THE BELL SYSTEM TECHNICAL JOURNAL
Vol. 62, No. 7, September 1983
Printed in U.S.A.

Total Network Data System:

Network Management

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(Manuscript received June 9, 1982)

This paper describes steps that have been taken to respond to the need for better network management in the evolving telecommunications network. In near-real time, network management functions recognize the onset of an overload and respond with control actions that change normal call routing through expansive or restrictive traffic controls. Emphasis is being placed on improved automatic controls that are built into the network and its switching systems. Advances in manual controls and real-time network performance monitoring have been accomplished through the introduction of computer-based systems that provide network managers with preprocessed network performance data and with the ability to intervene in problems that require human judgment.

I. INTRODUCTION

Network management consists of real-time network performance monitoring and control of the telephone network. It is a technique designed to optimize the call-carrying capacity of the network when the network is under stress due to traffic overload or failures. In recent years significant steps have been taken to respond to the need for better network management for the evolving Message Telecommunications Service (MTS) network. Advances have been made in manual

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network management controls and real-time network performance monitoring capabilities. These advances were accomplished primarily by the introduction of computer-based systems that support the operation of centralized network management centers. Network management centers employ automatic and manual capabilities that recognize the onset of overloads and respond with traffic control actions within a time span ranging from seconds for automatic controls to minutes for manual actions. Each center is supported by an operations system that collects the network data, monitors the status of the switching and signaling systems, and permits the implementation of appropriate control measures during overload and failure conditions. Advances have also been made in improved automatic network management controls that are built into Stored Program Controlled (SPC) switching and signaling systems. The current approach to network management is to provide an economical balance between automatic and manual network management capabilities, with greater emphasis on improvements in automatic controls.

This paper presents the status of network management and its application to the evolving MTS network. The network performance under overload and the motivations for network management are described in Section II. Section III discusses the centralized network management operations systems and the automatic network management SPC switching system controls. Section IV gives a description of the operations system Engineering and Administrative Data Acquisition System/Network Management (EADAS/NM). Section V discusses future network management needs for the evolving MTS network.

II. MOTIVATION FOR NETWORK MANAGEMENT

2.1 Network performance under overload

The North American Message Telecommunications Service (MTS) network functions as a single, integrated entity to which customers have shared access for voice telephone calls, data calls, and other uses such as facsimile transmission. The network is currently being enhanced by the rapid introduction of Stored Program Controlled (SPC) switching systems interconnected via the Common Channel Interoffice Signaling (CCIS) system.[1] In effect, the CCIS network is a separate high-speed, packet-switched data network that allows SPC switching systems in the message circuit-switched network to communicate with each other. The interconnection of SPC switching systems by a reliable, high-speed, high-capacity signaling system permits more efficient use and control of the network.

Under overload, modern telecommunications networks that employ common control and automatic alternate routing can be forced into a congested, inefficient state, as marked by a significant decline in the number of calls that can be completed. The loss of network capacity under overload was described by P. J. Burke.[2] Figure 1 presents a key study result obtained through simulation of a 16-node hierarchical network. This figure indicates that there is a decline in the amount of traffic that can be completed when the offered load substantially exceeds the design limits of the network (about 1600 erlangs). There are two basic reasons for the loss of capacity of a network in congestion: excessive alternate routing and regenerative switching delays that are compounded by customer reattempts. Excessive alternate routing causes an increase in the average number of links a call will use before it is completed, thereby increasing call blocking and reducing the efficiency of network utilization. This increase in blocking, with increased alternate routing for a network in congestion, can be mitigated by trunk reservation schemes and by constraining the number of links in alternate routes.[3]

Switching delays are the dominant cause for the loss of the call-carrying capacity of the network under overloads. If left uncontrolled, switching delays feed on themselves and can quickly spread throughout the network. They cause time-out conditions during call setup and occur when switching systems become severely overloaded. Switching congestion time-outs result in short-holding-time attempts on trunk groups, replacing normal-holding-time messages. Today, it is recognized that the telecommunications network's response to overload and the magnitude of the decline in call-carrying capacity of an overloaded

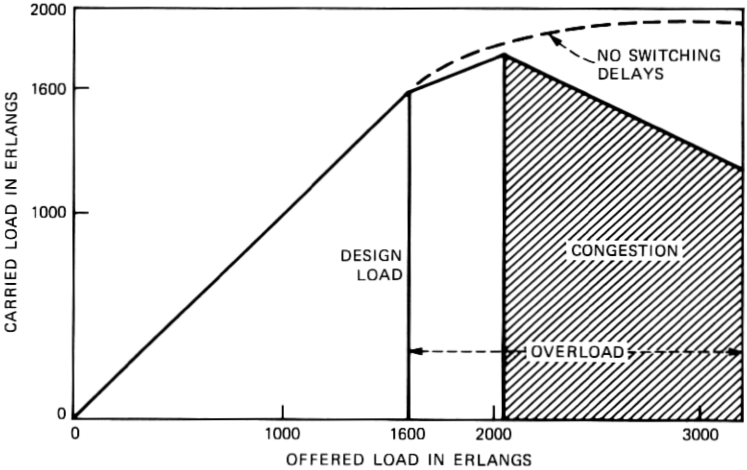

Fig. 1—Network performance under overload.

network depend on network architecture, call setup and routing procedures, signaling techniques, and switching system structure.[2–7]

2.2 Network management benefits

The primary motivations for network management in the Bell System are to maintain the integrity of the network and to ensure optimal performance of the network during overloads and failures. Telecommunications networks play a vital role during emergencies and natural disasters. The benefits of investments in modern network management capabilities are realized during such emergencies.[4] Network management, coupled with redundancy in critical switching components, assures network integrity in the Bell System at less cost than alternatives that do not involve network management. Maximizing call completions during overloads by network management techniques usually produces more revenue than network management capabilities cost.

