmission paths called trunks, so that customers in one office can reach customers in another. The network of trunks interconnecting central offices is referred to as the Interoffice Facility Network. To enable all stations in the network to be interconnectable while making efficient use of network equipment and facilities, switching and trunking arrangements employ a hierarchical network configuration and the principle of automatic alternate routing.[1] [A new traffic routing technique called Dynamic Non-Hierarchical Routing (DNHR), planned for deployment in the intercity network beginning in 1984, promises significant cost savings in the network.]

The hierarchical network configuration provides for the collection and distribution of traffic and permits switching systems to be completely interconnectable. The hierarchical aspect prevents "loop arounds" that might otherwise occur when calls are automatically alternate routed through the network. Each switching system is given one of five classifications based on the highest switching function performed within the hierarchy, its interrelationship with other switching systems, and its transmission requirements.

With the automatic alternate routing principle, a call that encounters an "all trunks busy" condition in the interoffice facility network on the first route tested is automatically offered sequentially to one or more alternate routes for completion, if such alternate routes are possible for that item of traffic. Arrangements, defined by the Network Routing Plan, that dictate the final routing of traffic are called "homing arrangements." Central offices whose only function is to route calls through the hierarchy are called toll offices. These offices do not directly serve customers (i.e., do not have any connecting loop facilities). Regional Centers, the switching systems at the top of the switching hierarchy, are examples of toll offices. Many central offices perform a tandem switching function (i.e., route traffic by simply interconnecting interoffice trunk groups). These offices may perform a pure tandem switching function or they may also function as local or toll switching systems.

2.2 The concept of service

Because only a small percentage of telephone customers originate calls at any time, the amount of equipment needed to carry the actual simultaneous traffic is only a fraction of that needed to carry simultaneous traffic from all customers. If we install a very limited amount of equipment, there is no assurance that we can meet service demands satisfactorily at all times. Therefore, we can anticipate that a percentage of calls will not be completed (i.e., will be "blocked") during peak traffic periods [e.g., during the busiest hour(s) of the day, during the busy season (busiest three months) of the year]. When calls are "blocked" too frequently, calling customers perceive service as unsatisfactory. Conversely, if we have too much equipment in the network, too much of it will remain unused even during peak traffic periods, which is not cost effective.

The proportion of calls blocked during the busy hour of a switching system is an index of the grade of service rendered. We define the grade of service as the probability that a certain percentage of calls originated during the busy hour will be blocked from utilizing the installed equipment and network facilities. There are strong justifications for providing a high grade of service (i.e., low probability of calls being blocked). For example, when a customer must dial a number more than once because of failure to properly connect, it generates additional traffic, and during peak periods this further aggravates poor service conditions. Acceptable service levels are determined by analyzing both network traffic data and customer reactions.[2] Objective grades of service, or service objectives, are established to balance customer service and network cost. It is the effort to strike a cost-effective balance between providing service and utilizing network equipment that imposes the need for network traffic data.

2.3 Requirements for network data

There are four key network functions that require network traffic data: network management, network administration, network design, and long-range network planning. The function of network management is to control network traffic overloads by distributing loads among circuits and equipment to meet customer service demands in a way that is best from a total network viewpoint. To do this, network management requires a near-real-time view of the traffic in the network. This is made possible through analysis of network traffic data.

The function of network administration is to control the assignment of lines and trunks to take maximum advantage of the installed equipment in the central office for serving the offered call traffic. This involves implementing a plan to spread the office load efficiently over all equipment, as well as to monitor the current load, service levels, and office capacities. A major task within network administration is to use traffic data to monitor the flow of traffic through the central office and to detect changes in office performance (e.g., service degradation) or in offered load. Network administration includes the task of providing sufficient, accurate network traffic data for all functions.

The function of network design is to estimate where, when, and how much equipment will be required within a five-year period so that the necessary additional equipment (i.e., relief equipment) can be ordered and installed in time to satisfy the service objectives.[4] This activity requires data that reflect traffic volumes being carried by existing equipment, as well as knowledge of equipment capacities.

The function of long-range network planning is to determine the most economic growth and replacement strategies for the network to meet estimates of future demand. This future demand is estimated using current traffic load trends and marketing information. The basic output of this function is a broad view of network topology 20 years into the future. Section 3.3 further discusses these key network functions relative to telephone company operations.

