STORED PROGRAM CONTROLLED NETWORK

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THE BELL SYSTEM
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STORED PROGRAM CONTROLLED NETWORK
P. K. Bohacek, Guest Editor

Stored Program Controlled Network:

Prologue

By F. T. ANDREWS, JR. and K. E. MARTERSTECK

The rapid introduction of electronic switching systems with Stored Program Control (SPC) has made possible the interconnection of the control processors by high-speed data links to provide common-channel interoffice signaling (CCIS). Not only does this permit higher-speed, lower-cost, more reliable setup of connections, but also the transfer of packets of information for more flexible call control. The papers in this issue describe the evolution of the SPC network concept since the introduction of CCIS in 1976 and the first new services which will exploit the power of this new network capability.

I. INTRODUCTION

This special issue of *The Bell System Technical Journal* covers Stored Program Controlled (SPC) network structure and the innovative new service capabilities that this structure makes possible. It follows a series of special issues that have covered individual SPC switching systems and the common-channel interoffice signaling (CCIS) system, which is being deployed at a rapid rate to interconnect them.

The first step in the evolution of the SPC network was the introduction of No. 1 ESS in Succasunna, New Jersey, in 1965. The principal emphasis in No. 1 ESS design was the use of SPC to replace the earlier wired logic that had been employed in electromechanical switching systems. The use of SPC allowed the introduction of significant new service features, as well as reductions in operating expense. No. 1 ESS was followed by No. 2 ESS and No. 3 ESS, designed to cover suburban and rural segments of the local switching market. Today, more than 2500 local ESSs are in operation, providing nearly 50 percent of Bell System lines with modern circuit switching of voice bandwidth signals.

In parallel with the introduction of local ESS, effort began on the application of SPC to a large toll switching machine. To meet this toll need, a second-generation ESS, No. 4 ESS, was introducted in 1976 in Chicago, Illinois. It included the use of a time division network, rather than the space division network used in the first generation switches. This produced a synergy between digital transmission and digital switching which has been responsible for much of the motivation for introducing No. 4 ESS at a rapid pace. Within a short period of five years, deployment has grown to 65 systems, with 1.5 million trunk terminations carrying more than 100 million calls per day. However, the key feature from the standpoint of the role of No. 4 ESS in the SPC network structure is not time division digital switching, but the use of SPC.

Stored program control systems incorporate the intelligence of a built-in digital computer, which gives the systems great flexibility. Service features are more easily incorporated by issues of software generics than was ever possible with wired logic systems. Once it was recognized that the network of SPC switching systems is really a network of special-purpose processors, an early objective became the interconnection of these processors in a way that would generate still broader capabilities than possible in individual SPC systems.

The first step in this networking was accomplished in May 1976, with the introduction of common-channel interoffice signaling (CCIS) between a 4A toll crossbar system in Madison, Wisconsin, and No. 4 ESS in Chicago. This signaling system provided a high-speed, high-capacity link between the central processors of the systems and made possible faster, more reliable call setup and supervision than had ever been possible before. Historically, the functions of initiating and terminating connections and passing forward address or control information had been accomplished in the same channel as that used for talking. The CCIS system accomplishes these same functions by multiplexing the signaling information for many channels on a separate 2400- or 4800-b/s data link.

The most obvious way of organizing a CCIS network would be to associate a data link with every trunk group interconnecting SPC systems. While this might be economic for large trunk groups, it is not an attractive approach for serving the vast majority of smaller trunk groups that exist in the public switched network. Actually, the CCIS network has evolved as an overlay structure involving 20 signal transfer points, two in each region of the switching hierarchy. These signal transfer points act as packet switches which route signaling information from one SPC system to another for performing supervisory and control functions.

While originally conceived as a means of communicating between

processors at the opposite ends of trunk groups to obviate the need for in-channel signaling, the packet transport nature of the CCIS network allows for the direct transmission of messages between any two points interconnected by the network of CCIS links and signal transfer points. This opens up many possibilities for exploiting the CCIS capability to accomplish objectives other than the higher-speed, lower-cost, more reliable setup of connections for which it was originally intended. These possibilities include access to data bases, the forwarding of calling numbers to the destination, and flexible routing to systematically modify traffic patterns. The immediate plans for exploiting the power of the SPC network include the addition of centralized data bases in the network for billing validation on direct dial credit card calling and for more flexible routing options in INWATS, now known as 800 Service. These new features for the SPC network are the vanguard of a long list of service capabilities likely to be introduced in the future.

The first three papers in this special issue provide an overview of the SPC network, a technical description of its basic elements, and the interconnection plan. Subsequent articles describe how the basic CCIS capabilities and features have evolved since the introduction of this concept in 1976, including the plans for extension to local SPC switching systems. Then the first new services that exploit the power of SPC switching systems interconnected by a CCIS network are described, in particular, direct dial credit card calling and 800 Service. The final article discusses the new administrative challenges introduced by these new services and how they are being met.

Organizing the SPC network for these services is one of the broadest projects ever undertaken by Bell Laboratories in terms of its impact on elements of the public switched network. To make it all happen, new capabilities are being deployed on a coordinated basis throughout the network. It would not have been possible to accomplish this without the support of many individuals and groups within the Bell System who share the common vision of the future telephone network as a network of distributed processors with an almost unlimited ability to serve customer needs for information transport.

Stored Program Controlled Network:

Overview

By S. HORING, J. Z. MENARD, R. E. STAEHLER, and
B. J. YOKELSON

(Manuscript received July 23, 1981)

This paper describes the evolution and architecture of the Stored Program Controlled (SPC) Network. The critical role of common-channel interoffice signaling (CCIS) is discussed, both as an improved method for providing the traditional signaling functions, and as the key to a wide range of new service opportunities. These are made possible by the ability to interrupt call progress and, in real-time, interrogate a distant data base and modify the subsequent call handling based on the information returned. The underlying architecture by which these services are implemented is based on the objectives of providing ubiquitous service with limited deployment of essential network capabilities and creating a structure which permits customized services by modifying the contents of a centralized data base.

I. INTRODUCTION

Two major trends in the North American telecommunications network today are the evolution to an Integrated Services Digital Network (ISDN) and the Stored Program Controlled (SPC) Network, which is an important component of the ISDN. The first is a product of the digital revolution and is driven by the fact that digital technology is increasingly becoming the economic choice for conventional voice applications while, at the same time, being the driving force for a wide range of data applications. In contrast, the term SPC network is the label given to a quiet but profound revolution in network intelligence, which is expanding the potential of our telecommunication network for both voice and data applications. More specifically, the SPC network refers to the set of SPC switching systems which is interconnected by common-channel interoffice signaling (CCIS).
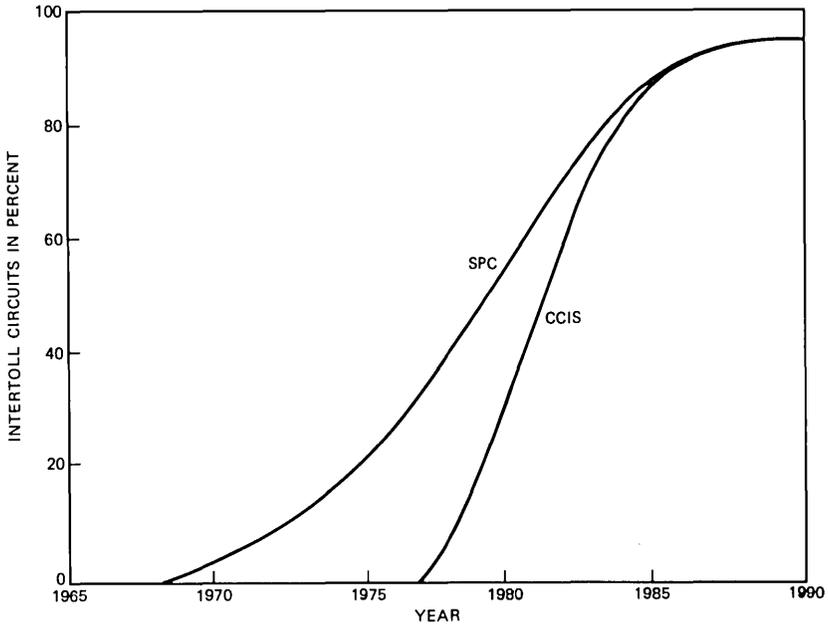
Fig. 1—Bell System intertoll circuits served by SPC.

II. DEPLOYMENT OF SPC NETWORK

The deployment of the SPC network started in the toll portion of the network with the introduction of CCIS in 1976, coincident with the introduction of the No. 4 ESS high-capacity, time-division toll switching system. CCIS was introduced into the toll network on selected systems to maximize trunk connectivity, while satisfying the constraint of making a positive economic contribution. Savings in expensive in-band signaling equipment and faster call setup supported the initial deployment, while new features, such as improved 800 Service, were made possible by the rapid CCIS penetration and buildup in connectivity. Figure 1 shows a recent view of SPC and CCIS intertoll projections.

In 1981, CCIS was introduced on TSPS to provide the capability to exchange CCIS messages between TSPS and network control points (NCPs), which contain centralized network data bases capable of supporting a variety of customer-specific service offerings. The first application of this capability was Mechanized Calling Card Service, an automated credit card calling capability that allows customers at *Touch-Tone** stations to place calls billed to their credit cards without operator assistance. Savings in reduced operator work time are ex-

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pected to support the capital and software investments required and represent an important contribution to the Bell System goal of most effectively utilizing the operator work force, while providing buildup of TSPS coverage along with the associated CCIS capability. Figure 2 shows the projected penetration of TSPS and its CCIS capability.