III. NETWORK MANAGEMENT SYSTEMS

3.1 Automatic control systems

Network managers at the Network Management Centers (NMCs) discussed in Section 3.2 plan the employment of automatic network management controls in the MTS network. The NMC is responsible for monitoring the performance of the automatic controls through data furnished to the network management support system EADAS/NM by the switching systems. Occasionally, the NMC must fine tune the control response actions of the automatic controls that are built into SPC switching systems.

3.1.1 Automatic protective controls

Based on results of network overload characteristic studies, automatic network management controls, such as Dynamic Overload Control (DOC) and Directional Trunk Reservation (DRE), were introduced in the mid-1960s and proved to be effective during peak-day overloads such as Mother's Day and Christmas. However, these controls are not very effective during congestion caused by focused overloads, which are characterized by a surge of traffic originating in many parts of the network to a single destination, because they cannot selectively discriminate and control traffic based on destination codes. Focused overloads, stimulated by mass-media advertising, preplanned call-ins, or natural disasters, are occurring with increasing frequency in telecommunications networks.

As the network evolved to *ESS** switching system and CCIS,

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* Trademark of Western Electric.

network management control capabilities also evolved. A major advancement was the introduction of improved automatic controls with the introduction of the 4 *ESS* switching system in 1976.[8] The automatic controls that were introduced and are now in operation are summarized in Fig. 2. They include two automatic protective controls, Selective Dynamic Overload Control (SDOC) and Selective Trunk Reservation (STR), as well as a new automatic expansive control called Automatic-Out-of-Chain routing, discussed in Section 3.1.2.

SDOC responds to switching congestion by dynamically controlling the amount and type of traffic offered to an overloaded or failed switching system. SDOC response actions are taken based on control request messages from the overloaded switching system, typically transmitted via the CCIS data network. STR, on the other hand, does not require the transmission of a control message; it responds to trunk congestion in the outgoing trunking field and is triggered on a particular trunk group when less than a certain number or circuits are idle in that group. The novel feature that makes these two protective controls selective is that they control traffic to hard-to-reach (HTR) points more severely than other traffic. An HTR code is a three-digit or six-digit destination code to which calls have a low probability of completing.

Based on real-time analysis of three-digit and six-digit destination code completion statistics, HTR traffic is automatically detected by the 4 *ESS* switching system. Every five minutes the number of Ineffective Machine Attempts (IMA), defined as attempts which fail within the 4 *ESS* switching system, and the number of Ineffective Network Attempts (INA), defined as the number of calls failing in the network between the node of interest and the call's final destination, are determined by each 4 *ESS* switching system in the network. The INA count is based on the number of calls that abandon after outpulsing without obtaining answer supervision from the called customer line.

OVERLOAD OR FAILURE IN	CONTROL	RESPONSE
SWITCHING SYSTEM	SELECTIVE DYNAMIC OVERLOAD CONTROL	PROTECTIVE
TRUNK GROUP	SELECTIVE TRUNK RESERVATION	PROTECTIVE
HIERARCHICAL ROUTES	AUTOMATIC OUT-OF-CHAIN ROUTING	EXPANSIVE

Fig. 2—4 *ESS* automatic network management controls.

The current 4 *ESS* switching system code detection and control system[8] uses the 4 *ESS* switching system for identification of HTR traffic destination codes and, in the near future, will use the CCIS network to distribute this information to other nodes in the network for control purposes.[3,9] Thresholds established at switching systems by the NMC identify HTR traffic destination codes. Traffic for such codes will be selectively controlled at the switching systems by SDOC, STR, and during congestion in the CCIS network.

Concurrent with the introduction of 4 *ESS* switching system was the initial deployment of the CCIS network. Failures are rare because of the high degree of redundancy built into the CCIS network. Nevertheless, new protective automatic controls had to be provided that sense overloads and failures in the CCIS network and cause SPC switching systems to respond with control actions that can affect the flow of traffic in the telecommunications network. For instance, a focused overload can overload the terminal buffers of CCIS data links. To avoid the loss of CCIS messages and corresponding calls for the circuit-switched telecommunications network, SPC switching systems apply automatic protective controls in response to CCIS terminal buffer overloads and CCIS processor congestion. The controls temporarily restrict the amount of new messages that are offered to trunk groups that signal via the overloaded CCIS link terminals. CCIS link overloads are usually caused by unsuccessful reattempts to HTR points in the network and can, therefore, be controlled most effectively by code-selective controls. Recent studies utilizing single server queueing models and mean value analysis indicate potential benefit in increased call completion (throughput) due to selective control on CCIS messages.

Figure 3 shows the predicted effectiveness of these selective controls for a simulated focused overload in a 24-node toll network. The nonselective automatic controls are contrasted with SDOC and STR, assuming full deployment in all toll switching systems. Performance is measured in Fig. 3 by the average number of completed calls in progress versus time. While the improvements due to the selective nature of these controls are greatest during focused overloads, simulation results and experience indicate improvement also for peak-day overloads. Other automatic processor controls are incorporated in the network, such as line load control which, when enabled, denies customer access to the switching system in congestion.