In addition to the network functions discussed above, the Bell Operating Company (BOC) marketing organizations request network traffic data to aid in the administration and provisioning of each individual customer's telecommunications service. Due to such factors as increased availability of Stored Program Control (SPC) features and vertical services, increased data sophistication of subscribers and increasing competitive pressures, the number and frequency of these traffic data requests have been increasing consistently. Regulatory needs for these data have also appeared. For example, to support requests for rate increases before regulatory bodies, the BOCs conduct very detailed traffic studies. Regulatory study data requests tend to be complex and difficult to anticipate. These marketing and regulatory needs are only examples of a growing family of special applications that require network traffic data. Though they don't constitute a basic network function, they do represent a significant environmental element that must be considered when planning for the collection and processing of traffic data.

Another function requiring traffic data is operator services force administration. This function involves forecasting the load that will be offered in each half-hour and determining the operator force necessary to carry that load at an objective grade of service. This requires data on traffic volumes, service, and force levels. Because this function has limited interaction with the above-defined key network functions, its data tend to follow a separate but somewhat parallel flow that will not be discussed in this article.

2.4 Network data

The fundamental types of traffic measurements include:

1. Event counts—These measurements simply represent the number of occurrences of an event that occurred in a specific time interval (e.g., hour ending 11:00). "Offered" calls are termed *peg* counts, while "blocked" calls are termed *overflow* counts.

2. Usage—These measurements represent the estimated amount of time an equipment component was busy during a specific time interval, generally an hour. In electromechanical (EM) switching systems, usage is typically obtained through a separate, special measuring device, the Traffic Usage Recorder (TUR). In SPC switching systems, usage measurements (as well as the others) are generated internally by the switch.

3. Delay—This type of measurement usually indicates, on the average, how long a particular type of event would have been delayed, say by an all-servers-busy condition, if it had chosen to wait. Some

different measures of delay include: average delay, average delay of events delayed, probability of delay, and probability of delay exceeding some specified time interval.

4. Status—This measurement, used for network management and administration, indicates the presence or absence of a condition (e.g., equipment outage, severe overload) and is usually in the form of a lamp indication.

With few exceptions, measurements are made at the location of the switching system. All switches make some traffic measurements internally. The interfaces for data collection from EM systems are traffic register leads for peg count, overflow, grouped usage and delay, as well as status-indicating leads. In the case of EM systems, it is usually necessary to provide special traffic measurement equipment (e.g., the TUR) at the switch location. This equipment, in conjunction with special software in the data collection machine, makes possible the gathering of more detailed individual circuit usage data rather than circuit group data. This concept, used for selected EM offices to help increase data accuracy, is called Individual Circuit Usage Recording (ICUR). For SPC switching systems, traffic measurements and status indications are collected by the basic internal programs. The information, equivalent to that stored in EM registers, is retained in memory until the accumulated results are read out on schedules established by the users.[4]

In the Bell System, the volume of network traffic data processed is overwhelming. It was estimated that in the average BOC, over 50 million pieces of traffic data per week were collected and processed in 1980 to support the management, administration, design, and long-range planning of the network.[3] Because of the size, complexity, and importance of the network data job, the management of the data has become a major internal function of the BOCs.

Next we discuss another fundamental element of the network data system environment—the BOC operational environment.

3. THE OPERATIONAL ENVIRONMENT

3.1 Operations planning

Planning for modern computer-based tools to help in the measurement and analysis of network data began in the late 1960s. During this same period, the rapid introduction of computer technology was changing the character of the network. The network was becoming more efficient and economical but, at the same time, more sophisticated and complex. The people responsible for the network's day-to-day operation (i.e., management, administration, engineering and planning) needed more timely and complete information. Bell System management recognized that the largely manual methods in use during the 1960s could not keep pace with the emerging operational needs of the 1970s and 1980s.

Three properties of network data made the planning of computer-based support tools particularly challenging.

1. The data are almost useless until they are processed.

2. A much larger volume of data must be gathered than will be used ultimately because of the way that data are generated and output by the SPC switch and the external measurement devices of the EM switch.

3. The same basic data must be summarized in varying ways to meet the needs of a diverse family of users (see Section 3.3).

Measurement, data processing, and user applications must, therefore, be considered together in planning for the mechanization of an "end-to-end" flow of data.

The formulation of such an end-to-end view of the data flow requires an understanding of the functions performed by various work groups and how these groups relate to one another. This allows the formulation of requirements that describe how the work groups can best be supported by computer-based tools. Finally, the tools must be related to one another and to the elements of the telecommunications network. This concept of a process view, encompassing functions to be performed by people and computers, has been one of the principles used in the design of the individual components, termed *Operations Systems* (*OSs*), that comprise the Total Network Data System (TNDS).[4]

This view of the overall data flow not only facilitated the allocation of functions to the specific TNDS-related OSs, but also resulted in the identification of functions that must be performed by people. Consequently, work groups, termed *operations centers*, were established to oversee the operation of the elements of TNDS and ensure the integrity of the process. The allocation of functions among people and computers, together with a specification of how they interact to accomplish an overall process, was among the initial efforts in a general discipline known as *operations planning*.