The extension of CCIS capability to local switching systems presents a different set of opportunities and challenges. The projected benefits associated with local CCIS are great and include the provision of capabilities which extend further the range of customized services which could be supported. These include alternate routing based on the busy/idle status of a line and selective treatment of calls based on the calling number (e.g., distinctive ringing, selective call forwarding). In addition, significant improvements in network operation are possible, including faster and more economical call setup, and the use of traveling class marks to identify calls requiring special handling. To capitalize on these opportunities, it must be recognized that despite an aggressive modernization program, the relatively large number of Class 5 offices (≈10,000 for the Bell System alone) extends the time required to penetrate this part of the network compared with the relatively short time required to introduce CCIS into TSPS and toll switching systems. The initial introduction of local CCIS is planned for 1981 with
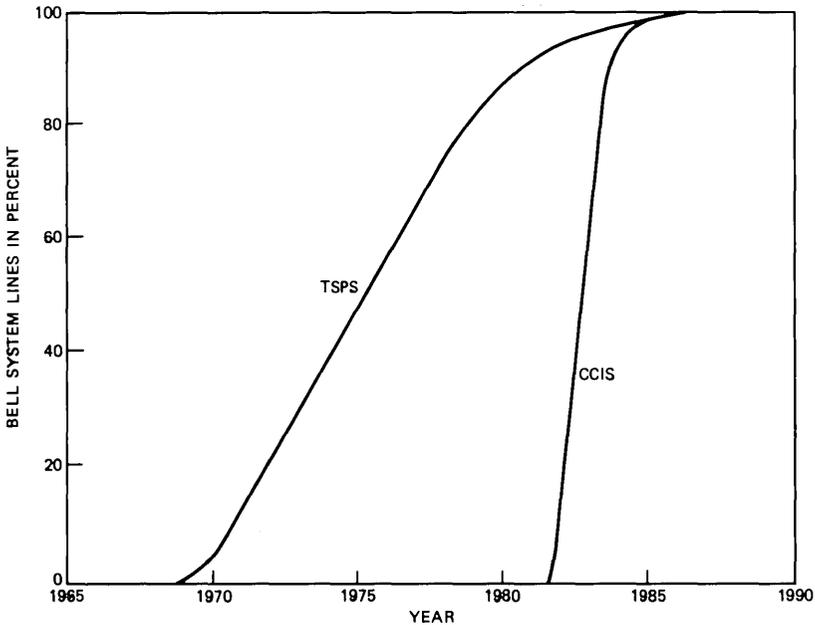
Fig. 2—Bell System lines served by TSPS.

the current projection of the buildup shown in Fig. 3, along with the corresponding projection of local SPC coverage of customer lines.

The network control point (NCP) was introduced in 1981 and is intended to support a wide range of SPC network applications. The first of these is an improved version of 800 Service and Mechanized Calling Card Service. A wide variety of other applications are currently being considered.

Figure 4 shows a simplified block diagram of the SPC network with these building blocks in place where the signal transfer point (STP) refers to the high-capacity packet switches which serve the CCIS network.

The growth of the CCIS network needed to support improved call setup and other applications is suggested by Fig. 5, which provides a projection of the growth of signaling network loads until 1995. To appreciate the size of this network, it is worth noting that, despite the apparent low load level shown in 1981, the message volume supported would probably classify it as the highest capacity data network in the world.

III. POTENTIAL SPC NETWORK BENEFITS

As indicated previously, the benefits of the SPC network tend to fall into two categories: improved network operation and the support of
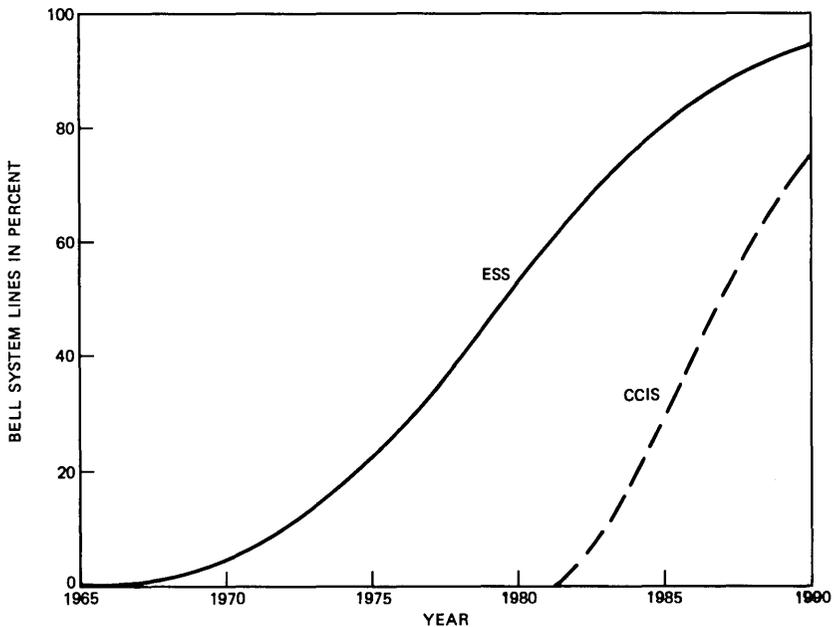
Fig. 3—Bell System lines served by ESS.

Fig. 4—Stored Program Controlled Network.

new customer services. While it will only scratch the surface of the potential opportunities ahead of us, a brief discussion of each of these areas will serve to illustrate the possibilities.

To begin with, the elimination of in-band signaling equipment provides an opportunity to reduce capital expenditures. In addition, network performance is improving as a result of the reduced call setup time associated with CCIS when contrasted with conventional signaling approaches. Figure 6 illustrates this improvement for a typical New York City to Chicago call. This provides direct customer benefits, as well as reducing capital expenditures for facilities as a result of the shorter circuit holding time. Additional reductions in capital expenditures also will result from the ability to determine the busy/idle status of the terminating line before setting up a voice path. This will eliminate the need to establish talking paths to busy destinations. The SPC network also makes the use of nonhierarchical network routing schemes, which can more efficiently utilize plant investment, a practical reality. Expense savings opportunities also exist. They include such possibilities as the reduction in average operator work time because of Mechanized Calling Card Service and utilitization of a "look-ahead-for-busy" capability. In addition, losses because of fraud will be reduced as a result of the ability to provide improved credit

Fig. 5—Signaling network projected loads.
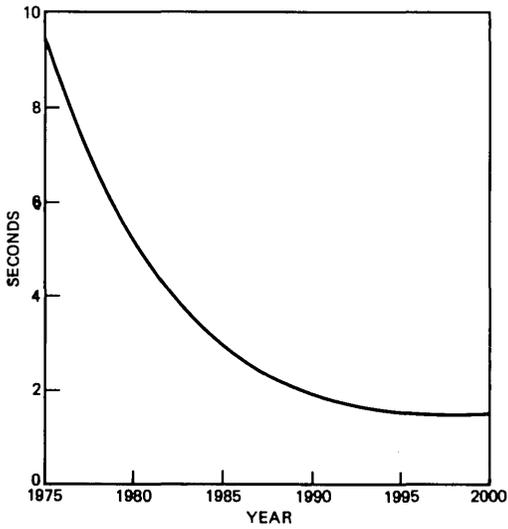
Fig. 6—Common-channel interoffice signaling impact—average call setup time, New York City–Chicago.

card and third-number billing checks. In addition to these benefits, the use of traveling class marks provides opportunities for improved network management and special handling of classes of calls (e.g., satellite avoidance).

In the area of new services which can be supported, the possibilities are limited only by the imagination. Improved 800 Service serves to illustrate these capabilities and is shown in Fig. 7. A customer-dialed 800 number is routed to an appropriately equipped CCIS node (designated an action point or ACP). Call setup is momentarily interrupted, while a message is sent via the CCIS network to query a data base (located at the NCP) for instructions on the desired routing of the call. These instructions are returned to the ACP where call routing progress continues. The illustration shows the case where the data base maintains real-time busy/idle status information of the terminating lines. Another possible new service would allow friends, family, and business associates to reach a subscribing customer wherever that customer might be. A possible implementation for such a person locator service is shown in Fig. 8. Customers would be given special telephone numbers (not associated with a particular line) and would enter into the NCP the phone number of the location where they could be reached. Terminating-end office features which could provide selective treatment of calls based on the calling number (e.g., distinctive ringing) further expand the range of possible services which can be supported. To allow customers control over the services they desire requires an innovative approach to the underlying network architecture.
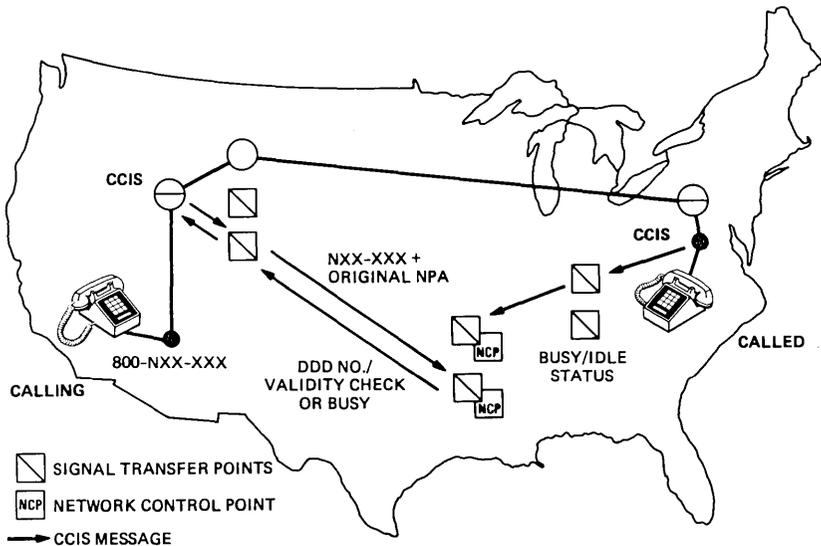
Fig. 7—Stored Program Controlled Network 800 Service.
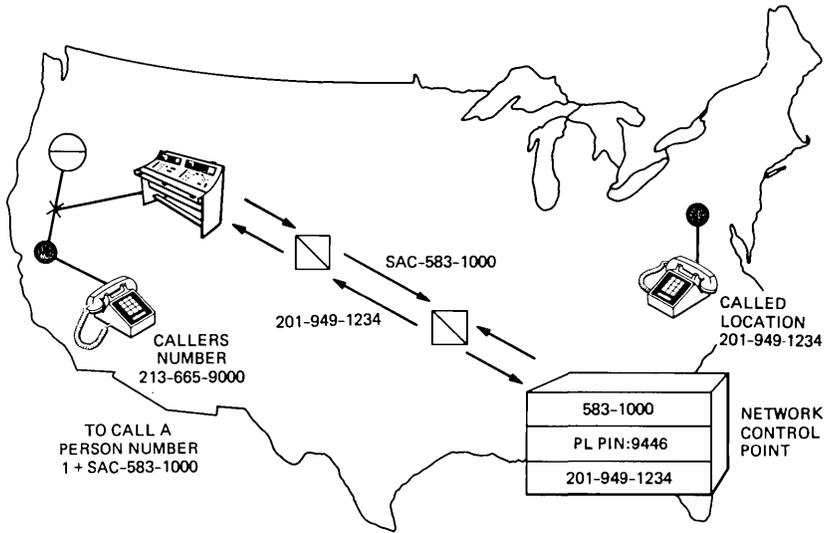
Fig. 8—A person locator example.