3.1.2 Automatic expansive controls

In contrast to protective controls, which restrict access to overloaded network resources, expansive controls take advantage of idle capacity on out-of-chain routes, i.e., on routes that are not within the design of

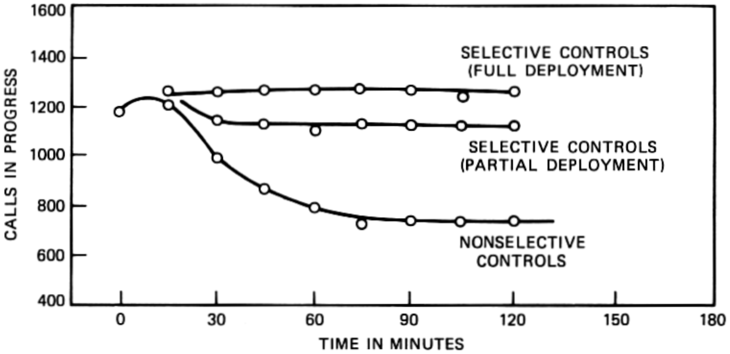


Fig. 3—Automatic control of focused overload.

the hierarchical routing structure. Automatic Out-of-Chain (AOOC) routing is a control that expands the route selection beyond the hierarchical routing constraints by offering calls overflowing the normal final-choice in-chain routes to up to seven out-of-chain routes. AOOC routing is the first step towards improved network utilization by taking advantage of network capacity that is often available through traffic noncoincidence. AOOC routing is made possible by the capabilities of the CCIS network, which permits AOOC routed calls to be classmarked, counted, and restricted to out-of-chain routes with idle capacity.

3.1.3 Controls for 800 Service with CCIS

The evolving SPC network with its inherent CCIS interconnectivity is also the key to new, innovative, communication services. These new services are made possible by computer-based Network Control Points (NCPs) to which switching systems are given direct switching access via the CCIS network. NCPs are specialized network nodes that provide the logic and routing information to handle enriched network services.

An example of new network management opportunities made possible by the SPC-CCIS network is the handling and control of 800 Service, formerly called Inward Wide Area Telephone Service (INWATS). Today, more than ten percent of the total toll calls are 800 Service calls; 800 Service mass calling is a frequent cause of overloads in the telecommunications network. In the SPC-enriched network, such calls first access a centralized NCP via the CCIS network. The NCP translates the 800 number to a new destination number and returns the number to the switching system, and the call is routed as a normal telephone call.

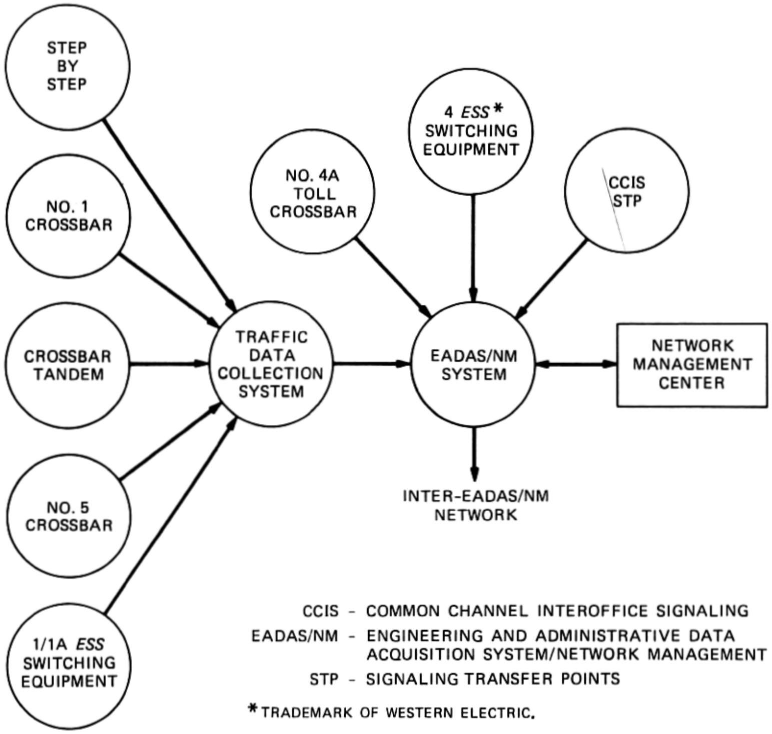
Network management controls are provided that protect the NCP, the CCIS network, and the circuit-switched telecommunications network from overloads. Code-selective controls are initiated automatically (or manually from the Network Operations Center described in Refs. 10 and 11) at the NCP. Call attempt thresholds are established at the NCP to detect excessive calling volumes. The Action Point (ACP) in the network (the switching system at which access to the NCP via the CCIS network is initiated) will recognize the control signals and limit attempts and NCP inquiries for high call volume destinations. The NMC will be informed via EADAS/NM when ACP controls are initiated.

3.2 Hierarchy of network management operations systems

Network managers in NMCs intervene in problems for which automatic system solutions would be excessively expensive and in problems requiring human judgment. In the past, NMCs were associated with major toll switching systems on a one-to-one basis. Each NMC displayed information that pertains to only one switching system and was able to affect call completions through manual controls in only that switching system. Later, real-time network performance monitoring capabilities were expanded by telemetering data to the NMC from a few distant lower-ranking switching systems. The main drawbacks of these older NMCs were decentralization and inadequate real-time network performance monitoring capabilities.

To overcome these drawbacks, the Bell System has developed a minicomputer-based system called EADAS/NM, which supports the operation of a centralized NMC.[9,12,13] Figure 4 shows this system collecting data in near-real time from toll and local switching systems in a large geographical area, such as an entire metropolitan area or a state. This allows such an area, called a "cluster," to be managed as a whole, and breaks away from the older concept of managing individual switching systems. Local and small toll switching systems are connected to the EADAS/NM system through an intermediate traffic data collection system. This intermediate data collection system consists of the Bell System Engineering Administrative Data Acquisition System (No. 1A EADAS) or a data acquisition system supplied by the General Trade. Large toll switching systems and CCIS Signaling Transfer Points (STPs) which have their own traffic data collection systems, interface with EADAS/NM via direct data links. As explained in more detail in Section 4.1.1, the EADAS/NM processor performs exception calculations on five-minute traffic measurements and displays the results in the NMC on a wall panel, printers, and Cathode Ray Tube (CRT) display "pages."

