The Total Network Data System

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ABSTRACT

Application of traffic theory to the dimensioning and administration of a telephone network depends heavily on the availability of a sufficient quantity of usable, reliable data. To be usable, the data must be properly identified and must be processed with the correct number of related existing equipment quantities for specific measurement periods. To be reliable, the data must be checked frequently during collection and processing. Finally, for data to be in sufficient quantity, the mechanisms for collecting and processing must exist and must be justified in cost by the benefits derived.

The increasing complexity of telephone networks and the need for immediate information for network management have increased the need for complete, processed data. No longer can engineering judgment satisfactorily compensate for the omissions and errors that occur when large volumes of traffic data are collected and processed manually.

This paper presents the concept of a network data system and describes the Total Network Data System (TNDS) now being constructed and implemented in the Bell System. TNDS provides the capability for handling network data from the source in the switching machine to the ultimate user such as the network manager, network administrator, or network engineer. New machines have been designed for the acquisition and rapid dissemination of data; a major part of the development effort has been in the area of general purpose computer programs which transform raw data into meaningful, validated network information. By the end of 1976 the Bell System will be more than halfway to complete implementation of TNDS.

1.0 INTRODUCTION

The increasing cost, size, and structural complexity of modern telephone networks intensify the problems of a telephone administration in its efforts to use its investment efficiently while giving its customers objective grades of service. Fortunately, the same technical revolution which has provided more complicated networks has also provided the capability of obtaining greatly improved network data and, most important, of processing the data for convenient use by people.

Two properties of network data make them particularly difficult to deal with:

1. They are almost useless in raw form, so that they must be processed before they can be used.

2. A great deal more data must be collected than will actually be used.

Measurement, data processing, and user applications should, therefore, be considered together in planning to mechanize all or parts of network administration and engineering. The Bell System is constructing and implementing such a mechanized process, known as the Total Network Data System (TNDS). As we shall see, TNDS consists of a set of subsystems, each performing part of the total process. The concept of data flow has been an implicit factor in designers' thoughts for a long time. However, emphasis upon the total data flow from generation to final user, together with explicit identification of the subsystems involved and their mutual interactions, are key aspects of the TNDS approach, and have facilitated the planning and design of the TNDS subsystems to provide the needed functions. The formulation of and adherence to a system plan has helped assure that all parts of TNDS are available when needed. In this paper, we review briefly the uses of network data, the key features of a network data system, the general organization of TNDS, the main attributes of the TNDS subsystems, and the current status of TNDS in the Bell System.

2.0 BASIC TRAFFIC FUNCTIONS

There are four primary traffic functions which depend on network data: network engineering, network administration, network management, and force administration. A key factor in designing a successful network data system is the identification of the people performing these functions, both in the type of data provided and in the time delay from data collection until reports are available. Thus, it is important to understand the basic functions, together with their requirements for processed data, since they play a major role in defining the structure of a data system and in specifying the characteristics of the subsystems.

The role of network engineering (dimensioning) is to estimate where and how much equipment will be required in the future, so that the necessary additional equipment can be ordered and installed in time to satisfy the service objectives specified in the traffic practices. Three major, but somewhat separate activities, are the engineering of central office switching equipment, trunks, and operator equipment. All of these rely on traffic volumes being carried by existing equipment to establish base load levels and growth trends, from which future traffic loads are estimated. Using capacity tables or formulas relating load to objective grade of service, the network engineer determines the configuration and amount of equipment required to carry these estimated loads. The resulting traffic order is used by equipment and facility engineers to produce orders for equipment manufacture and installation.

The network engineer typically does not use the raw traffic counts, but needs processed information. For example, the load on a trunk group must be converted from an hourly carried load to an average (over 20 consecutive busy season days) offered load, then projected 1 to 5 years into the future, and finally transformed to trunks required. Thus, processing requirements call for extracting the necessary traffic data from the data collected over a year and performing extensive calculations on these large quantities of data to provide as accurate an estimate as possible of future needs. Such forecasts are typically made
Once equipment is installed, it is the function of network administration to control the assignment of lines and trunks to take maximum advantage of the installed equipment. In addition, administrators are responsible for providing sufficient and accurate data. The data, which form the basic input to the network-engineering process, are also used by the administrator to monitor the flow of traffic through the office and to detect changes in office performance or in offered load. The administrator is in the best position to analyze and validate the data, because he is aware of the state of the network when the measurements are made. For the administrator, the interval between the collection of data and the availability of processed information depends upon the application but must be short - i.e., from a few minutes to a few weeks. For example, when new equipment is being added to an office, virtually real-time surveillance of office performance is desired. For line-load baseline and inventory, the data must be available in about a week. Since the administrator is primarily interested in current network behavior while the engineer is more concerned with projecting future demands and economical equipment arrangements, the calculations required by the administrator tend to be less complex than those of the engineer.