IV. SPC NETWORK ARCHITECTURE

The architecture of the SPC network has been designed to meet a number of fundamental objectives. Principal among these is the desire to provide flexibility which permits customers to configure services tailored to their specific needs, along with rapid response in providing ubiquitous availability of new capabilities as they are introduced. The two characteristics of the architecture which support the first of these objectives are: (*i*) the use of a set of basic network capabilities which can be combined under administrative control to define a wide range of services, and (*ii*) the introduction of a centralized data base which contains customer-specific data needed to define individual services from these capabilities. The set of switching primitives utilized includes such building blocks as "collect N digits," "send a CCIS message to the NCP," "make a billing record," and "provide announcement K." The problem of providing rapid ubiquitous deployment of new capabilities is intimately related to the number of systems in which the capabilities must be deployed. To circumvent some of the difficulties of achieving rapid ubiquitous deployment, the architecture permits ubiquitous access to capabilities that have limited deployment. Migration of the capabilities to additional network nodes as economics and time permit can then be accomplished in a manner which is transparent to the customer. This migration concept is shown in Fig. 9, which illustrates the migration of the action point (ACP—the collection of basic capabilities, located at appropriate SPC switching systems, which support
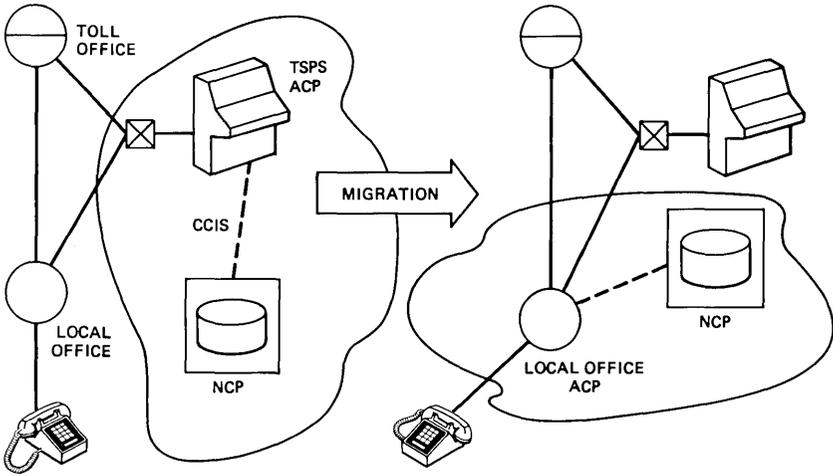
Fig. 9—Action point migration.
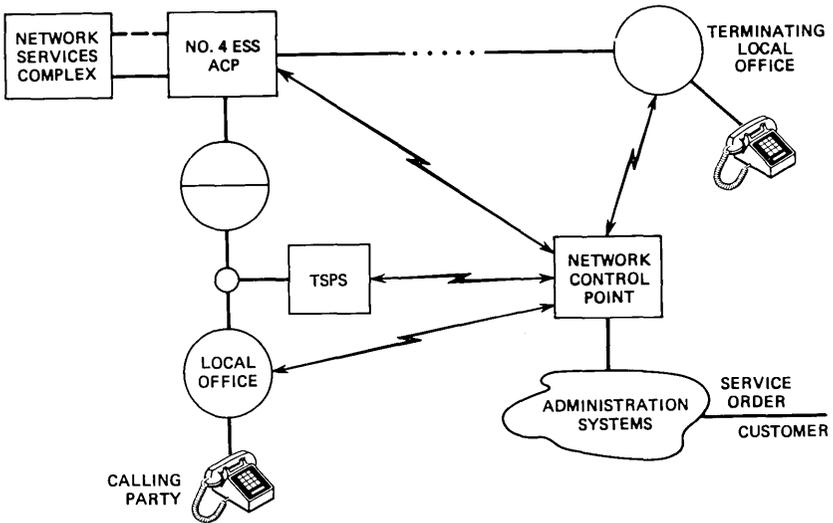
Fig. 10—Direct services dialing capabilities.

the variety of potential network services) from a TSPS site to a local SPC office. The set of SPC network capabilities which support this architecture are known as Direct Services Dialing Capabilities (DSDC). They are shown in Fig. 10.

V. SUMMARY

This paper has provided an overview of the SPC network, its struc-

ture, status, and potential. With the introduction and rapid penetration of the SPC network, the North American telecommunications network can properly be viewed as a large, distributed processing system, capable of providing efficient, intelligent communications capabilities to its customers. Despite its recent introduction, the SPC network is spreading rapidly and is already undergoing major modernization. As an example, planning is in progress for the transition of the CCIS network to a higher capacity CCITT-based signaling system to support the growing potential applications.

This paper is also intended to provide a general background and should serve as an introduction to the papers that follow. They present a more detailed technical view of the current status of the SPC network.

Stored Program Controlled Network:

Generic Network Plan

By J. J. LAWSER, R. E. LeCRONIER, and R. L. SIMMS

The network of stored program control communication processors interconnected with common-channel interoffice signaling (CCIS) is commonly referred to as the Stored Program Controlled (SPC) Network. The SPC network will result in new call handling and routing improvements and in new network-based services. It is desirable to tailor the services to meet special customer needs and to deploy them rapidly. A generic plan is described which provides a basis for building services from basic functional capabilities that are deployed in network action points and controlled by network control points. Terminating-end office features can be used to provide additional customer service options. Thus, service for a customer can be composed of sequences of actions stored at appropriate network central points using basic switching capabilities deployed in the network. As needs for customer service evolve, new capabilities can be added to the repertoire of existing capabilities. By equipping key nodes with the capabilities described, the generic plan will also allow the SPC network to evolve efficiently to meet future customer needs.

I. INTRODUCTION

The network of stored program control communication processors interconnected with common-channel interoffice signaling (CCIS) is referred to as the Stored Program Controlled (SPC) Network. The potential power of the SPC network is that new nationwide network services can be provided and introduced rapidly. In particular, the SPC network will permit the following:

(*i*) Services on demand, wherein customers will be able to request and receive services quickly, as needed, and terminate them when no longer needed.

(*ii*) Rapid introduction, wherein services are offered in shorter intervals than previously possible for network services.

(*iii*) Widespread availability, where services are offered ubiquitously, both as initially desired by the customer and then modified as dictated by customer needs.

Additionally, the SPC network will permit improved network operations and service, such as improved network management arrangements and faster call setup.

To achieve these objectives, the SPC network is being built with basic functional capabilities called switching primitives, which in various combinations can be used to construct network services desired by customers. Thus, service for a customer can be initiated by invoking the needed sequence of switching primitives at the appropriate points in the network. Since the control of these functions will be centralized, services can be quickly provided and modified, as required.

Switching primitives include the ability to route calls, to make billing records, to collect additional information through prompts, and to give announcements. Since the switching primitives are not tied to a specific service, they will form the foundation for future services through use in different combinations and with new switching primitives that will be added later. The collection of switching primitives are called Direct Service Dialing Capabilities (DSDC).

II. GENERIC MODEL FOR SPC NETWORK SERVICES

Figure 1 is a schematic representation of the SPC network. The switching hierarchy of local and toll switching systems is interconnected by the CCIS network. The CCIS network uses signal transfer points (STPs) to concentrate signaling information and to provide access to network control points (NCPs). The NCPs are equipped with data bases that contain the information relevant to services that customers have requested. Thus, the CCIS network is used for the signaling functions needed for call transport, as well as for communication among switching offices and NCPs. Traffic Service Position Systems (TSPSs) provide automated operator functions and have CCIS access.

The centralization in the NCPs of the information pertaining to customer services and call control permits the rapid provision and changing of customer service records and is the central element in the ability of the SPC network to offer services ubiquitously. An additional important feature of centralizing the intelligence of the SPC network in the NCPs is that data can be compiled on individual calls that would be useful to customers in planning their communication needs. For example, call volumes could be compiled by time of day, day of week, by origin (3, 6, or 10 digits, etc.) and destination (dialed and substituted number). Calls using DSDC are called direct service dialing (DSD) calls.
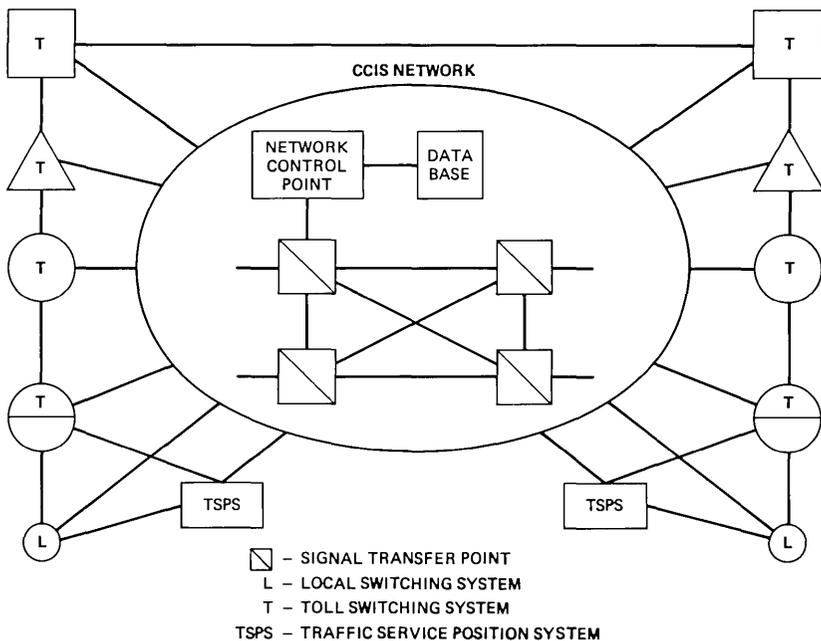
Fig. 1—Stored Program Controlled Network—switching hierarchy.

Functionally, the generic architecture of the SPC network for network services is shown in Fig. 2. A DSD call is identified by the dialed number, which includes a service access code (SAC). This number along with the identity of the calling customer's line [typically referred to as automatic number identification (ANI)] is transmitted to an office which has the capability to process the call. This office is called the action point (ACP). Upon receipt of a call, the ACP recognizes the need for information on how it should be processed and launches a CCIS direct-signaling message to a NCP for instructions. The direct-signaling message contains the dialed number, ANI number, and the identity of the ACP. The ACPs can be local ESS, toll ESS, or TSPSs. The NCPs similarly are stored program control systems. The NCPs contain the customer record and service parameters which specify how calls to the customer location(s) should be handled. Different treatment is possible, depending on calling number plan area, time of day, day of week, busy/idle status of customer line, etc. The proper treatment for call handling is determined by accessing the call-handling instructions resident in the NCP data bases.