Since then, the concept of operations planning has been expanded to encompass virtually all areas of telephone company operations. It is an organized, disciplined procedure to provide an integrated operations structure. This, in turn, will permit the Bell System to meet customer and market needs while minimizing the operational cost through applied computer technology. These efforts have produced a family of operations plans that guide AT&T, Bell Laboratories, and the telephone companies in the planning and deployment of the over 100 currently available OSs.[5]

Planning for the evolution of the network data collection process is now one element of an overall plan known as the Total Network

Operations Plan (TNOP). The planning process is not static; efforts are now under way to define the directions in which operations centers, systems, and processes should evolve to meet the future needs of the telecommunication network and the people who operate it.

3.2 *Modeling the environment*

A key factor that influences the plan for mechanized support of the network traffic data acquisition and analysis process is the telephone company operating environment. We can gain insight into the requirements imposed by this environment by analyzing models that represent typical situations and by conducting detailed field studies and experiments. These types of activities ensure that both the operations strategy and the operations system developments meet the needs imposed by both the evolving telecommunications and operations environments.

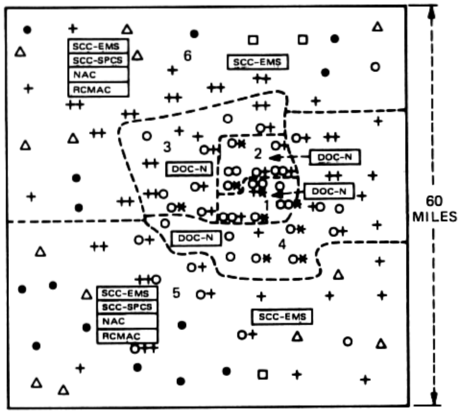
Many existing operating areas in the Bell System have similar characteristics and face similar network operations requirements. Thus, four basic types of model areas can be constructed to represent the various geographies, populations, and network equipment configurations that presently exist in the Bell System.

One, termed Model Area II, represents a large, densely populated metropolitan region, such as Detroit or Cleveland, with about two million main stations. Another, Model Area III, characterizes a state or portion of a large state containing over one million main stations and having an urban center with over two hundred thousand main stations. Indiana and Georgia resemble this model. Figure 1 shows maps of the geographic distribution of local switching equipment and key line operations centers in these two model environments. Table I shows a summary of physical plant statistics in each model environment. Of the two remaining models, Model Area IV characterizes large, primarily rural states, while Model Area I describes New York City and its immediate vicinity.

While line operations functions can be reasonably studied on an area basis, the span of other operations functions, such as trunking network design, often covers more than one operating area. Hence, the model areas were combined to form model BOCs. Figure 2 illustrates the typical deployment of selected operation functions for one such model company. It consists of one Model Area II and one Model Area III and resembles a single-state company like the Illinois Bell Telephone Company. Similarly, model companies can be combined to form a model territory to study toll operations.

These models provide a basis for quantitatively evaluating the effect(s) of the environment on alternative mechanization strategies. Among the key elements that influence the design and evolution of network data mechanization are:

MODEL AREA II



1981

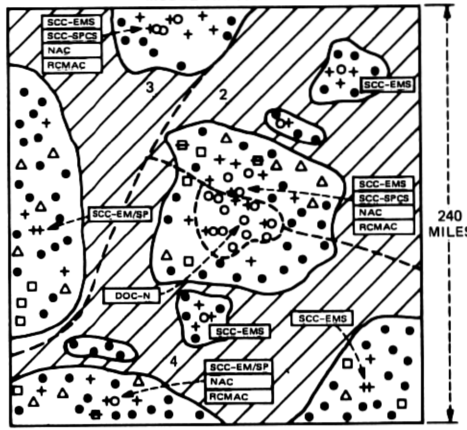
LOCAL SWITCHING PROFILE

DISTRICT	1	2	3	4	5	6	TOTAL
SWITCH TYPE							
✱ 1XB	3	2	1	3			9
+ 5XB	2	3	12	12	17	19	65
o 1 *ESS*†	8	8	8	10	7	1	42
△ 2 *ESS*					7	6	13
□ 3 *ESS*					1	2	3
● SXS					8	6	14