Because modern telephone networks employing common control switching and alternate routing operate at a high traffic efficiency, the number of effective carried calls could drop below the available network capacity under heavy overloads due to unexpected traffic patterns or network damage. The function of network management is to control these overloads by distributing loads among circuits and equipment to meet customer service demands in a way which is best from a total network viewpoint. [1], [2], [3]. To be most effective, the network manager requires a current view of the network, including key indicators of switching congestion, network performance calculations derived from traffic data, and communication with other network managers. Thus, a subset of the traffic data is needed by the network management (NM) center every five minutes. The processing requirement in the NM center is to accept the data, perform calculations, display a waveform, and store the data for periods of 15 minutes for later reference via cathode-ray-tube displays.

In Operator Services, the size of the operating force is tailored to meet the objective grade of service at minimum expense. Force administration includes forecasting what load will be offered in each half-hour, determining the force necessary to carry it at the objective grade of service, and providing that force throughout each day. The speed of the operators' service and the adequacy of force administration must be measured. This information on volume, service, and force must be available as processed results within a few minutes after each half-hourly data-collection interval. Because force administration has a limited interaction with the network functions, its data tend to follow a separate, but somewhat parallel, flow. To simplify the paper, this flow will not be considered further here.

3.0 TNDS CONCEPTS

Before describing the implementation of a network data system, it is worthwhile to look at the basic data functions which the system must perform and then to look at the interaction between the data functions and the traffic functions described in Section 2.0. The basic functional blocks of the data system are shown in Figure 1.

3.1 FUNCTIONAL DESCRIPTION OF THE NETWORK DATA SYSTEM

Network data are generated in the switching systems which connect and disconnect calls, sustain the talking paths between customers, and associate various call processing elements with calls as the elements are needed to execute the communication functions required of a telephone network. The first block, labeled measurement, is therefore a function performed by the switching system or by special measurement equipment which is located nearby. The measurements, which will be discussed in more detail later, are primarily the familiar peg counts, overflow counts, and usage counts.

After the measurements have been taken, it is desirable to collect them at a central point where large scale data processing can be brought to bear. This function has been labeled acquisition. Because the acquisition equipment is centralized and has access to the offices it serves, it is convenient to include in the acquisition function measurement control, such as turning on a traffic usage recorder, as well as network management control, such as signaling to an office to cancel alternate routing. Also combined in this function is data administration. Measurements to be collected from switching machines must be scheduled so that the measurements are not collected during low traffic periods. The measurements must also be associated with a record base which associates each measurement with the equipment being measured. The generation and maintenance of the record base in itself a major task, since any one central office may have on the order of 1,000 different measurements which must be accurately and uniquely identified in subsequent processing.
stages. Frequently, more data are collected than are actually needed - e.g., if both trunks and central office equipment are being measured by a traffic usage recorder, then one obtains both types of data even though some hours may be of interest for only one type. Once the data are identified, it is possible to remove much unneeded data; this is accomplished as part of data administration. It is also necessary to validate data at this stage before any significant processing has been started, both in order to avoid the waste of processing incorrect data and to prevent incorrect data from poisoning the associated good data. One simple validation is to check that the number of measurements received agrees with the expected number. Finally, the data administrator must distribute the data to the appropriate downstream subsystems.

The next function is that of processing and reporting. The preferred presentation is in an easy-to-read format for human users on the loading and service of equipment groups. This information can be immediately interpreted and can be validated in more depth by the data administration stage. The reports are used for both the network administration and network engineering functions. Data from the reports are associated with estimates of traffic growth for submission to the final processing stage where equipment and trunk needs for future engineering periods are calculated. Several passes through this last stage may be required to study different alternatives in growth or in configuration.