Figure 5 shows manual network management centers organized in



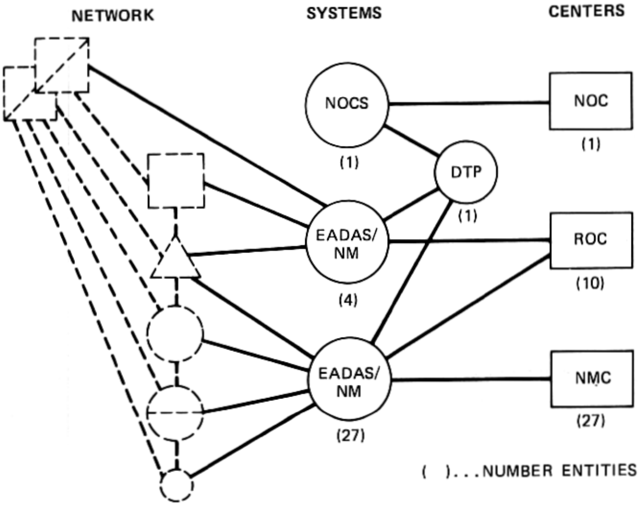
CCIS - COMMON CHANNEL INTEROFFICE SIGNALING
EADAS/NM - ENGINEERING AND ADMINISTRATIVE DATA ACQUISITION SYSTEM/NETWORK MANAGEMENT
STP - SIGNALING TRANSFER POINTS

*TRADEMARK OF WESTERN ELECTRIC.

Fig. 4—EADAS/NM interfaces.

a three-level hierarchy. The first or basic level is occupied by the EADAS/NM-supported Network Management Center. Twenty-seven such centers are now in service, spanning the entire United States.[11] The switching systems and CCIS STPs of the telecommunications network are shown as dotted lines. Each NMC is jointly staffed with Bell Operating Company, Long Lines, and in some cases, Independent Company personnel.

The Regional Operations Center (ROC) occupies the next level in this hierarchy. Each ROC is supported by an EADAS/NM computer system and provides a higher level of network performance monitoring and control than the basic Network Management Center. Whereas the basic NMC has the direct responsibility for the control and real-time performance monitoring of the toll and local networks in its cluster, the ROC has the responsibility for the coordination of activities between the two or three NMCs in its region. There are ten switching regions in the United States and therefore ten Regional Operations Centers. The ROCs are also focal points for real-time



DTP - DATA TRANSFER POINT
EADAS/NM - ENGINEERING AND ADMINISTRATIVE DATA ACQUISITION SYSTEM/NETWORK MANAGEMENT
NMC - NETWORK MANAGEMENT CENTER
NOC - NETWORK OPERATIONS CENTER
ROC - REGIONAL OPERATIONS CENTER

Fig. 5—Network management structure.

performance monitoring of portions of the CCIS network. As shown in Fig. 5, four ROCs are supported by dedicated EADAS/NM computer systems. Each of the remaining six ROCs is supported by an EADAS/NM system which also supports an NMC. There are 31 EADAS/NM network management operations support systems now in use.

A single center called the Network Operations Center (NOC)[10,11] makes up the top level of this hierarchy. As described in more detail in Ref. 11, this center is supported by its own computer system and it is responsible for coordinating interregional network management problems between the 10 ROCs, the 27 NMCs, and 2 regional network management centers in Canada. It also has the main responsibility for international network management and real-time performance monitoring of the entire CCIS network. A large amount of data are transmitted between the EADAS/NMs and the NOC system via a data network. The hub of this network is a data switch called the Data Transfer Point (DTP), which furnishes the NOC with a constant flow of high-speed performance monitoring data for all key toll switching systems, CCIS STPs, and international switching systems in the United States.

3.3 Centralized network monitoring and manual control

Even a highly sophisticated automatic system cannot respond optimally to all network disturbances. Thus, manual controls are required to provide additional adjustments to traffic flows in the network.

Figure 6 shows an example of an EADAS/NM-supported NMC in Boston, with the wall display panel in the background and interactive CRT systems in the foreground. The display system, which is described further in Section 4.1.2, is organized so that the activation of an indicator on the wall display panel directs the manager to CRT display pages for problem investigation and control activation. From one EADAS/NM-supported NMC, network managers can monitor and control several hundred switching systems.

Manual controls are activated from an NMC in many switching systems simultaneously through interactive CRT control pages. Control commands are communicated back to the switching systems by EADAS/NM over the same interface links over which data are collected from these systems. As shown in Fig. 7, manual network management controls are either protective or expansive in nature. Protective trunk group controls include trunk group controls which deny certain traffic access to a trunk group (cancel and skip controls) as well as trunk group directionalization. Protective controls are typically employed to limit traffic and thereby prevent the spread of traffic congestion. Expansive controls include controls that reroute traffic away from overloaded or failed facilities to facilities with idle capacity. Some computer-based tools that permit network managers to identify and solve traffic problems between regional switching systems are available at the NOC. These problems are solved through reroutes of which hundreds are implemented on peak days. Code block controls, which stop all or most of the traffic destined for overloaded points in the network, are employed mostly during focused overload congestion situations.