CHARACTERISTICS

3600 MI^2 AREA
URBAN AND SUBURBAN AREAS
ONE NPA
NO INDEPENDENTS

MODEL AREA III



1981

LOCAL SWITCHING PROFILE

DISTRICT	1	2	3	4	TOTAL
SWITCH TYPE					
+ 5XB	4	10	11	12	37
o 1 *ESS*	11	5	3	2	21
△ 2 *ESS*		5	5	5	15
□ 3 *ESS*		1	3	5	9
⊟ RSS		2		1	3
● SXS		18	26	45	89

CHARACTERISTICS

58,000 MI^2 AREA
TYPICALLY A STATE
TWO NPAs
MEDIUM-SIZE URBAN AREAS
LARGE AREAS SERVED BY INDEPENDENTS

▨ NON-BELL SYSTEM

† TRADEMARK OF WESTERN ELECTRIC

SWITCH AND OPERATIONS CENTERS

DOC-N – DISTRICT OPERATIONS CENTER-NETWORK (LOCATED SCCs, NAC, RCMAC)
EMS – ELECTROMECHANICAL SYSTEMS
EM/SP – COMBINED FUNCTIONS
NAC – NETWORK ADMINISTRATION CENTER
NPA – NUMBERING PLAN AREA
RCMAC – RECENT CHANGE MEMORY ADMINISTRATION CENTER
RSS – REMOTE SWITCHING SYSTEMS
SCC – SWITCHING CONTROL CENTER (MAINTENANCE)
SPCS – STORED PROGRAM CONTROL SYSTEM
SXS – STEP BY STEP
XB – CROSSBAR

Fig. 1—Two representative model operating areas.

Table I—Physical plant statistics in two model areas

	Model Area II (1.93M Main Stations)		Model Area III (1.39M Main Stations)	
	No. of Entities	Main Stations (1000's)	No. of Entities	Main Stations (1000's)
Local switching				
No. 1 Crossbar	9	189	0	0
No. 5 Crossbar	65	738	37	450
Step-by-Step	14	28	89	281
1 *ESS**	42	904	21	542
2 *ESS*	13	65	15	97
3 *ESS*	3	6	9	18
RSS[1]	0	0	3	2
DCO[2]	0	0	0	0
DRSS[3]	0	0	0	0
Total local entities:	146		174	
Wire centers:	98		159	
Toll and local tandem switching				
4 *ESS*	1		1	
1 *ESS*[4]	—		6	
No. 4A Crossbar	3		2	
Crossbar Tandem	5		1	
No. 5 Crossbar with tandem features[4]	3		6	
SXS with tandem[4] features	—		7	
Trunks (1000's)[5,6]	162		118	
Special Service circuits (1000's)[6]	114		80	
T-Carrier channels (1000's)[6]	165		101	
N-Carrier channels (1000's)[6]	—		16	
High-Capacity Carrier channels (1000's)[6,7]	21		26	

1. Remote Switching System.
2. Digital Central Office.
3. Digital Remote Switching System.
4. Local switches with toll or tandem features are included in local entity count.
5. Interoffice circuits. Intraoffice circuits are not included.
6. Count includes intra-area plus one-half interarea circuits.
7. Includes low-capacity carrier systems multiplexed directly to broadband carrier.

* Trademark of Western Electric.

1. Number, type, and geographic distribution of data sources (i.e., switching systems)

2. The relative scope, number, and geographic distribution of operations centers that require mechanized support.

These factors, together with the nature of the functions performed by the various operations centers (see Section 3.3) and insights gained through detailed field studies, form the foundation for a network traffic data mechanization plan for the 1980s. Section 3.3 discusses the key network traffic functions in the BOCs.