A network data system is never a finished product, but continues to evolve as new switching machines are introduced, as new provisioning or network design algorithms are formulated, and as new functions arise for the data system. Rather than constructing a single, very large system, it is desirable to design the system as a collection of interconnected subsystems so that, when change is desired, a subsystem can be modified without rearranging the entire system. This is also important in converting from manual processing to a data system, since the individual subsystems can be implemented sequentially to provide a more graceful transition than if the entire system had to be implemented as a unit. The costs of conversion can also be incurred a step at a time.

3.2 INTERACTIONS BETWEEN BASIC FUNCTION AND DATA

Figure 1 shows the main interaction between the data flow and the basic traffic functions. For network management, it is necessary to obtain data as close to the source as possible so the accuracy of traffic assumption is maintained throughout the network management process. Network administration must also have access at this point in order to assure that the data flow is correct and to obtain advance warnings of situations that might require administrative action. Here, schedules are entered, record bases are maintained, and errors are corrected. The reporting function serves as an additional checkpoint for the data administrator for assurance that valid results are being obtained. The reports then go to the network engineer who selects appropriate values for the final processing which produces orders for new network trunk and switching facilities.

4.0 MEASURING TRAFFIC

With few exceptions, measurements are made at the location of the switching equipment. All switching systems make some traffic measurements internally, but in the case of electromechanical systems it is usually necessary to provide additional equipment specifically designed to measure traffic. Electronic systems are usually self-contained and present a different interface to a data-collection system.

4.1 ELECTROMECHANICAL SWITCHING SYSTEMS

The simplest measurement for a switching system is the count of events - e.g., peg counts or overflow counts. In the course of processing a call, the system can score registers in accordance with the type of processing it is doing at the moment. These basic measurements are still being taken today in many offices by accumulating counts on traffic registers for periodic reading, either directly or indirectly from photographs.

Counts of events only give part of the traffic picture; measurements of circuit usage are also needed. Usage is typically obtained through a separate measurement device, the traffic usage recorder (TUR). The TUR scans leads from the switching machines which indicate the busy or idle states of circuits. The counts of scanned busy circuits represent usage in multiples of the scan interval.

A third type of traffic measurement is that of delay. Special equipments are used for this purpose. Bell System examples are the Dial Tone Speed (DTS) machine which initiates test calls on test lines at 4 second intervals, scores the total number of tests, and scores the number of tests delayed over 3 seconds; and the Sender Attachment Delay Recorder (SADR) which initiates test calls and measures delay encountered by incoming trunks when requesting senders in crossbar toll and tandem systems.

A fourth type of measurement is that of status indication. This is used for administrative or network management applications, usually in the form of a lamp indication.

The interfaces for data acquisition from electromechanical systems are traffic register leads (for peg count, overflow, grouped usage, and delay), and status indicating leads. Another interface which is required for individual circuit usage recording is described in Section 5.1.

4.2 ELECTRONIC SWITCHING SYSTEMS

Because electronic switching systems (ESS) contain complete information on the state of all calls as they are processed, traffic measurements and status indications are collected by the basic internal programs. The information, equivalent to that stored in electromechanical registers, is retained in memory until the accumulated results are read out as required by the users.

The interface for data acquisition in electronic systems is a data port through which traffic data and status indications are transmitted to the collection system in a specified format.

5.0 DATA COLLECTION AND DATA ADMINISTRATION

We now turn to a description of TURS and the particular subsystems used therein. Figure 2 shows the relative positions of the subsystems in TURS.
The TNDS concept calls for transmitting the data to a centralized location where the data are recorded and arranged for distribution to the users. In this section, we described the approaches used in TNDS for data-collection and for centralized data administration. This latter function is important since it includes maintaining accurate records of the assignment of measurement equipment and arranging for the timely distribution of data to the users.