Because of the high number of reattempts, code block controls are not very useful in a mass-calling situation. With the deployment of CCIS, call-setup times are significantly reduced. Thus, the number of ineffective attempts per trunk can exceed 10,000 calls per hour, thereby defeating any mechanism to "choke" traffic flow based on the provision of a few, temporary, segregated trunk groups for traffic destined to a particular code. As shown in Fig. 8, a code block control based on a percentage restriction will still result in a high traffic volume under extreme conditions. Thus, a new control, "call gap," has been introduced. It consists of an adjustable timer that blocks all calls to a specified destination code for the set interval of time. The next call that arrives after the expiration of the time interval is allowed, after which the time gap begins again. This rate is strictly limited and

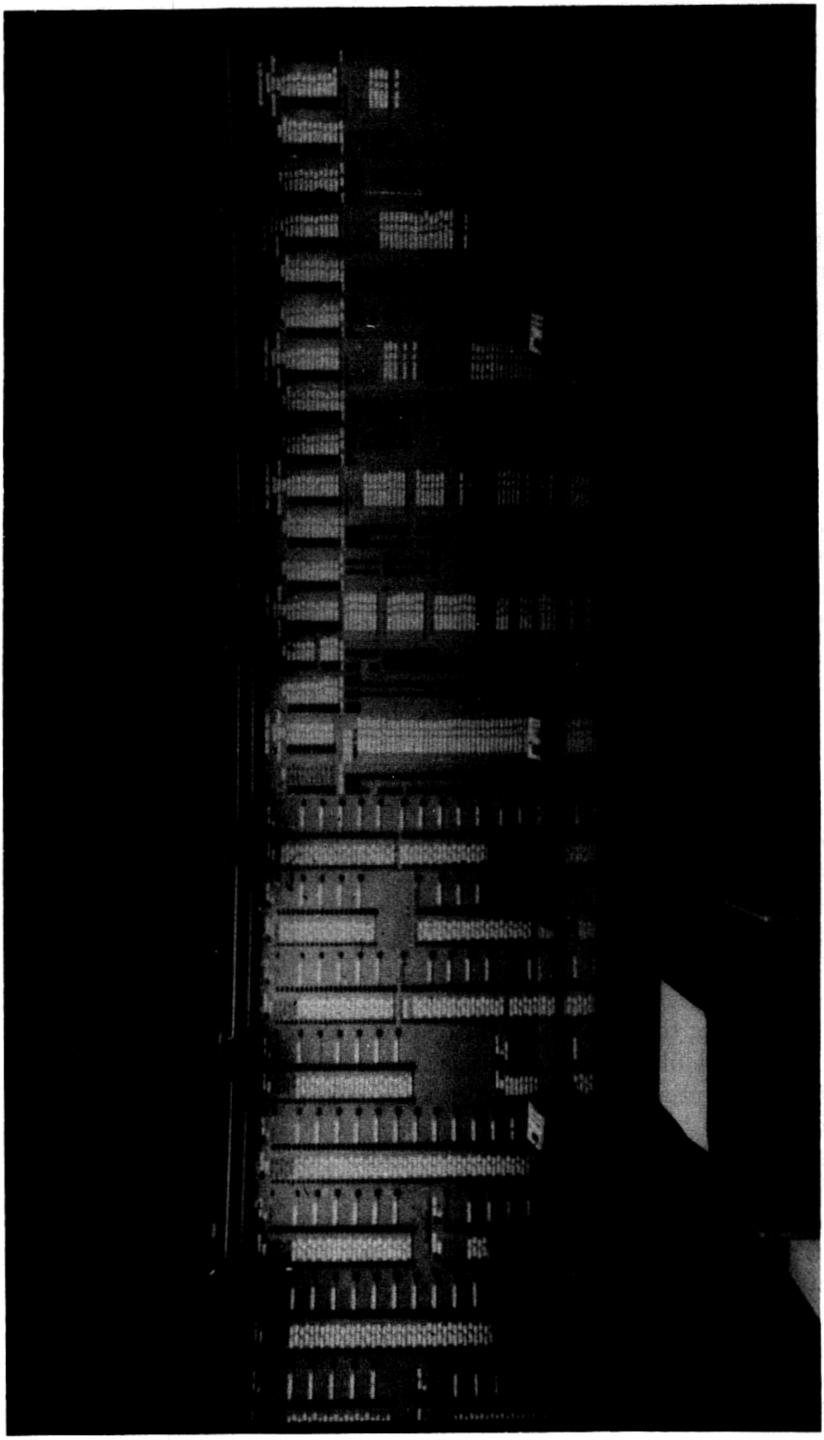
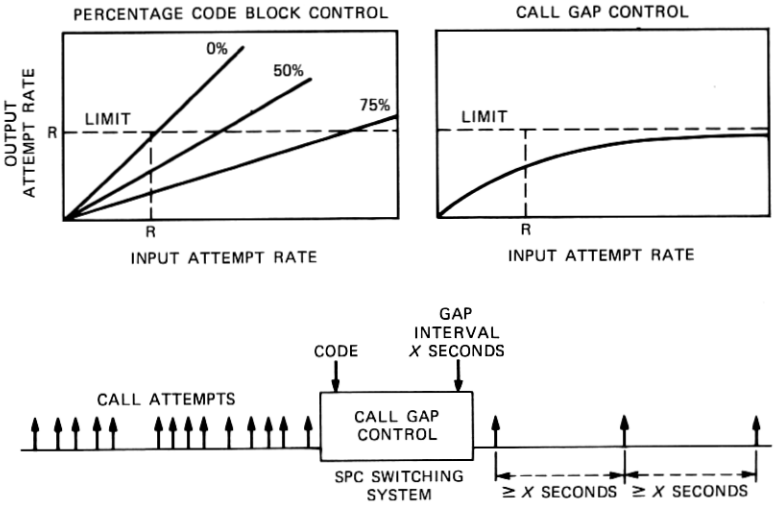


Fig. 6—Network management center.

PROBLEM	CONTROL	RESPONSE
NETWORK OVERLOADS OR FAILURES	CANCEL-TO/FROM SKIP TRUNK DIRECTIONALIZATION	PROTECTIVE
	REROUTE	EXPANSIVE
FOCUS OVERLOADS OR MASS CALLING	CODE BLOCK CALL GAP	PROTECTIVE

Fig. 7—Manual network management controls.



SPC - STORED PROGRAM CONTROL

Fig. 8—Comparison of code controls.

approaches the inverse of the gap interval. This control will be useful in situations that require a set rate of traffic flow, particularly in mass calling and focused overloads.