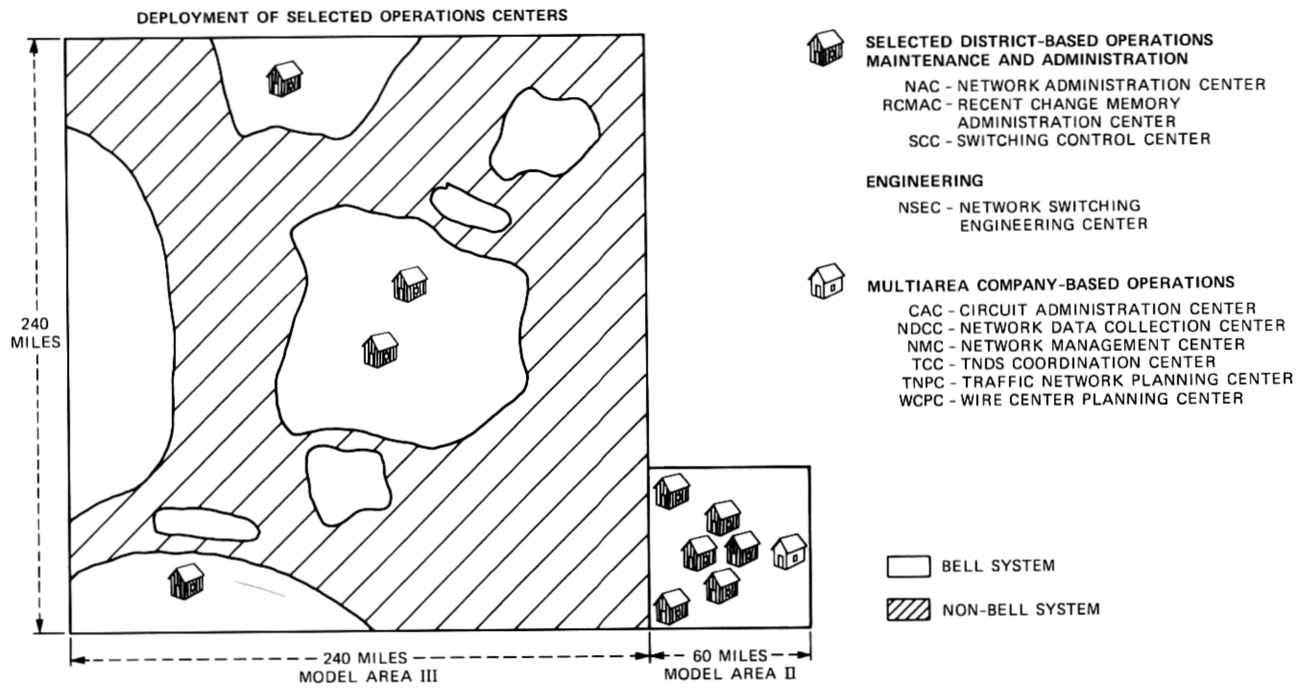


Fig. 2—A model operating company.

3.3 Managing, engineering, and planning the network

The BOC operations centers are responsible for network management, network administration, network design, and long-range planning. This section describes how the centers interact and how the information flow among centers is managed.

3.3.1 BOC Operations Centers

3.3.1.1 Network management. The Network Management Center (NMC) keeps the network operating efficiently when unusual traffic patterns or equipment failures would otherwise result in congestion. The NMC analyzes network performance and prepares contingency plans for situations such as peak days, telethons, and major switching system failures. The NMC also routinely monitors near-real-time network performance data to identify abnormal situations. Once an abnormal situation is detected, appropriate network management controls are implemented. When the critical situation has passed, the network management controls are removed. For further details, see the papers entitled "Network Management" and "National Network Management" later in this issue of the *Journal.*

3.3.1.2 Network administration. The Circuit Administration Center (CAC) and the Network Administration Center (NAC) perform network administration. The NAC is responsible for optimum loading, balancing, and utilization of installed central office equipment. It performs daily surveillance of central office and connecting trunk groups to ensure that service objectives are being met. In addition, the NAC reviews profiles of office load relative to profiles of anticipated capacity growth. It initiates corrective actions to deal with current as well as potential service problems by working with the Network Switching Engineering Center (NSEC) to initiate work orders to increase equipment in service (Section 3.3.1.3).

The CAC ensures that in-service trunks meet current as well as anticipated customer demands at acceptable levels of service. There are two activities, planned and demand servicing, that the CAC performs to discharge this responsibility. In planned servicing, the CAC compares current traffic loads with the forecasted loads for the upcoming busy season. If the loads are consistent, the CAC issues the orders to provide the forecasted trunks. When inconsistencies are found, the CAC examines the variation, develops a modified forecast for the busy season, and issues orders (if appropriate) based on the new forecast. In demand servicing, the CAC reviews weekly traffic data to identify trunk groups that imminently need augmenting beyond what the forecast states, and issues the appropriate trunk orders.

3.3.1.3 Network design. The network design function is performed by the CAC and NSEC work centers. The CAC projects current traffic loads for a one- to five-year period based on estimates of main station and call rate growth trends, and also develops corresponding forecasts of network trunk requirements. The NSEC is responsible for developing an analogous forecast of loads for traffic-sensitive switching equipment, setting office capacities, and determining relief size and timing.

The forecasts developed specify the amount of equipment (switching and trunking) that will be needed for the busy seasons of each of the next few years. Based on these forecasts, construction budget dollars are committed. The CAC and NSEC ensure that these forecasts are consistent with long-range planning.