The SPC network architecture also includes flexible administration systems that provide the mechanisms to handle customer service requests for changes in SPC network service arrangements. These
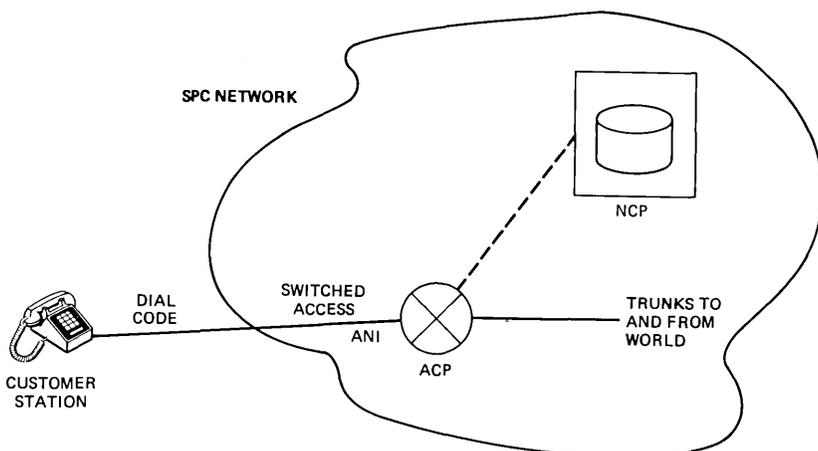
Fig. 2—Elements of a generic service plan.

systems are integral to meeting the SPC network architecture objectives described earlier. For example, the administration systems could handle customer service requests via attendants, service orders, or in many cases directly under customer-controlled *Touch-Tone** dialing. An example of the latter is when a customer directly enters commands to change the routing of calls based on the dialed number or on the time of day.

Referring again to Fig. 2, upon receipt of the initial direct-signaling message from an ACP for a call, the NCP retrieves the customer call-handling instructions resident in the NCP data bases that pertain to the dialed number. These instructions are analyzed by the NCP, and call-handling commands are returned to the ACP. Typical instructions to the ACP are, "route the call to a number supplied by the NCP," "play prompting announcements requesting the customer to enter additional digits," "collect the additional digits," or "create a billing record for the call." In some cases, the initial ACP in a call may not be able to provide the needed capability so the instructions from the NCP might be to hand off the call to another ACP with the desired capability. In other cases, the initial ACP may only temporarily transfer the handling of a call to another ACP—such as for the playing of a change clarification announcement. Such an arrangement is called a service assist. The situations when control of the call is permanently transferred are called hand-offs. Service assists and hand-offs permit the objectives of rapid introduction and widespread availability to be achieved; a few

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ACPs can be equipped with a needed capability and provide universal access to the capability.

The instructions returned from the NCP to the ACP form a command language which can be flexibly used to provide the call handling specified by customers. The command language identifies unique building blocks corresponding to switching primitives which are used to provide services. Examples of switching primitives are shown in Fig. 3. The command language consists of initial inquiries, data messages, exception messages from the ACP to the NCP, and of command, check, and data messages from the NCP to the ACP. Commands received by the ACP are executed sequentially and are completed before another command is processed. As the customer needs change, the command language can be used to specify new orderings of the building blocks (switching primitives) desired. Additionally, the command language is a unique and standard language used throughout the SPC network so that new elements can be introduced smoothly.

Essential roles in the SPC network architecture are played by the family of stored program control local offices. These offices can be queried to determine the status of the terminating (called) customer lines prior to call routing and to determine if the call should be given special handling. For example, as shown in Fig. 3, upon receipt of a service request from an ACP, the NCP could examine the data base records for the call and determine the routing. Before replying to the ACP, the NCP could launch a query to the terminating-end office (TEO) to determine its usage and service complement in effect at that time.
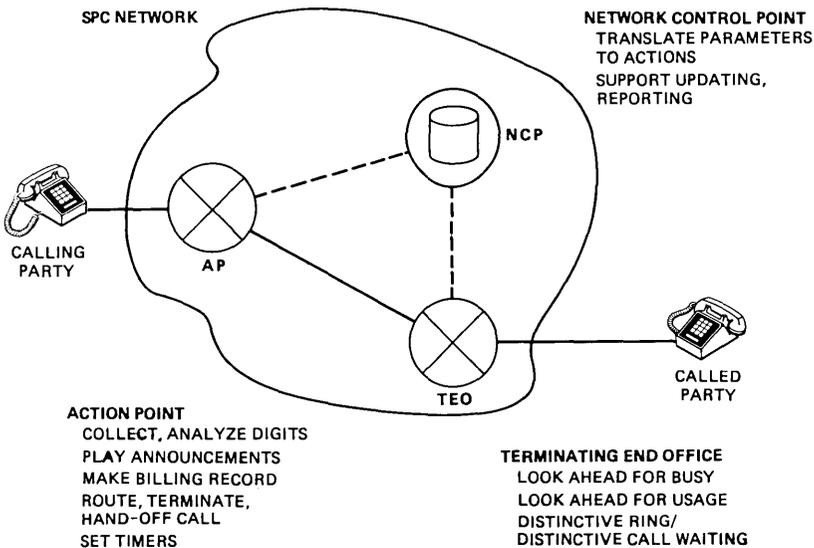
Fig. 3—Stored Program Controlled Network generic architecture.

If, for example, the TEO line were busy, the NCP data base instructions could be programmed to instruct the ACP to route to another destination, thus offering customers flexible control of how their calls are routed and also improving call completion. Alternatively, the NCP data base could eliminate a busy attempt from the rest of the network by instructing the ACP to route the call to a busy tone. In other cases, the NCP may request from the TEO the current number of calls in progress to a given number or group of numbers. The TEO would return the current counter values so that the NCP could determine if an alternate handling of the call is necessary. These network capabilities could be useful for call management purposes. In cases where the customer desired to identify certain incoming calls at the TEO, a call tag arrangement can be invoked. Upon receipt of a query from the NCP, the TEO returns to the NCP a special type of line number identified with the TEO but not used by regular customer lines. This number is then returned to the ACP for routing, and when the call to this number is received by the TEO, the TEO associates this call as the one to be uniquely identified. Alternatively, this same identification of certain incoming calls could be achieved by using traveling class marks (TCMs). In this case, the NCP first queries the TEO to determine if the incoming call should be uniquely identified to the called customer. If so, the NCP directs the ACP to mark the call with a special traveling class mark which remains associated with the call while it is routed to the TEO. This TCM method requires CCIS on all links between the ACP and the TEO, whereas the call tag method does not. The SPC network architecture has been designed to accommodate both methods of operation. Examples of some of the basic SPC network functional capabilities just described are also shown in Fig. 3.

The introduction of ACP capabilities in the network can be managed to help meet the objectives discussed earlier through ACP migration. For example, new ACP capabilities could be introduced in toll and/or TSPSs and later, as service demand increased, the capability could be migrated to local systems. The service-assist and hand-off capabilities discussed earlier will allow migration of capabilities among ACPs in the network without changing the customer's service. This migration can lead to network efficiencies. For example, if the dialed call were destined to be routed to a line served in the same local office as the dialing customer, routing to a toll or TSPS ACP would introduce extra links in the call which would not be needed if the local office were the ACP. Additionally, the cost of transmitting the ANI information to a distance ACP would be eliminated. Modern local systems also offer the advantage of being able to accept extra digits dialed from rotary dials. In cases where a toll or TSPS ACP is used and extra digits are needed, *Touch-Tone* dialing or operator assistance may be required. There-

fore, as local offices are added to the SPC network, the ACP function can be migrated to them to accrue these efficiencies.

III. APPLICATION OF ARCHITECTURE TO MEET OBJECTIVES

This section includes discussion of how the SPC network architecture is applied to meet the following objectives stated earlier:
- Services on demand
- Rapid introduction
- Widespread availability
- Improved network operations and service.

First, the basic concepts of offering new network capabilities via the SPC network with switching primitives is illustrated in the open-ended matrix in Fig. 4. Each capability is assigned a row in the matrix. Switching primitives are assigned columns. A mark in the matrix indicates the requirement for a switching primitive for the corresponding capability. The matrix is open-ended because new capabilities may require at least one more switching primitive. The set of switching primitives has been selected to correspond to the repertoire of SPC network capabilities now envisioned as necessary.

Once a matrix has been built, it can be instructive in determining how to develop and deploy SPC network capabilities. For example,

SWITCHING PRIMITIVES

CAPABILITIES	1	2	3	4	5	6	7	8	9	10	11	12	•••
1	✓			✓	✓			✓	✓	✓			•••
2		✓		✓				✓	✓			✓	•••
3	✓		✓			✓		✓			✓		•••
4				✓			✓	✓	✓				•••
5	✓				✓			✓		✓		✓	•••
6		✓				✓	✓	✓			✓		•••
7			✓		✓		✓	✓					•••
8		✓	✓					✓					•••
9		✓		✓						✓			•••
10						✓	✓	✓					•••
11						✓	✓	✓					•••

Fig. 4—Determining basic ACP requirements for offering new services.

referring again to the hypothetical matrix in Fig. 4, note that switching primitive No. 8 is needed in almost all the capabilities. This indicates the value of getting it developed for key ACP locations. This concept of deploying certain switching primitives in key ACP locations, coupled with the service-assist and hand-off capabilities explored earlier in this paper, is a means of meeting the objectives of rapid introduction and widespread availability. Note that capabilities Nos. 10 and 11 require the same primitives, which indicates commonality and efficiencies possible by coordinated developments with this plan.

Improved methods of providing network operations are also inputs to the planning process, as primitive switching functions could be developed to improve network efficiency. The look-ahead primitive discussed earlier could be used to improve network efficiency. Often a primitive has application to improve network operation and to meet service needs. For example, the look-ahead primitive can also be used to establish TEO features for a call.

The way the SPC network architecture can be deployed to meet objectives is illustrated in Fig. 5. The starting point is the capability/switching primitive matrix. The plan selected will define which systems will have which capabilities at what time. Each system is represented by a card with a replica of the matrix on it. A mark means the system has that capability. There is a set of cards for each year (or other planning interval).

The transition between the matrix and the selected development plan is accomplished by an analysis based on all relevant factors. Two main factors are areas of application potential and cost, but there are others. For example, capacity of systems in service may be important, having practical, as well as cost, effects on service introduction. Because of the interrelated development alternatives in the SPC network, integrated analysis is done to provide consistency of analysis and the required integration of individual system plans.