5.1 ENGINEERING AND ADMINISTRATIVE DATA ACQUISITION SYSTEM (EADAS)

EADAS provides for transmitting the data from the individual central offices to a centralized minicomputer for recording and some real-time distribution. Under control of a minicomputer, EADAS collects data automatically from electromechanical and electronic switching systems via telemetry. EADAS processes the data for network administration to provide exception reports on selected parameters as well as routine and demand reports on the condition of the switching offices and data flow. For downstream use, EADAS sums the data and, at regular intervals, records the data on a magnetic tape for subsequent input to the Traffic Data Administration System (which is the main data-distribution point in TNDS). For network management purposes, EADAS provides selected data at five minute intervals to EADAS/Network Management (EADAS/NM), and also passes alarm and status-indicator leads. Measurements on these leads are identified and transmitted, one-at-a-time as they occur, to the central processor over a dedicated data link. EADAS also can interface with a variety of devices which store data in the office and are polled periodically.

The EADAS central processor accesses up to 100 input channels, each of which is associated with a dedicated data link to a central office. This 100 input channel capacity is sufficient to handle most administrative areas in the Bell System. EADAS can operate as many as 16 independent remote teletypewriters (TTYs) for network administration. The TTY enables the administrator to obtain near real-time traffic reports.

An important consideration in using Traffic Usage Recorders (TURs) in electromechanical offices is ensuring the correct connection between each TUR scan point and the circuit to be measured, and ensuring the correct grouping of scan points into circuit groups since the usage for a circuit group is the sum of the usage measured by the scan points associated with the group. A relatively new approach is the Individual Circuit Usage Recording (ICUR) option in EADAS, wherein usage measurements of individual circuits are acquired using existing TURs. Usage data, detected on an individual circuit basis, have heretofore been grouped into circuit-group usage data by using a cross-connection field at the TUR output. With the ICUR option, this circuit-grouping cross-connection field is removed and replaced with a software grouping map at the EADAS minicomputer.

ICUR data words, which convey usage counts on individual circuits, are transmitted in real time over the data link to the EADAS processor. There the data are summarized using the ICUR program which monitors the data for indications of record errors or faulty equipment.

5.2 INDIVIDUAL CIRCUIT ANALYSIS (ICAN) PROGRAM

The ICAN program, which performs administration analysis and usage analysis, plays a central role in ICUR operation. First, administration analysis is intended to insure the integrity of the EADAS/ICUR circuit-grouping map, a key requirement for successful operation of ICUR. This is accomplished by subjecting each map update to an extensive set of consistency checks (some elementary checks are performed in EADAS/ICUR when the update is entered). ICAN also provides reports that describe the current circuit-grouping map and reports that show the current status of each TUR scan point for use in TUR lead assignment.

Second, usage analysis is used primarily to detect equipment faults by identifying abnormal load patterns observed on individual circuits. The ICAN analysis algorithms have access to two measurements for each TUR input; the accumulated usage from TUR scans that found the circuit to be busy and a count of times that a TUR scan found a circuit's state to be different from that of the previous scan. Defective
circuits with abnormally short holding times are detected by statistical tests on these two measurements; circuits that appear "always busy" (1 erlang in each hour) or "always idle" (0 erlangs in each hour) are also identified for investigation.

ICAN is a batch program that is run daily, since it is too time-consuming to check each record and perform the usage analysis quickly. The "always busy" and "always idle" analyses are performed weekly.

5.3 TRAFFIC DATA ADMINISTRATION SYSTEM (TDAS)

TDAS is a batch-process subsystem whose job is to administer the data flow primarily on behalf of the downstream user subsystems. From data requests and schedules supplied by each user, TDAS generates data-collection schedules so as to coordinate and organize the data task. TDAS accepts the data as they arrive and, in accord with user requests, sorts labels, stores, and finally, provides the data in the proper format for each downstream subsystem. Thus, TDAS acts primarily as a warehouse and does not operate on the data other than to ensure proper labeling and elementary validity. The subsystems must be dimensioned according to the load offered for all users. TDAS does not perform the data-processing function. It is necessary to check map updates and perform the downstream user subsystems. From data reorganization and the trunk network, the specification of the data-collection process.

Under typical operation, TDAS might run once a week to process data gathered during the preceding week. The capacity of TDAS depends upon the specific computer configuration. The load on TDAS depends upon the number of hours and days of data taken, and upon the number and size of the data-collection systems forwarding data.