3.3.1.4 Long-range planning. Long-range network planning is performed by work centers such as the Traffic Network Planning Center (TNPC) and the Wire Center Planning Center (WCPC).

The TNPC conducts studies to determine the most economic growth and replacement strategies for the network to meet its estimates of future demand. The estimates of future demand are based on current traffic load trends and marketing information. The plans developed start with the present environment and provide corporate guidance for future network configurations over a 20-year period. This planning process includes the tandem switching systems, operator services networks, trunks interconnecting all switching systems, and switching terminations to accommodate the trunks.

The WCPC conducts similar studies for the local wire center areas. The WCPC planning process includes the local switch and its interaction with other network elements (such as the subscriber network and interoffice facility network).

The basic output of the long-range planning function is a broad view of the future network topology. This includes the numbers, types, and locations of switching systems and the homing arrangements. The resulting long-range plan embodies various routing rules, such as whether local and toll traffic will flow through the same tandems in a metropolitan network and what sequences of alternate routes will be used. Such planning does not involve commitments to spend money but rather to ensure that the long-term consequences of current decisions are foreseen and that the evolution of the network proceeds smoothly and economically.

3.3.2 Work center interrelationships

Figure 3 illustrates how these work centers interact to perform network management, network administration, network design, and long-range planning.[6]

The TNPC and WCPC provide the CAC and NSEC with the fundamental office and network evolution plans (20-year horizon).

The CAC and NSEC review current trends in traffic offered to in-service network and switching equipment. They develop forecasts of specific equipment needs for the next one to five years, consistent with the fundamental plans. The forecasts result in construction budget allocations and equipment orders.

The CAC and NAC review the current level of traffic offered to in-service equipment. The CAC and NAC identify current (within a year) equipment rearrangement and growth needs. Accordingly, equipment is rearranged, ordered, and installed.

The NMC, with the help of the CAC and NAC, prepares contingency plans for situations such as peak days, telethons, and major switching system outages. The NMC routinely monitors the load, in near-real time, to identify unusual traffic patterns and equipment failures that have resulted or will result in congestion. The NMC will implement the network management plans, as required, to deal with the problems.

As an example of the interrelationships of these centers, Table II outlines the role of the NMC, NAC, and CAC relative to the surveillance of network service. The primary differences that can be noted are: the time frame of interest and action, the geographic domain (network), and the network components of interest.

Table II—Summary of relative service surveillance roles in BOC Operations Centers

Center	Surveillance Objective	Network Traffic Data Used
Network Management Center	Monitors traffic congestion in a portion of the network (e.g., a numbering plan area) and initiates controls to maximize call completion during times of overload or equipment failure	5- to 20-minute traffic data and 30-second network status data for selected central office equipment and trunk groups in selected central offices
Network Administration Center	Monitors load and service status for each switching system and its trunk groups in a central office district, determines if service objectives are being met, detects or is informed of potential or actual service-affecting problems, initiates corrective action when necessary, and verifies that problems are being resolved	Hourly and weekly central office equipment and trunk group traffic data and selected status indicators
Circuit Administration Center	Monitors traffic loads on the message trunk network in an operating area or company, determines the need for near-term trunking rearrangements and additions to resolve conditions that are network service-affecting and that are expected to persist	Weekly and longer-term summaries of trunk group traffic data

3.3.3 Management of information flow

Coordinating the flow of information to and among the work centers is a complex task for which work centers have been established. The Network Data Collection Center (NDCC) coordinates schedules and ensures that the requested data are collected and distributed appropriately (i.e., in the most timely and cost-effective manner). Operations systems have been developed for internal operations and information exchange. The NDCC coordinates the execution of these systems on a day-to-day basis.

Up to this point, we have discussed the network and the BOC operational environment. Now let us turn our attention to the functional objectives of a data system to mechanize the network data process.

IV. MECHANIZATION OBJECTIVES

Until the early 1970s, the collection and processing of network traffic data by the BOCs was a combination of manual and semi-mechanized processes. A number of environmental changes made this type of network data environment inadequate to meet the needs of the business. These influences included:

1. Growing sophistication and complexity in an increasingly SPC network
2. Need for immediate information for network management and for more complete and timely information for all network-related functions
3. Increasing regulatory and competitive pressures.

Accordingly, the trend was toward mechanizing the network data process. The overall objective of this effort has been to automate the process of collecting and summarizing network traffic data so that BOC decision makers have adequate quantities of timely and accurate information to administer and engineer the network. To be effective, the system must be robust to varying BOC environments (e.g., organizational responsibilities, mechanization deployment) and must be expandable to meet the growing processing needs of the BOCs. The system must offer a manageable and cost-effective implementation for the BOCs in the context of their operations.