In practice, the application of the architecture to meet objectives is planned as follows. First, recall that the central element or feature of the SPC network architecture is the centralization of customer call-handling service records in the NCPs and the ability to easily and quickly change these records. Introduction of new services requires that the NCP first be in place along with the customer administration system needed to handle service requests. Additionally, access to ACPs must be provided so that all originating calls can be routed to an ACP. This could be done by initially deploying ACP capabilities in all No. 4 ESSs and TSPSs. Together, these systems provide ubiquitous access to all customers. Trunking arrangements from originating local offices to these ACPs would be required to transmit the ANI information necessary for the NCP to determine proper call routing. This architecture allows
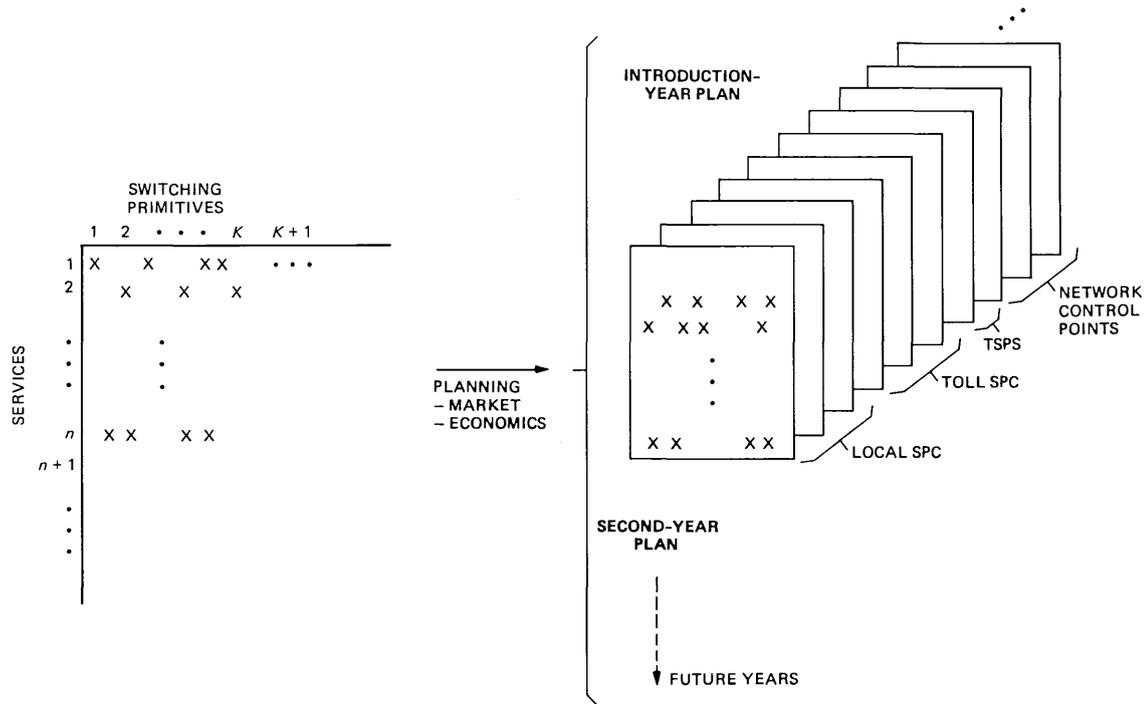
Fig. 5—Service/SPC network switching planning.

customers to get access to network capabilities early, as these capabilities are initially deployed in the network.

Many lines are served by equipment that is located on the customer's premises. This includes private branch exchanges, automatic call distributors, and key telephone systems. Future customer needs may require that new interfaces to the SPC network be developed for these systems.

IV. SUMMARY

The basic elements of a generic SPC network architecture have been described. The architecture allows for introduction of new network capabilities that can be offered ubiquitously and can be changed quickly under customer control. Plans also have been formulated to allow for the addition of new offices into the SPC network to increase the network capabilities and efficiencies without changing how the customer uses the service. Specific examples of these points are given in the companion articles in this issue.

Stored Program Controlled Network:

Routing of Direct-Signaling Messages in the CCIS Network

By R. F. FRERKING and M. A. McGREW

This paper compares and contrasts the two methods currently used to route messages through the common-channel interoffice signaling (CCIS) network. Since its introduction in 1976, the CCIS network has been providing routing of telephone signaling messages between switching offices using permanent virtual circuits. In 1980, a new datagram routing capability, called direct signaling, has been added that significantly enhances the network's ability to interconnect Stored Program Control (SPC) systems. Stored program control systems interconnected by the signaling network can now communicate in support of improved SPC network services in addition to CCIS trunk-related call-control signaling. This paper briefly reviews banded telephone routing and then describes and compares direct signaling routing. The new flow control procedures required to implement direct signaling are discussed and two examples of applications using direct signaling are presented.

I. INTRODUCTION

This paper describes the basic components and message routing in the common-channel interoffice signaling (CCIS) network. Examples are used to show how direct signaling supports services which may be provided by offices connected to the new CCIS network. Basic knowledge of the existing CCIS network is assumed, but background information may be obtained from Ref. 1.

Since its introduction in 1976, the CCIS network has been providing addressing and routing of trunk-related telephone signaling messages for interconnection of switching offices. In 1980, a new capability,

direct signaling, was added which significantly augments the network's capability to interconnect Stored Program Control (SPC) systems. The evolving network is called the SPC network, reflecting that offices interconnected by the signaling network have new stored program capabilities and are no longer connected only for trunk-related CCIS signaling.

Whereas telephone messages routed by band are confined to a preassigned end-to-end signaling path, direct-signaling messages are not banded but contain a full destination address. Direct-signaling messages are addressed by offices to gain access to a network feature. The signal transfer points (STPs) route direct-signaling messages to their destination address, regardless of where in the network the message originates, independent of any assigned signal paths. The typical direct-signaling relationship is not between two switching offices but is between an action point (ACP) and a dialed-number translation data base, called a network control point (NCP). An ACP is an office with the direct-signaling capability that provides access to NCP features. Many of the CCIS switching offices already connected to the network are ACPs. The direct-signaling capability was essential to provide network-wide access to NCP features.

II. BASIC CCIS

The CCIS network is a packet-switched network handling telephone-signaling messages defined within the CCIS protocol. The CCIS network is a quasi-associated system, achieving the economies of signaling traffic concentration through STPs, since few trunk groups are large enough to justify direct associated links. The network is redundant to provide the high reliability required for telephony. The signaling links initially operated at 2400 b/s, but 4800-b/s links are now being installed.

The end-to-end band assignments through the network are used for trunk-related signaling between two switching offices. Trunks are grouped into bands of 16 trunks. Within a band, each trunk is identified using a 4-bit trunk number. Each band is identified by a 9-bit band number. Thus, each trunk is assigned a 13-bit identifier called a label. The basic unit of routing in the network is the band. The STPs only look at the band and not at the trunk number in the label.

Most of the message format codes are reserved for banded messages to make the trunk-related signaling most efficient. When a message heading code indicates that an incoming message is banded, the STP uses the incoming signaling link number and band as the input to a translator which outputs the outgoing link and band. The new band is substituted for the old band, and the message is transmitted on the outgoing link. In this manner, each module of 16 trunks has a unique

signaling path through the network consisting of the band and link between each signaling point (switching office or STP) along the way.

In a sense, an end-to-end permanent virtual circuit is established for every band. The large community of interest between switching offices (because of the trunks between them) and the high efficiency of CCIS justifies the administrative expense of assigning dedicated signaling paths.

The network redundancy is provided as follows, with reference to Fig. 1. Two STPs, called mate STPs, are provided in each region. Access links (A-links) from a switching office to an STP are provided in pairs, called mate links, with one link to each STP. Bridge links (B-links) from each STP to mate STPs in another region are also provided in mate pairs. The quad of four links between regions fully interconnects mate STPs in different regions. Mate links operate in a load-sharing mode, with adaptive procedures directing all the traffic from a failed link to its mate in case of link failure. Mate STPs are interconnected by cross links (C-links) which have no band assignments, but are used to complete a signal path via the mate STP when the direct A- or B-links have failed.

Additional links may be provided in layers (each pair of A-links or quad of B-links is a layer) to increase the signaling capacity for CCIS trunk growth. The band assignments on each layer of links are independent of all other layers.

III. DIRECT SIGNALING

Direct signaling is a datagram type of service, with network routing capability based entirely on a destination address in the message independent of the origination point. Direct signaling is a new address-
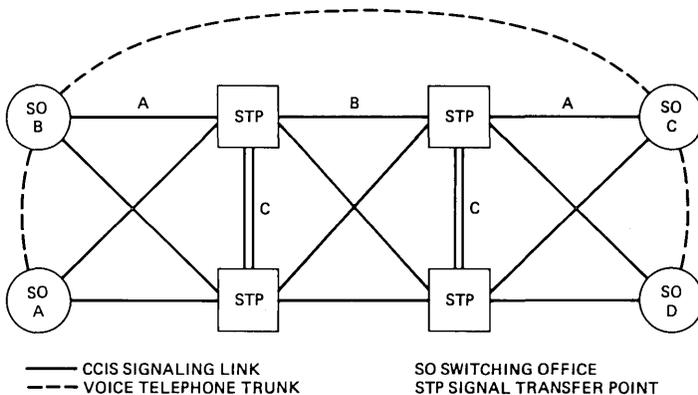
Fig. 1—Common-channel interoffice signaling network.

ing capability which does not require a fixed end-to-end relationship between signaling nodes like trunks between switching offices. Direct-signaling messages are not associated with any particular link or administratively assigned path through the network. The new signaling capability accommodates the addition of NCPs which contain features in the form of dialed-number translation data bases. Addresses in direct-signaling messages may be customer-dialed digits, thus, providing a customer feature through an ACP. With the features available in the network, it is economically attractive for ACPs to gain access to the network for non-trunk-related signaling. A network with ACPs and an NCP is shown in Fig. 2.

To provide the direct-signaling capability, each signaling node identifies its pools of signaling links, defined as all the links which terminate on a common far-end signaling node. Since mate STPs are load sharing, the two pools of links to mate STPs together form a combined pool. Thus, more than one layer of links between signaling points, which were previously independent, are now coupled (in a pool) for direct-signaling purposes.

Because of network growth, there usually is more than one link in a pool. A load-balancing algorithm distributes the direct-signaling traffic over all the links in a pool. A traffic measurement (which is updated every minute) is used to determine the desirable load distribution. If one link in a pool is carrying less banded traffic because of an imbalance in assignments, that link will carry more direct-signaling traffic. This results in more efficient overall use of the links.

Routes, identified at STPs, are used to relate a message destination address to the pool of links associated with that address. If the

ACP ACTION POINT
NCP NETWORK CONTROL POINT
STP SIGNAL TRANSFER POINT

$\Longrightarrow$ DIRECT-SIGNALING TRAFFIC FLOW
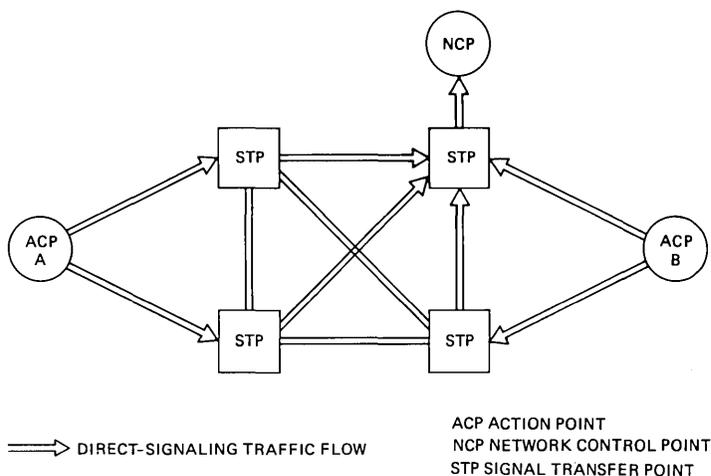
Fig. 2—Common-channel interoffice signaling direct-signaling routing.

destination is in another signaling region, the route points to the combined pool of links to the mate STPs in that region.