5.4 COMMON UPDATE (CU)

To avoid error, a large data system must include the capability of maintaining an accurate record base. For example, the TNDS must be corrected for each traffic register, i.e., upon the meaning of the number recorded by each register. This is accomplished by translating tables that provide labels for each measurement.

TNDS relies upon a centralized record-base subsystem, called CU, which includes for each office information on the arrangement of switching equipment and the trunk network, the specification of what each register is measuring, and the trunk servicing and trunk forecasting characteristics for each trunk group. CU stores the trunk group base-loads generated by TSS for input to TFS.

CU uses basic input documents to establish and maintain record-base files in a standardized format on measurement equipment, trunk groups, and certain other items for the programs that utilize CU. CU is a batch program that is generally run once a week to update the data base. Presently, CU serves as the record keeper for TDAS, TSS, TFS, LBS, and part of ICAN.

5.5 CDO/PBX DATA

Traffic data are needed from Community Dial Offices (CDOs) and the larger PBXs for administrative and engineering purposes. Historically, data-acquisition costs have been too high for broad coverage of these smaller switching systems. Planning is currently underway for new, more economical data-collection arrangements for this market. [4]

6.0 NETWORK ENGINEERING AND NETWORK ADMINISTRATION REPORTING SUBSYSTEMS

The subsystem described previously, sort, screen, and partially forward the data to the engineering and administrative computer programs to complete the process of turning data into information. Because the information is highly dependent upon the use to be made of it and upon the particular type of equipment affected, specific programs are required for each function and often for each type of switching machine. To keep within the bounds of a total data system, report formats are kept as similar as the particular switching systems allow.

6.1 CENTRAL OFFICE EQUIPMENT REPORTING SYSTEMS (COERS)

COERS is a generic term that is applied to the reports which are used by both the network engineer and the network administrator. For each report, extensive validation checks are made and doubtful results are marked. While simple calculations are made, such as the conversion from peak count and overflow count into percent overflow, more complex computations, such as theoretical estimates of peak day traffic to compare with the same days are also performed. Since these subsystems are switching-machine dependent, there is a separate COERS subsystem for each machine type.

Of the COERS outputs, the network administrator uses primarily the Machine Service Report (MSR) and the Machine Load and Service Summary (MLSS). The MSR provides an indication of the overall service of an office. The information contained in the MLSS may be trended to ensure that the office will continue to meet its service criteria. In addition, the MLSS contains the hourly information on which the engineering reports are based. It may be used as a diagnostic tool and also furnishes a common meeting ground for network administrator and network-engineer discussions.

The Load Distribution Report is used to determine component busy hours. (By component is meant that portion of central office equipment which must be dimensioned according to the load offered to it. For example, common control and switching network may be very differently behaving.) With load given for all hours for each component, the correct busy hour for each component may be selected for subsequent data gathering. The Load Service Report is used to engineer the office. It contains, by component, busy hour loads carried on the 15 highest busy days, the average of the 10 highest days, and the average for each of three busiest months and the corresponding "busy season" average. This information is used in the traffic engineer's basic studies to assess office capacity and to forecast future needs.

*In order to describe the administrative and engineering uses of COERS, the 4 ESS reports have been chosen as an example.
6.2 CENTRAL OFFICE EQUIPMENT ESTIMATION SYSTEM (COEES)
COEES, which assists the traffic engineer in designing new central offices or additions to existing offices, is divided into three parts: sizing, pricing, and economic evaluation.

The sizing programs first calculate the equipment quantities required to serve expected customer demand at objective service levels. The output and details of these computations are at a planning level of detail. Programs next compute capacity information, and subsequently, exhaust dates. Under user control, these programs calculate service levels based on previous equipment quantity calculations for different sets of input load data.

The pricing programs apply broad gauge cost factors to required items of equipment, providing estimates of charges for engineering, furnishing, and installing equipment. Results include capital dollar costs for material, engineering and installation labor, and a modification work on existing equipment to add new frames, adding work, and frame work and distributing frame operations.

The economic evaluation program applies established engineering economics principles to produce present worth analyses of the possible alternative busy seasons considering calculated exhaust dates and equipment quantities and associated costs.