Before describing the implementation of the Bell System's computer-based network data system, let us look at the basic data function objectives that such a system must meet to satisfy the needs of users performing key BOC traffic functions.

4.1 Data collection

After the traffic measurements have been taken by the switching system or by special measurement equipment located near the switch, it is desirable to collect the measurements at a centralized location where large-scale data processing can be brought to bear. The system must be capable of collecting network traffic data from all types of switching entities—EM and SPC systems, local, tandem, and toll switches.

Because the equipment collecting the data is centralized and has access to the switching systems it serves, it is practical to delegate measurement control (e.g., turning on a TUR to begin taking measurements on the basis of a collection schedule) and network management control (e.g., signaling to a switching system to cancel alternate routing) to the same collection equipment.[4]

4.2 Data administration

The system must also support a number of "data administration" activities. Measurements to be collected from switching systems must be scheduled so they are not collected during periods when they are not required (e.g., during low traffic periods). In addition, the system must allow users to control the data processing schedules (e.g., hours of the day for which the data collected are to be summarized into the various reports).

The measurements must also be linked to records that associate each measurement with the equipment being measured. In addition, records of the individual switching system characteristics (e.g., inventories of installed central office equipment) must be maintained. No less important than the network traffic data, complete and accurate records are absolutely required by the system to transform raw traffic measurement data into useful information. The generation and maintenance of these records are major tasks that must be supported by the system.

At times, more data are collected than are actually needed due to the way measurements are accumulated and "packaged" by the switch or by the special measurement equipment. The system should identify and remove these unneeded data as early as possible to avoid wasteful processing.

It is necessary for the system to validate data (i.e., inspect them to determine if they truly reflect network traffic conditions that they are intended to measure) soon after collection to avoid processing incorrect data and allowing them to contaminate the associated good data.

As a final data administration task, the system must ensure that measurement data are distributed as appropriate between the different processing elements of the system as well as to any other Operations Systems that require those data.

4.3 Report generation

To present BOC users with useful information, the system must perform a number of processing and reporting tasks. As Section 3.3 showed, there are four key traffic-related functions that depend on network traffic data. A primary factor in designing a successful network data system is satisfying the needs of the BOC people performing these functions—both in the type of information reported and the timeliness with which it is made available.[4]

Reported information should be in formats that allow users to quickly identify and interpret the information. The system should provide a set of predefined, standard reports as well as capabilities for selective, demand query of information to allow users to obtain information in formats customized to their special needs. In addition, the system must allow the users to control the routing of processed outputs and must be able to deliver processed results to users in the form to be used in their local operations (i.e., paper reports, microfiche reports, hard copy or cathode ray tube terminals, status board).

Automatic, more detailed, validation should be performed to augment that carried out shortly after data collection. Validation reports should be generated to help users detect suspect data. In addition, the system must allow users to highlight and exclude information that is judged suspect so that it is appropriately treated in affected reports.

The system should provide access to network information in time frames consistent with the spectrum of user functions (see Fig. 3). For instance, the system must provide five-minute network load information in an immediate time frame as the basis for real-time management of the trunk network. However, the system must summarize and maintain information for a year or more to support central office and facility engineering and long-range planning. In general, the system should store data and results for periods of time based on anticipated information usage patterns and economic considerations.

The system must collect and report information on its performance (e.g., data collection availability) to allow the BOCs to promptly identify and resolve system performance problems and to otherwise manage the system.

4.4 Robustness

A mechanized network data system must continue to evolve as new switching machines are introduced, as new network services and features demand the processing of new measurements, as new provisioning or network design algorithms are formulated, and as new functions arise for the network data system. In addition to simply evolving to meet new processing needs, the network data system must do so at or near the time of introduction of new technology to help minimize the impact on Bell System operations.