With direct signaling, the concept is introduced that a node in the network may perform more than one function and that each of those functions needs to be uniquely identified in the network. The first application of this concept is in the NCP, which itself has a unique identity and which may host more than one application, each with its own identity. The NCPs are installed in pairs, collocated with mate STPs. The network identifies each of the functions separately so that ' it can control routing to those functions separately.

Direct-signaling addresses are modified by the domain field contained in each message. There are two basic capabilities, distinguished by domain equal to zero and domain greater than zero. Domain zero is for addressing by function number. Each separately identifiable function is assigned its own function number at each location in the network. A function number, presently 14 bits, may be used as the destination address of that function at each network location. When the domain is greater than zero, the address consists of two three-digit numbers each coded as a 10-bit binary number. Domains greater than zero are distinctive for two reasons. First, the pair of three-digit numbers may be customer-dialed digits to give the customer access to a feature identified by the domain- and dialed-digit combination. Second, with multiple domains greater than zero, the address space is expanded so that the same six-digit address can be routed to different destinations in the network by combining that six-digit number with different domains. Presently, domains one and two are used, and existing format capacity will allow expansion to domain number seven.

A function at an NCP must be accessed by many addresses, such as the set of 800 numbers processed at a particular NCP. Direct signaling achieves a mapping of multiple addresses to a single destination. Thus, a set of common customer-dialed numbers, which could have been dialed from anywhere in the network, may be routed to the same NCP containing the translation data base for those numbers. Other sets of numbers for the same feature may be routed to different NCPs that are provided for growth.

Figure 3 shows a typical direct-signaling message with a return address. The message heading code in the initial signal unit (ISU) is used for all miscellaneous multiunit messages (MMUMs). A special message category code in the first subsequent signal unit (SSU) is reserved for direct-signaling messages. Each direct-signaling application is assigned a unique direct-signaling application code.

When an STP receives a direct-signaling message, it looks at the address fields and determines the outgoing route. The STP has routing tables providing for all valid network addresses. If there are no routing

MMUM
HEADING   LENGTH   DOMAIN   ADDRESS

| 1 | 0 | 1 | 1 | L | L | L | D | D | D | * | * | * | * | * | A | A | A | A | A | A | ISU

                MESSAGE
    SSU   CATEGORY   ADDRESS

| 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | P | 0 | B | B | B | B | B | B | B | B | B | B | 1st SSU

                        DIRECT-SIGNALING
    SSU   APPLICATION CODE   APPLICATION

| 1 | 1 | 0 | R | 0 | 0 | X | X | X | X | X | | | | | | | | | 2nd SSU

    SSU   RETURN ADDRESS (OPTIONAL)

| 1 | 1 | 0 | | | | | | | | | | | | | | | | | 3rd SSU

    SSU   APPLICATION-DEFINED ADDITION SSUs AS NEEDED   4th THROUGH 8th SSU

| 1 | 1 | 0 | | | | | | | | | | | | | | | | |
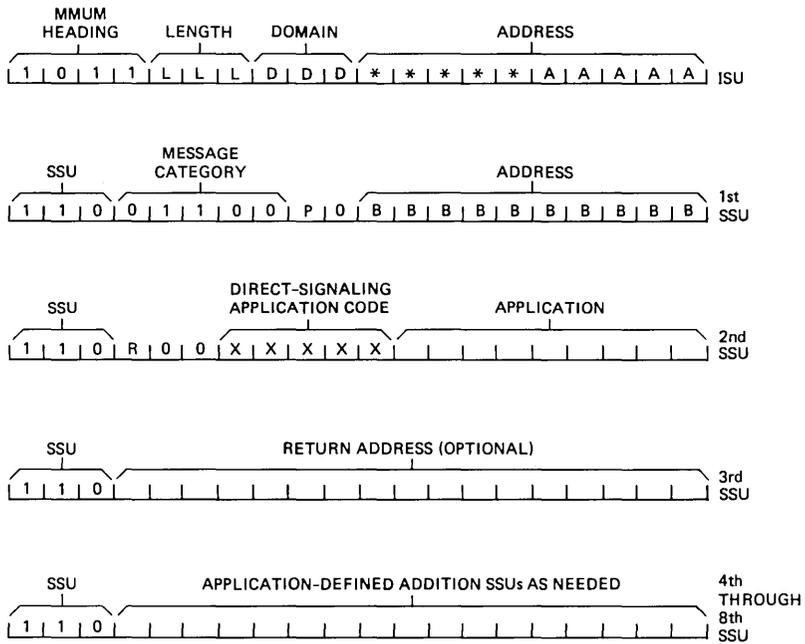
* SPARE BIT POSITION WHEN ROUTING BY FUNCTION NUMBER (DOMAIN = 000)

Fig. 3—General direct-signaling message.

restrictions, the STP selects a link from the pool of links to that destination.

Since the direct-signaling message is not associated with a particular signaling path, the destination address does not identify the originator. Messages which need to identify the originator have format space allocated for the return address, which is always the originating function number. As an example, a direct-signaling application may consist of an inquiry-reply operation at an ACP. The direct-signaling inquiry message is addressed to an NCP application using a domain greater than zero. The inquiry contains the originating ACP's function number, which is used by the NCP with domain zero to address the reply.

An administrative advantage of direct signaling is that only the network needs the routing data to access any destination, especially feature destinations at NCPs. The ACPs do not know, nor do they need to know, the location of the NCP which is the destination of their direct-signaling inquiry. Such an inquiry may be sent on any A-link (which by definition terminates on the home STPs), and all the routing is handled by the network. Because of this approach, network administrators have the flexibility of moving feature destinations around in the network to accommodate growth without the ACP awareness that any changes are made.

Traffic destined to an NCP which originates in the same region will routinely produce C-link traffic if it is sent to the wrong STP. In terms of system resources, this C-link traffic is the only penalty which results from putting direct-signaling routing data only in the STPs. However, much of the traffic is destined for different NCP regions, to which all STPs have direct pools of links. STPs route this traffic directly to the correct STP, so C-link traffic is avoided. The originating office is merely accessing a feature, and it is not concerned about where the physical destination turns out to be in the network.

Because direct-signaling routing is via the most direct path, a signaling link failure causes the direct-signaling traffic to be carried by the remaining links in the same pool. The STPs themselves are backed up by the signaling paths through the mate STP. If all the links in a pool fail, there is still an alternate path via the mate STP. In addition, some feature functions, such as 800 Service, are backed up at the NCP equipped at the mate STP. The NCP functions with backups are called duplex functions; one NCP is called the primary destination, while the mate is called the secondary destination.

The STPs are notified of a duplex function failure through the function out-of-service procedure. A direct-signaling function status message is sent to each adjacent STP. When a duplex NCP function is out of service, the network performs secondary routing to the mate secondary function. If an NCP fails, all the functions at that node fail; however, the secondary routing to the mate NCP is automatically performed for those duplex functions by the adjacent STPs. When a previously failed function is returned to service, function in-service messages are sent to restore normal routing.

The ACPs will not be aware of a function failure at one of the duplex NCP functions, for the network is solely responsible for the secondary routing. When one of the duplex functions fails, there is additional C-link traffic because of messages originating in the NCP region but arriving at the out-of-service function's NCP. The C-links are engineered to carry this expected level of traffic.

The ACPs become aware of failures or overloads in the network by a response method; every blocked message requesting a reply is modified and returned to the originator with the appropriate failure indication. The originator receiving a network failure message is required to cut back traffic to limit the amount of ineffective attempt traffic in the network.

If a duplex function fails during a failure of its mate, the adjacent STPs recognize the complete function failure when they receive the function out-of-service messages. In this case, all of the direct-signaling inquiries addressed to the failed function will be returned to the originating ACP. Originating nodes maintain a list of all inaccessible

addresses and limit the number of inquiries to those addresses to one message every 10 or more seconds until either NCP of the pair is restored to service.

If an NCP is not directly accessible from an adjacent STP in another signaling region because of link failures, its primary traffic could be alternate routed to the mate STP and from there transmitted directly to the primary NCP. If all direct links to the primary NCP location are failed from another signaling region, the traffic may be directed to the secondary NCP, where it would be forwarded to the primary destination via the C-links.

The direct-signaling reply message transmitted by the NCP is addressed to the origination of the inquiry message. The reply message also can be alternate routed through a mate STP to bypass link failures.

IV. COMPARISON OF BANDED AND DIRECT SIGNALING

To meet signaling delay requirements, all trunk-related signaling utilizes the band as a concise identification of both the originating and terminating points of the message. Since call setup messages are short, most of them only one signal unit, their network transit time is faster (because of shortest possible queueing delay and emission time) and more efficient use is made of the signaling links. Since trunk-related signaling is an unmistakable indication of a large community of interest between offices, the efficient assigned signaling path is a reasonable means for the network to provide for this interest.

Direct-signaling messages are longer because of their less efficient message codes, their longer addresses, and their originating addresses. Since direct-signaling traffic is balanced over a pool of links, it can make more efficient use of the links and compensate for the coding inefficiency. Direct signaling does not replace banded signaling but is ideal where signaling needs are significantly different from trunk-related signaling:

(*i*) When signaling delay is not as critical.

(*ii*) When the community of interest is between an ACP and an NCP, whose physical destination may be anywhere in the network and is unknown to the ACPs.

(*iii*) Where the feature is implemented at several physical network locations, all operating simultaneously to share the total feature traffic load.

(*iv*) Where the mapping of multiple customer-dialed addresses to a single destination or feature is desired.

(*v*) Where flexibility is needed to move a destination between NCPs without ACP knowledge or intervention.

(*vi*) When the communication is point to point, but there are no trunks that require band assignments.

In many cases, the above signaling needs could have been accommodated by the assignment of pseudo-bands (not related to trunks) between every ACP and NCP. But that would have required a prohibitive volume of data for ACPs to know which NCP should be addressed by each inquiry. Also, the network administrative burden, which is confined to the STPs for direct signaling, would have been extended to the ACPs at considerable expense.