IV. EADAS/NM—THE COMPUTER SYSTEM

4.1 Basic EADAS/NM functions

EADAS/NM is the minicomputer-based operations support system for NMCs and ROCs.[14] Its major functions are: (1) collection of network traffic and performance occurrences on an event basis every 30 seconds and associated traffic counts every five minutes; (2) analysis of traffic data to ascertain exception conditions and output of results to a wall display, printers, and interactive CRT terminals; (3) implementation of network management controls by transmission of control messages to appropriate switching systems; (4) record base maintenance by auditing selected information from SPC switching systems and by manual input of record items; and (5) transmission of selected information to the NOCS for national network performance monitoring.

4.1.1 Data collection and exception calculations

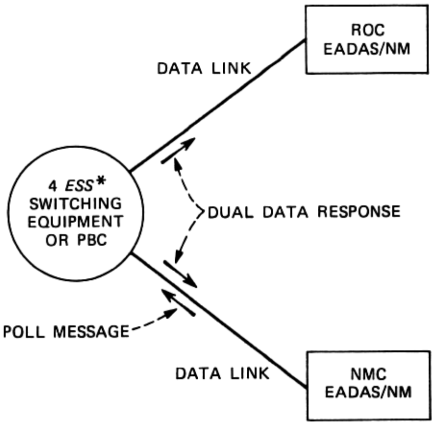
Data collection is done on a five-minute basis for traffic counts and on a 30-second basis for discrete (event) information. At the start of a five-minute interval (or a 30-second interval for discretes), EADAS/NM dispatches poll messages over direct data links to 4 *ESS* switching systems and PBCs (Peripheral Bus Computers), and through EADASs or equivalent General Trade systems to various local and small toll switching systems. The PBCs are administrative adjuncts to No. 4A Toll Crossbar Electronic Translator Switching Systems (No. 4A ETSs) and to STPs. Upon the completion of data acquisition for a given switching system, exception calculations are performed by comparing traffic data to preset thresholds. Once all polling and exception calculations are complete, the wallboard is updated to alert network managers of any changes in network conditions that may require further attention. Critical discrete changes update the wallboard on a 30-second basis. Exceptions of interest to the NOC (usually those involving switching systems and trunk groups in the upper three levels of the MTS network hierarchy) are routinely sent over a dedicated data link through the DTP to the NOCS.

The operation of an ROC EADAS/NM system is similar to the operation of an NMC EADAS/NM system except that the ROC EADAS/NM system obtains data both by direct polling and by passive monitoring. Typically, an ROC EADAS/NM system directly polls the regional switching system and the PBCs associated with STPs. It also receives data from passive connections to selected 4 *ESS* switching systems and PBCs. Figure 9 illustrates this arrangement.

4.1.2 Data display

The data display systems for EADAS/NM include the wallboard and exception printer as alerting devices, a monitor printer, and a repertoire of over sixty CRT display pages. The exception printer prints out a record of exceptions as they occur. The monitor printer allows the network manager to designate particular trunk groups (often those which are being used in a network management reroute control) for continuous observation.

The EADAS/NM CRT subsystem is comprised of a number of fixed-format displays which provide demand access to traffic data for



PBC – PERIPHERAL BUS COMPUTER
ROC – REGIONAL OPERATIONS CENTER
EADAS/NM – ENGINEERING AND ADMINISTRATIVE DATA ACQUISITION SYSTEM/NETWORK MANAGEMENT

* TRADEMARK OF WESTERN ELECTRIC.

Fig. 9—ROC passive data collection feature.

the last 20 minutes and to current control and discrete status. Displays also may be used by network management personnel to implement or remove network controls, to modify certain trunk group-related reference database information, and to initiate requests for continuous observation of network components through the monitor system.

The CRT displays are divided into the following categories: *trunk group*, for traffic data on trunk groups at a selected switching system or switching systems within a geographical area; *machine*, for equipment and control status for a selected switching system; *control*, to display and implement network controls at one or more switching systems; *exception*, for resolution of data triggering exception indicators on the wallboard; *input and monitor*, for certain database and monitor system requests; and *analysis*, for analyzing traffic data to ascertain, for example, where there is idle capacity in the MTS network for network management reroutes.

The human interface to the CRT subsystem employs standard CLLI (Common Language Location Identification) codes to designate switching systems and trunk groups. In this way, a consistent identification of network components is achieved throughout the NMC/ROC/NOC hierarchy.

4.1.3 Controls

Network Management controls are activated and deactivated from selected CRT pages, after which appropriate messages are transmitted to the switching systems where the controls are actually instituted. A control log is maintained in EADAS/NM so that network managers have a record of what actions were taken. Control changes affecting traffic in the upper levels of the MTS network are sent to the NOCS. If, for some reason, a network management control is applied locally at a switching system, an alerting discrete is picked up by EADAS/NM on the next 30-second discrete poll. EADAS/NM then does an audit to determine and record the new control status for that switching system.

4.1.4 Record base definition and maintenance

EADAS/NM requires a very large record base which describes the "cluster" or portion of the network being managed. A full set of database management tools are provided for network management personnel (system users) to input record information and to validate it. Manual and automatic audit capabilities are provided to keep the record base current. For example, if more trunks are added to a trunk group, EADAS/NM receives an alerting discrete that triggers an automatic audit to update its database.

Reference information is also exchanged between EADAS/NM and the NOCS. Specifically, the NOCS transmits to EADAS/NM a list of switching systems that are of interest to the NOCS, along with a set of switching system and trunk group exception threshold levels. In this way the NOC can control what network information it receives. The NOCS can also audit EADAS/NM for the status of controls in switching systems that are of NOC interest.