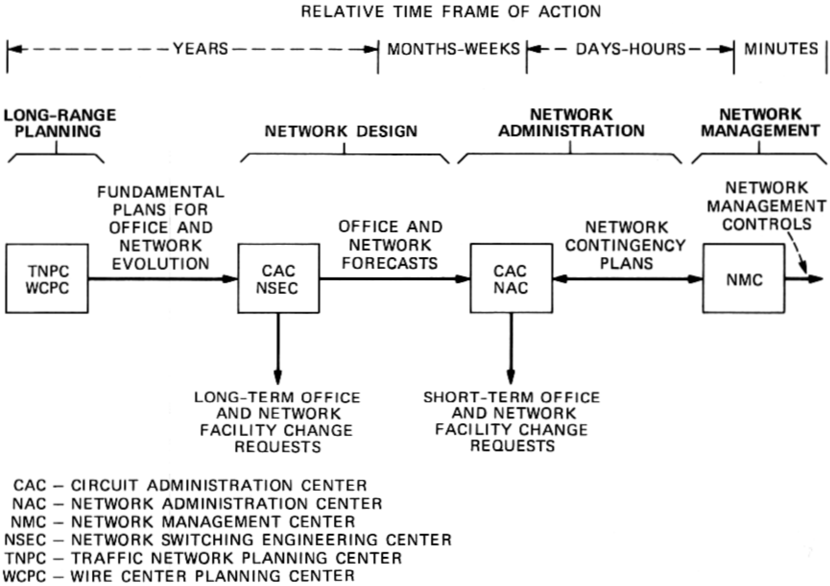


Fig. 3—Work center interrelationship.

V. CONCLUSION

The Bell System has implemented a mechanized process known as the Total Network Data System to meet the needs we have outlined. This TNDS consists of a set of subsystems, each performing part of the overall process. The formulation of and adherence to a system plan has helped assure that all parts of TNDS have been available when required to support the network management, administration, design, and long-range planning needs of the BOCs. The paper that follows discusses this "TNDS System Plan" and the component TNDS subsystems that have evolved.

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AUTHORS

Anthony L. Barrese, B.E., 1970, M.E.E., 1971, Ph.D., 1978, Stevens Institute of Technology; Bell Laboratories, 1969—. Mr. Barrese was first involved in the development and testing of the Safeguard antiballistic missile system. He then worked as a systems engineer, developer, and tester on the Total Network Data System project. He supervised a group with methods development responsibilities for the Circuit Administration Center. He is currently Supervisor, System Architecture Group, with long-range planning responsibilities for the Operations Systems Network. Member, IEEE, Tau Beta Pi.

Donald E. Parker, Southern Bell Telephone and Telegraph Company, 1967–1968; South Central Bell Telephone Company, 1968–1976; Bell Laboratories, 1976–1979; American Telephone and Telegraph Company, 1979—. Mr. Parker's involvement with TNDS began in 1974 when he was assigned responsibility for training and implementation of Total Network Data System/Equipment (TNDS/EQ) in the Alabama Area of South Central Bell. It has continued through a rotational assignment in the Personnel Subsystems Group at Bell Laboratories, where he was responsible for user documentation and consultation for Traffic Data Administration System (TDAS), Common Update (CU), and Individual Circuit Analysis Program (ICAN). He is currently assigned to the Network Services Department of AT&T as Project Manager for TNDS/EQ and Stored Program Control Systems Central Office Equipment Reports (SPCS COER).

Thomas E. Robbins, B.S., 1968 (Mathematics), Westminster College; M.S., 1971 (Operations Research), New York University; Bell Laboratories, 1968—. Mr. Robbins has been involved in various aspects of the Total Network Data System since 1972, including both development (SPCS COER) and systems engineering (SPCS COER, TNDS/EQ) assignments. He is presently Supervisor of the TNDS Planning Group responsible for planning the feature evolution of the TNDS elements to support new network switches and services. Member, IEEE.

Larry M. Steele, B.S.E.E., 1969, University of Kentucky; M.S.E., 1971, Princeton University; AT&T, 1975–1977; Bell Laboratories, 1969–1975, 1977—. Mr. Steele joined Bell Laboratories in 1969 and employed modeling and simulation techniques to evaluate the accuracy and vulnerability of proposed military missile detection systems. In 1971 he developed the requirements and the software for a system to analyze the performance of No. 1 Crossbar switching entities. He was subsequently given responsibility for the determination of downstream analysis requirements and the formulation of an administrative plan for the individual circuit usage recording feature of a standard Bell System traffic data acquisition system. In 1975 Mr. Steele went on a rotational assignment with the General Departments of the American Telephone and Telegraph Company, where his responsibilities included project management and methods development for a family of traffic data acquisition and analysis systems. Upon his return from AT&T in 1977, he conducted a comparative analysis of system architectures for providing a standard methodology for gathering detailed data relating to point-to-point traffic loads. Between 1978 and early 1981, Mr. Steele supervised a group responsible for studying and recommending improved methodologies and mechanized capabilities in the area of telephone network administration. The group was also responsible for synthesizing administrative plans for incorporation into the Total Network Operations Plan (TNOP). Currently, Mr. Steele is the Head of the Network Operations Planning Department, which is responsible for planning for the integration and use of computer-based systems to support network-related operations functions.