Both banded- and direct-signaling routing techniques are necessary and compatible in the CCIS network. The ACPs can be connected to one network and take advantage of both CCIS per-trunk signaling and the new services provided through direct signaling.

V. AN EXPANDED 800 SERVICE EXAMPLE

An example of how direct signaling can provide for new SPC network features is Expanded 800 Service. A complete description of the Expanded 800 Service capability is contained elsewhere in this issue. In this example, Expanded 800 Service is provided for a reservation service. The feature will allow parties in all sections of the country to dial the same Expanded 800 Service number and each call will be routed to the nearest reservation center that is open at the time the call is made. Each call is advanced to a CCIS office, the ACP for this service, which transmits a direct-signaling inquiry message to an NCP collocated with one of the STPs. The inquiry message contains the dialed 800 number, the NCP of the calling party, and the function number of the originating CCIS office. The Expanded 800 Service application at the NCP performs a validity check on the inquiry and transmits a direct-signaling reply message back to the originating CCIS office. The reply message contains the direct distance dialing (DDD) number of the appropriate reservation center to which the call is then completed as if it had been dialed directly by the calling party, except that the reservation center pays for the call.

If the central office local to the reservation center has CCIS capabilities, the busy or idle status of the called lines can be transmitted to the NCP using direct-signaling status messages. When all the called lines are busy, the call can be directed to another reservation center or a busy reply message can be returned to the CCIS office originating the inquiry causing generation of a busy tone for the calling party. Thus, Expanded 800 Service provides improved operation of the switched network and also new service capabilities.

VI. EXPANDED 800 SERVICE IMPLEMENTATION

Expanded 800 Service is implemented as follows: Each of the three-digit codes a customer dials immediately after dialing 800 is assigned to a pair of NCPs. A single pair of NCPs will provide service for many

three-digit codes. Each NCP of a pair is designated to be the primary destination for approximately one-half of the three-digit codes served by the pair as determined by traffic considerations. That same NCP is also designated to be the secondary destination for the remaining three-digit codes assigned to the pair of NCPs. Under normal conditions, all of the direct-signaling inquiries addressed to a given three-digit code are routed to the primary NCP, as shown in Fig. 2. When either of the NCPs fails, its primary traffic will be routed to the mate NCP, the secondary destination for each of those three-digit codes. The procedures used to perform this secondary routing were described earlier.

VII. AN AUTOMATED CALLING CARD SERVICE EXAMPLE

The Expanded 800 Service example is but one of the services and features made possible by the direct-signaling capability. Another planned service is Automated Calling Card Service, which automates credit card, collect, and third-number-billed calls. Automated Calling Card Service reduces requirements for operators and provides improved fraud protection. Additionally, Automated Calling Card Service provides new service possibilities such as preauthorized collect and improved third-number billing capabilities. A complete description of the direct dial credit card capability is contained in this issue of *The Bell System Technical Journal.*

VIII. AUTOMATED CALLING CARD SERVICE IMPLEMENTATION

The data bases accessed for Automated Calling Card Service are not duplicated at mate STPs in contrast to the backup strategy used for Expanded 800 Service. Since the customer has dialed the called number with automated operator services, the customer's call can be completed even when a reply is not returned for the data base inquiry. This results only in a temporary decrease in automated fraud protection. However, with Expanded 800 Service the customer's call cannot be completed if no reply is received for the data base inquiry. Customer service objectives necessitated the implementation of a backup data base strategy for Expanded 800 Service. The requirement that accurate called lines busy status be contained in the NCPs at all times necessitated implementation of the primary/secondary backup strategy previously described for Expanded 800 Service.

Alternate routing to an Automated Calling Card Service data base in case of link failures is identical to the alternate routing used to access a primary Expanded 800 Service NCP in case of link failures. If an Automated Calling Card Service data base itself should fail, all its inquiries are returned by the STP collocated with the failed NCP. If the collocated STP should fail, this failure is recognized by all adjacent STPs which then return the blocked inquiries to their origination nodes. As

with Expanded 800 Service, originating nodes maintain a list of all inaccessible or overloaded addresses and limit the number of inquiries to one message every ten or more seconds until the data base is restored to service.

IX. CONCLUSION

The concept of direct-signaling routing has been described and compared with call setup routing by bands. Routing by bands is very efficient for the trunk-related signaling traffic necessary for call setup. Direct-signaling routing provides the addressing and administrative flexibility necessary for implementation of SPC network services and features. The brief descriptions of Expanded 800 Service and Automated Calling Card Service provided examples of the SPC network features made possible by implementation of the direct-signaling capability. The generalization of such SPC network service capabilities revolutionizes the types and number of potential services made available to telephone customers.

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Stored Program Controlled Network:

NO. 1/1A ESS—SPC Network Capabilities and Signaling Architecture

By L. J. GAWRON, S. J. LUEDERS, and K. L. MOELLER

(Manuscript received June 2, 1981)

The No. 1/1A Electronic Switching System (ESS) will play an important role in the evolving Stored Program Controlled (SPC) Network because, as a major electronic switching system for local and combined local/toll service, it provides direct interfaces to many of the Bell System's customers. It provides important capabilities required for System 800 Service and for a variety of other new SPC network services. This paper describes several of the basic SPC network capabilities provided by the No. 1/1A ESS. It also describes the architecture and implementation of its common-channel interoffice signaling (CCIS) subsystem, CCIS call-processing software, and System 800 software.

I. INTRODUCTION

The No. 1 ESS was the Bell System's first major electronic switching system to provide commercial service. It went into service in 1965 and has served since then as a metropolitan local switching system. It uses Stored Program Control (SPC) capabilities to provide basic telephone service, as well as numerous residential and business features. In 1976, an improved metropolitan local switching system, the No. 1A ESS, went into service. It uses the same switching network as the No. 1 ESS, but with a higher performance processor it has about twice the call capacity of No. 1 ESS. Today, No. 1 and No. 1A ESSs serve nearly one-half of all Bell System subscriber lines. In addition, these systems also provide toll-switching capabilities when they are used as toll offices.

In 1976, SPC toll switching systems were first interconnected with a modern common-channel interoffice signaling (CCIS) system. No. 1 ESS

joined the resulting SPC network with the introduction of CCIS in 1978. No. 1A ESS followed in 1979. The CCIS system currently provides toll network signaling improvements, which result in such benefits as faster call setup, as well as trunk and service circuit cost savings.

Ultimately, the major benefits to be derived from the use of modern common-channel signaling systems will be in the new features and customer services that they can provide. To fully realize these benefits, the SPC network is being extended to include local switching offices which provide direct interfaces with the customer. The No. 1/1A ESSs will be the first local switching systems to utilize CCIS with such service scheduled to begin in 1981. This will then permit local, as well as toll, calls to be handled using CCIS. It will permit basic call-handling improvements such as providing busy tone from the originating office rather than from the terminating office, thus reducing trunk holding time for interoffice calls requiring busy treatment. It will also provide the customer interfaces required for implementation of many new SPC network features and services.

II. NETWORK CAPABILITIES

The SPC network improves basic call handling through the use of CCIS. However, the major benefits of the SPC network will be in the new services made possible because of capabilities provided by SPC network nodes operating in unison. The SPC network plan is described in another article in this issue.[1] The following paragraphs describe SPC network capabilities available in No. 1/1A ESSs.

2.1 Basic signaling

No. 1/1A ESSs have the ability to use CCIS for basic call handling, as well as for special features. This includes a banded signaling capability which uses trunk band and member numbers to identify CCIS trunks in call-processing messages. Banded signaling is described in an earlier article.[2]

The No. 1/1A ESS has the ability to pass along banded messages for an established CCIS trunk connection. This pass-along capability can be used by any switching office in a completely CCIS trunk connection to look ahead or to look backward to an end office for information which can be used in processing the call. For example, a terminating office could use the pass-along capability to transmit a request for calling-party information from the originating office. This information could then be used to provide terminating office services, such as special alerting or special call handling.

The No. 1/1A ESS also has the capability for signaling directly to any other SPC network node. Direct signaling does not require an established trunk connection. One example of its use would be for a

switching office to communicate with a nonswitching office node, such as a centralized data base. Using this capability, switching offices could obtain call-handling information needed for special types of calls. Switching offices, especially local switching offices, could use direct signaling to provide customer status information to such data bases. The data would then be immediately available to the entire SPC network for processing calls. The System 800 features described in Section V of this article use direct signaling for providing customer status information to national data bases and for accessing those data bases to obtain call-handling information. Direct signaling is described in another article in this issue.[3]

2.2 SPC network interfaces

The SPC network provides faster, more efficient basic call handling. It will now also provide a variety of new and improved services. Rapid deployment of these services can be achieved through the use of centralized feature logic and national data bases at SPC network nodes called network control points (NCPs, see Fig. 1). Universal availability of SPC network service depends on all subscribers having access to the SPC network. Access for call handling is provided at SPC network nodes called action points (ACPs). Stored program control local offices, such as No. 1/1A ESSs, could serve as ACPs, thus providing direct SPC network access to customer lines. Customers served by non-SPC local offices can also obtain access to SPC network features via trunks to SPC network toll office or traffic service position system (TSPS) ACPs, as illustrated in Fig. 1. However, such indirect access may involve trunking penalties, call setup delays, and/or overloading at toll offices and TSPSs. Therefore, it is advantageous to provide access to the SPC network at the local office whenever a high percentage of that office's customers subscribe to or are likely to use SPC network services.

In addition to the ACP call-handling interfaces, other SPC network interfaces are required to provide service data to NCPs. Such data might include customer class-of-service information or busy/idle line status. This type of information is often accessible only at the local office. Thus, for certain SPC network services, the subscriber must be served by an SPC network local office. Because No. 1/1A ESSs serve such a high percentage of the subscriber lines including lines to many business customers, they can play a major role in the SPC network.