4.2 System hardware configuration

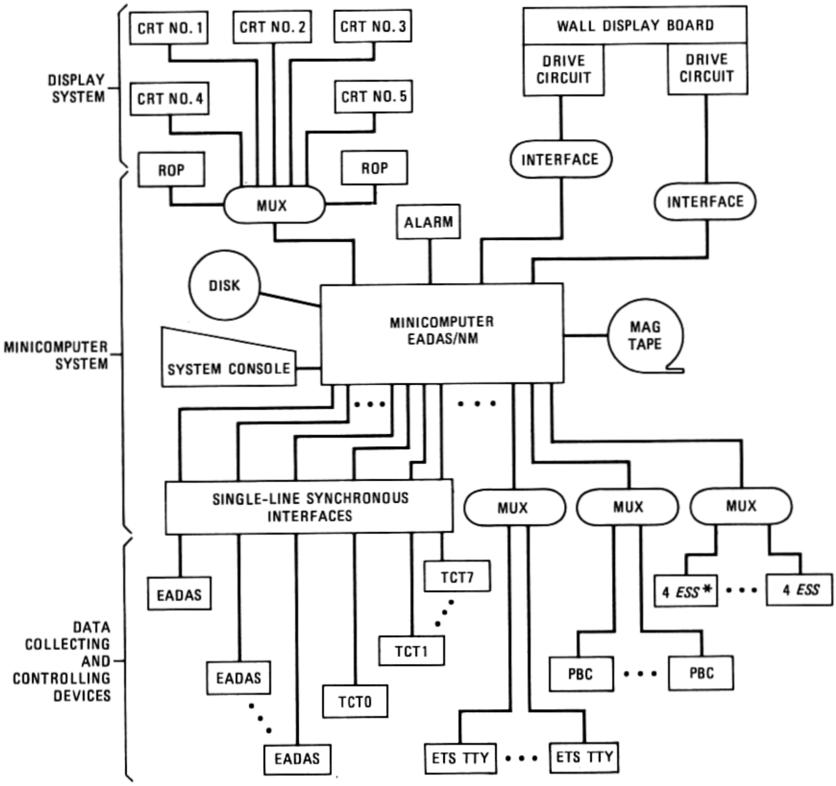
Figure 10 shows a block diagram of the EADAS/NM minicomputer system and its relation to the data collecting and display devices. A brief description of the components follows:

EADAS/NM Minicomputer—The data processor for the system; it interfaces to all of the data collection, storage, and display peripherals, and executes the main system programs.

CRT Display Devices—Up to five DATASPEED Model 40 cathode ray tube terminal station arrangements in a KDP (Keyboard, Display, Printer) configuration.

Wall Display Board—Consists of an array of fluorescent, reflective, electromagnetically controlled indicators. A maximum of 4095 indicators can be used with a single wallboard driver. Up to two wallboard drivers may be equipped on an EADAS/NM system.

Disk Drives—Mass storage system using magnetic disk packs. The disk packs have a capacity of 80 million 16-bit words.



CRT – CATHODE RAY TUBE
EADAS – ENGINEERING AND ADMINISTRATIVE DATA ACQUISITION SYSTEM
EADAS/NM – ENGINEERING AND ADMINISTRATIVE DATA ACQUISITION SYSTEM/NETWORK MANAGEMENT
ETS – ELECTRONIC TRANSFER SYSTEM
MUX – MULTIPLEXOR
PBC – PERIPHERAL BUS COMPUTER
ROP – RECEIVE-ONLY PRINTER
TCT – TELEMETRY COMPUTER TRANSLATOR
TTY – TELETYPEWRITER
* TRADEMARK OF WESTERN ELECTRIC.

Fig. 10—Hardware configuration.

Command Console—Data terminal which may be used for any of the system commands.

Magnetic Tape System—Standard nine-track tapes at either 800 or 1600 bits per inch (bpi) used to initially load the programs, to back up the database, and to record real-time data for subsequent playback. The playback feature helps network managers review and critique specific events of network management interest using the wall display board and CRT displays. Such events can be played back in slow, real, or fast motion.

Telemetry Computer Translator (TCT) Interface—The E2A telemetry computer translators, each of which interfaces with up to four remote terminals, are used to receive discretes and send controls to

No. 4A ETS and Crossbar Tandem switching systems via the E2A telemetry system.

General Purpose Interface—Interface for both the wallboard and the E2A telemetry system.

Single Line Synchronous Interface—Interface capable of transfers at up to 9600 characters per second. These are used to transfer data from an EADAS to EADAS/NM and from EADAS/NM to NOCS.

Multiplexor (MUX)—Connects the processor with up to 16 asynchronous serial communication lines. One multiplexor is required for the EADAS/NM CRT terminals and receive-only printers (ROPs), and one or more additional multiplexors are required for No. 4A ETS, PBC, and 4 *ESS* switching system data links.

ETS TTY—100-baud teletypewriter channels used to transmit certain network controls to No. 4A ETS switching systems.

4.3 Software architecture

The EADAS/NM minicomputer software consists of the *UNIX** operating system and a collection of application programs that perform the EADAS/NM tasks. The application programs can be divided into real-time tasks, which perform data gathering, processing, and display functions; and certain non-real-time tasks. All applications programs are written in the C programming language. There are 12 major subsystems comprised of over 70 independent programs and over 1100 C-language modules. The overall software structure is depicted in Fig. 11 and will be discussed in more detail in this section.

4.3.1 The UNIX *operating system*

The *UNIX* operating system is general purpose, multiuser, and interactive. Utilized by EADAS/NM, its features include the following:

1. A hierarchical file system incorporating demountable files.
2. Compatible file, device, and interprocess Input/Output (I/O).
3. The ability to initiate asynchronous processes.
4. A system command language that can be selected on a per-user basis.

It should also be noted that the *UNIX* operating system is used for program development of the EADAS/NM project, providing a complete environment for the entry, compilation, loading, testing, maintenance, and documentation of the software product.