6.3 NETWORK MANAGEMENT SYSTEM
The network management subsystem (EADAS/NM) provides network management control centers having joint surveillance over both local and toll networks [1], [2], [3]. Using EADAS traffic data and other network status information, EADAS/NM continually scans the network for congestion problems which it reports to the network manager on an exception basis by operating wall displays organized for the portion of the network under surveillance. The wall display is a standard generic design which is specifically arranged and labeled to meet the needs of each installation. EADAS/NM also generates cathode ray tube (CRT) displays that provide detailed traffic data and which enable the network manager to analyze current data to determine the sources of network blockage. An additional set of CRT displays enables the network manager to remove network controls directly from the EADAS/NM center.

6.4 LOAD BALANCE SYSTEM (LBS)
In assigning subscriber lines to a switching machine, it is desirable to distribute the traffic load uniformly over the switch. This is accomplished by first measuring the load on each line group of the switch - e.g., in a crossbar office, the set of lines assigned to a crossbar switch on a line link frame. The data are used to determine the most lightly loaded groups to which new subscriber lines are to be assigned. An important measure of office performance is the load-balance index, which measures the degree to which an office is properly balanced. LBS also provides correction reports that indicate the location and magnitude of possible existing imbalances. LBS also provides correction reports of nonindexed equipment such as trunk link frames. Results from LBS are used by the network administrator.

6.5 TRUNK SERVICING SYSTEM (TSS)
The traffic data collected on message trunk groups are used to generate base load levels from which future demands are forecast, and to compute current service levels and trunk requirements to assist in trunk administration. This latter step is important, since the traffic demands that actually develop may differ from the forecasted demand for which the trunk network is basically constructed. When a significant deviation occurs, one attempts to provide additional trunk capacity, usually within a few weeks.

TSS is designed to process the peg count, overflow, and usage measurements on trunk groups to automatically accumulate the base load levels (that are later used by the Trunk Forecasting System), estimate current trunk requirements, identify for corrective action any trunk groups that are significantly under- or over-provided, and generate the Monthly Trunk Service Report and the Annual Busy Season Report. TSS is a batch process designed to run on a weekly basis using hourly traffic data supplied by TDAS. Circuit identification, network characteristics, and provisioning parameters are supplied by COEES, also maintains the trunk group base loads developed by TSS which are required as input to TFS.

6.6 TRUNK FORECASTING SYSTEM (TFS)
To plan for the orderly and economic evolution of the trunk network, it is necessary to order and install new transmission equipment to meet future trunk requirements, it is necessary to project the current load levels forward in time to estimate future traffic requirements. TFS is a batch process which predicts message trunk requirements, both local and toll, for five years to assist in the determination of future trunking.

Currently, TFS is being expanded to add a traffic-routing capability to the mechanized forecasting process now in TFS. Using local and toll point-to-point information, combined with measured base load and network busy hour load data from TSS, TFS will project this information, assist in the identification of new trunk groups, and estimate the traffic that would be diverted to these groups. The Multithread Engineering methods [5] are also being incorporated in TFS. This will reduce network costs by capitalizing upon time non-coincidence in offered loads and should reduce servicing activity since the forecasted trunk requirements should agree more closely with the actual loads that develop.

7.0 IMPLEMENTATION STATUS
With over ten thousand central offices, over 50 operating areas and many different pre-existing measurement and analyses methods, the transition of the Bell System to TNDN has by necessity been evolutionary. It has also not been uniform. The various subsystems have been designed, for the most part, as stand-alone systems with clearly defined interfaces among them. Thus, one can find in the field today a wide variety of TNDN configurations where some of the functions are being provided by machines or programs different from those described above. In other places, the mechanization process has not been completed so that several functions are carried out by hand while others are mechanized.

The transitional state of TNDN makes difficult any precise assessment of the extent of its use. Our estimates of the present, April, 1976, status are given here. Thirty-one percent (31% of the projected total) are serving about 1000 of the 10,000 central offices. Altogether about 2000
central offices are served by either EADAS or some other mechanized data acquisition system. TDAS, TSS and TFS are filling about half their projected total applications. COERS is being used for about 1500 central offices, while COEES is being used for planning most major central office new starts and additions. EADAS/NM is installed in two locations out of a projected 30. LBS is under trial. Overall, it can be estimated that the TNDS will pass the fifty percent implementation mark by the end of this year.

REFERENCES