4.3.2 The EADAS/NM database

The EADAS/NM reference database consists of a number of user-

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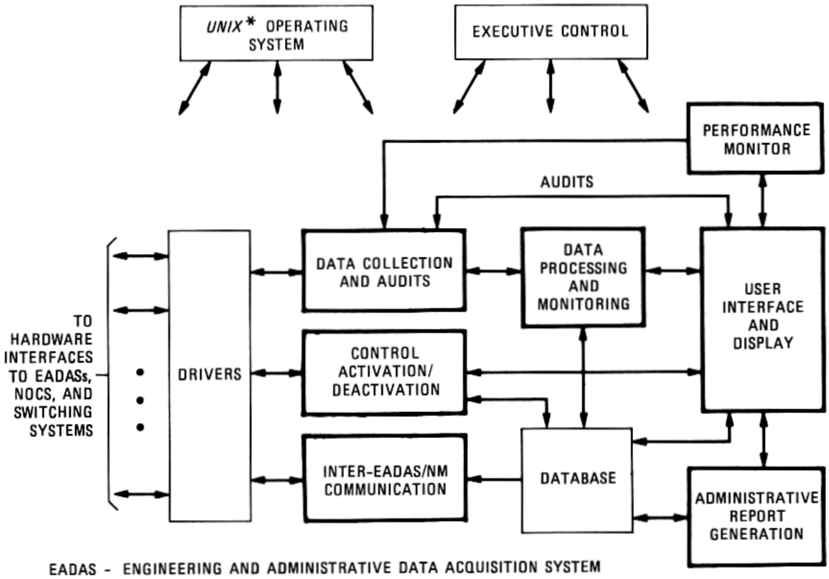
* Trademark of Bell Laboratories.



EADAS - ENGINEERING AND ADMINISTRATIVE DATA ACQUISITION SYSTEM
EADAS/NM - ENGINEERING AND ADMINISTRATIVE DATA ACQUISITION SYSTEM/NETWORK MANAGEMENT
NOC - NETWORK OPERATIONS SYSTEM
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Fig. 11—EADAS/NM software structure.

built text files. These files are entered into the system using the *UNIX* operating system text editor.

In general, the information contained in these files falls into two categories. First is the information that pertains to the NMC itself, which includes the configuration of the center, the wallboard layout, and the threshold tables. The second category of information is concerned with the network to be monitored. This includes details about the switching systems and trunk groups in the NMC's cluster.

Once the database files are prepared, an operational database can be built using the database commands.

4.3.3 Executive control program

The executive control program is responsible for system initialization and for controlling the various real-time application processes. It accepts initial system parameters, starts the real-time application processes, monitors those processes for abnormal termination, and in general establishes and maintains the heartbeat of the system.

4.3.4 Interface drivers

A collection of driver programs interface the application software with the interface hardware. These programs provide the basic communications protocols for transmitting and receiving information on the data links that connect to EADAS systems, the NOCS, and the various switching systems.

4.3.5 Application programs

Those blocks that are heavily outlined in Fig. 11 represent the actual EADAS/NM application programs. The major functions of these programs include data collection and audits, control activation and removal, inter-EADAS/NM communication, data processing, and user interface and display. In addition, a performance monitor maintains performance statistics on major system events such as data collection, exception calculations, and delivery of information to the NOCS. Also, a set of administrative report programs automatically generate needed switching system and trunk group summary reports.

The data collection and audit subsystem includes programs for polling both five-minute traffic data and 30-second discrete information. For example, the 4 *ESS* switching equipment traffic data polling programs poll 4 *ESS* switching equipment for switching system, trunk group, and HTR code data and then store these data on disk for subsequent retrieval by the data processing programs. Discrete polling programs perform similar functions and also update the wallboard based on the discrete information. Audits are essentially demand polls that may either be requested manually by the network manager or automatically whenever an alerting discrete (see Sections 4.1.3 and 4.1.4) is received. The audit program collects the new information and updates the system reference or control data accordingly.

Control activation and removal programs receive control requests from the user interface and display subsystem, format the control messages in the appropriate switching system command protocol, and send them to the switching system via the interface driver programs. The control programs perform checks to verify that controls are properly activated and deactivated. They also maintain up-to-date control status records in the database and the control log.

The inter-EADAS/NM subsystem handles all communication with the NOCS. It includes programs that receive appropriate information from the NOCS and then establish in the database a record of what switching systems and trunk groups are of NOC interest. Other programs arbitrate queues that contain exceptions, control status changes, and HTR code data for transmission to the NOCS. Still other programs format the messages and pass them to the NOCS interface driver for transmission. The inter-EADAS/NM subsystem can also handle messages that come from or go to other EADAS/NMs via the DTP.

The set of data processing and data monitoring programs perform calculations on five-minute traffic data to determine whether exception thresholds have been exceeded and to support trunk group data monitoring requests. These programs also update the wallboard, based upon the results of the exception calculations, and feed the inter-EADAS/NM subsystem with NOC-interest exceptions. Discrete monitor programs monitor user-specified discretes for user-specified time intervals and produce a discrete monitor list which is passed to the user interface and display subsystem for display.

The user interface and display subsystem includes all of the various CRT page programs (see Section 4.1.2), the programs that control the printing of information on the exception and monitor printer, and the programs that receive and interpret user commands.

V. FUTURE NETWORK MANAGEMENT NEEDS

Future network management studies are aimed at providing improved methods for controlling the evolving switched network under overload and failure conditions. These efforts are expected to increase the reliance on automatic controls and improve centralized operations procedures and supporting system capabilities.

Simulation and analytical studies are under way to characterize the overload dynamics of a network dominated by electronic switching systems and CCIS. Specific studies focus on control strategies for new NCP-based services such as enhanced 800 Service, and the proposed evolution from the present hierarchical network to nonhierarchical, time-varying routing.[15]

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