System 800 will be the first service implemented on the No. 1/1A ESS to utilize the types of SPC network interfaces described above. A busy/idle status indicator (BISI) feature will provide customer line status from local offices to national System 800 data bases in real time. An originating screening office (OSO) feature, operating in either local or toll offices, will access these data bases to obtain call-handling
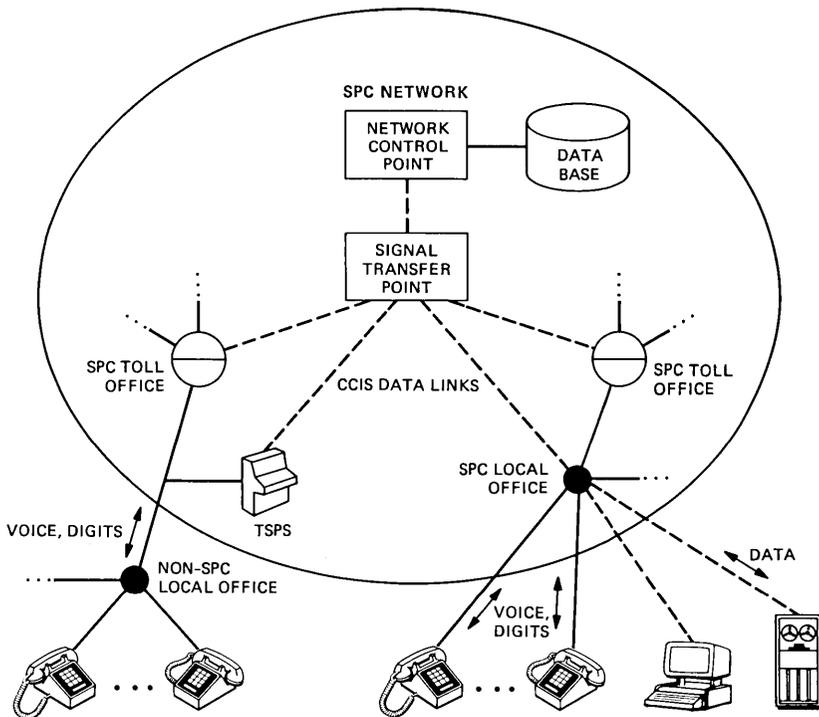
Fig. 1—Stored Program Controlled Network interfaces.

instructions for 800 Service calls. Section V describes the No. 1/1A ESS implementation of these features.

2.3 Customer interfaces

The objective of the SPC network is to provide new and improved customer services. Some services can be provided by an intelligent network which contains a variety of customer data stored either in centralized data bases or in local switching offices. Other services will require new customer interfaces including new dialing sequences and voice dialogues for prompting customers and providing call status. These interfaces are part of the SPC network dialing plan described in this issue.[4] Some services may also require nonvoice interfaces for communicating service-related information between the SPC network and the customer. The following paragraphs describe some of the useful customer interface capabilities of No. 1/1A ESS local offices.

The SPC local offices have direct access to subscriber lines and to line-related data stored within the office. Line access allows local offices to collect service-related data through special dialing sequences

from customers using either rotary dial or *Touch-Tone** telephones. Toll offices may also collect digits via trunk connections, but this is only practical from *Touch-Tone* phones. The TSPS may also collect such information from customers verbally.

Direct line access permits special alerting, such as distinctive ringing. Since alerting is strictly a local office function, special alerting for SPC network services must be provided from SPC network local offices.

Access to line-related data contained within local offices allows these offices to provide such data to other SPC network nodes when required for special features. For example, an originating office could provide calling number information to an NCP as part of a call-processing query or to a terminating office in response to a pass-along request for such information. Local offices could provide busy/idle line status either on request or whenever line status changes. They could also provide customer class-of-service information indicating the types of services that customers have subscribed to or currently have active.

In addition to line-related customer interfaces, SPC network features may require special data interfaces with the customer. As illustrated in Fig. 1, the No. 1/1A ESS could provide such interfaces to customer computers or keyboard terminals. These interfaces could be used for exchanging service control and/or status information. The No. 1/1A ESS currently provides such interfaces to private network customers and System 800 customers.

III. SIGNALING SUBSYSTEM ARCHITECTURE

3.1 Objectives

The objectives of the No. 1/1A ESS signaling subsystem include providing hardware-independent signaling capabilities to a variety of No. 1/1A ESS application programs. These include programs such as CCIS call processing and System 800 features that use CCIS directly. They also include many other feature programs that use CCIS indirectly, e.g., via general-purpose trunk supervisory programs.

Because toll offices handle greater volumes of interoffice calls, they generally have greater signaling capacity requirements than local offices. However, local offices have more stringent data-link equipment cost constraints than toll offices. Two different data-link hardware subsystems have been developed to meet these differing needs in No. 1/1A ESS offices. Certain software must be included in a switching office when a particular data-link subsystem is used. Other software is common to both subsystems. Software packaging must be provided

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* Registered service mark of AT&T.

that allows an office to load only the software required for its particular equipment arrangement.

The following sections describe the signaling subsystem architecture that satisfies these objectives.

3.2 General description

The No. 1/1A signaling subsystem comprises several layers of control as illustrated in Fig. 2. This structure allows ESS applications software to send and receive CCIS messages without being concerned about Input/Output (I/O) details or data-link administration procedures.

The ESS applications software that uses the signaling subsystem includes call processing, maintenance, network management, and other feature programs. Supervisory programs provide special signaling interfaces for application programs that perform trunk-related signaling without knowledge of whether a trunk is a CCIS trunk or not.

The signaling software layer provides hardware-independent signaling capabilities. It provides macro-accessible subroutines for formatting and transmitting CCIS messages. It also reads CCIS messages from the data-link equipment and delivers them to appropriate ESS applications programs.

The data-link software layer provides all hardware-dependent inter-

ESS APPLICATIONS
SOFTWARE

SIGNALING
SOFTWARE

DATA LINK
SOFTWARE

DATA LINK
FIRMWARE
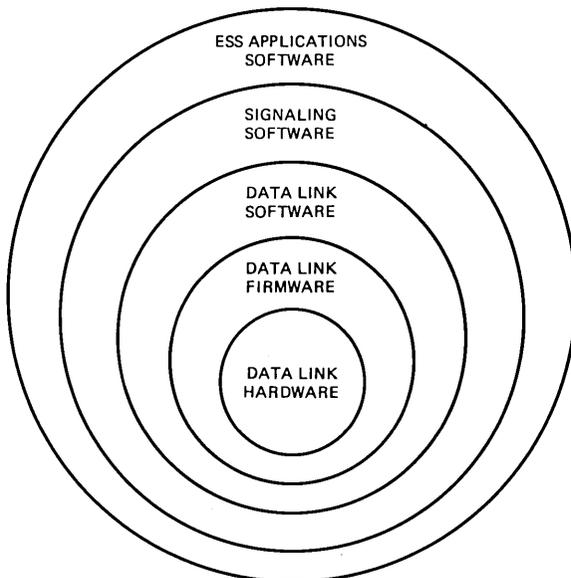
DATA LINK
HARDWARE

Fig. 2—Signaling subsystem layers of control.

faces for each type of CCIS data-link equipment. It also provides data-link administration and maintenance capabilities.

Each of the CCIS data-link hardware subsystems used in No. 1/1A ESS is microprocessor controlled. The data-link hardware, along with its firmware programs, implements much of the CCIS protocol including message queuing, data transmission, error detection, and error correction through retransmission. The firmware also includes diagnostic programs that can be invoked by data-link layer software.

The following paragraphs further describe each of the signaling subsystem layers beginning with the lowest layer—the data-link hardware.

3.3 Hardware

The No. 1/1A ESS currently supports two types of CCIS data-link hardware. One is a 2400 b/s data link called the CCIS data terminal frame (DTF). It is the result of a common development for initial CCIS service on CCIS signal transfer points (STPs), No. 4A/Electronic Tandem Switching (ETS), No. 4 ESS, and No. 1/1A ESS toll switching offices. The CCIS-DTF satisfies the common needs of toll network STPs and CCIS switching offices, i.e., high volumes of trunk-related signaling traffic. The CCIS DTF is used only for CCIS signaling.

The other type of data link used for CCIS is the peripheral unit controller-data link (PUC-DL). The peripheral unit controller (PUC) was developed to provide microprocessor control of digital carrier trunks (DCTs). The PUC was later modified to provide microprocessor control for data-link applications. The resulting PUC-DL was first used to communicate with a remote switching system (RSS) and was later adapted for ETS private network service and then for CCIS service. A single PUC-DL frame can be shared among all three applications. Each application has its own type of data terminal or line interface unit. The CCIS PUC-DL terminal, like the CCIS-DTF terminal, operates at 2400 b/s.

Because of several years advance in technology between development of the CCIS-DTF and the PUC-DL, the PUC-DL is not only smaller than the CCIS-DTF but its per-terminal cost is less than the CCIS-DTF per-terminal cost. The cost advantage of a CCIS PUC-DL terminal is increased when the PUC-DL frame is shared with other applications in the same office. Thus, the PUC-DL is not only a cost-effective terminal for local offices, but it can be used as a cost-reduced terminal for No. 1/1A ESS toll offices as well.

Figure 3 illustrates the No. 1/1A ESS's signaling subsystem architecture used for CCIS. This illustration is applicable to both the CCIS-DTF and the CCIS PUC-DL. The data-link equipment provides the interface
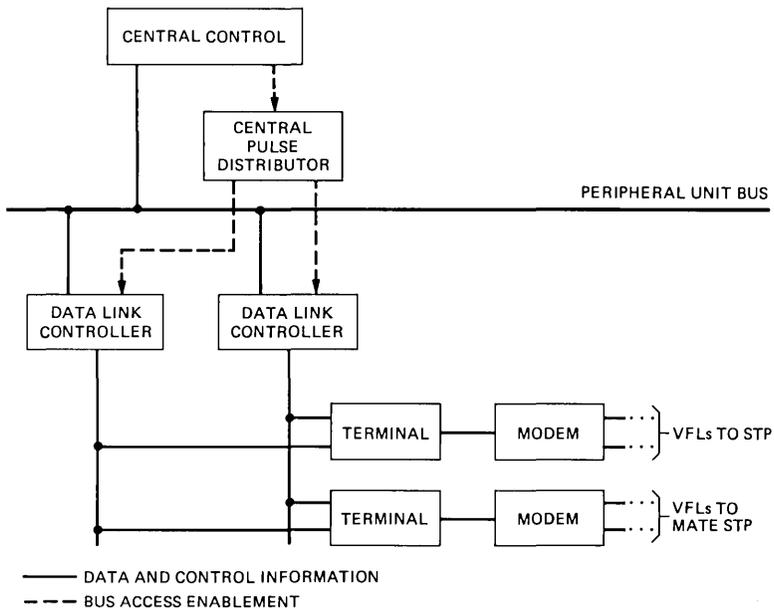
Fig. 3—Signaling subsystem hardware.

between the ESS central control and the Voice Frequency Links (VFLS) used for data transmission.

Each type of signaling subsystem used for CCIS comprises a duplex data-link controller and one or more pairs of data-link terminals. The CCIS data links are always assigned in pairs, with the number of pairs determined by the volume of signaling traffic in the office. Each link of a pair connects the ESS to a CCIS STP. Signaling traffic is shared on each link of the pair, both of which are concurrently active. Each link includes two geographically diverse VFLS—one active and one standby. This permits rapid link recovery in the event of transmission failures. The signaling network is described in greater detail in an earlier article.[5]

Data and control information is exchanged between the central control and the signaling subsystem via the peripheral unit bus. Many peripherals are connected to the bus. Thus, the central control uses a central pulse distributor to enable a particular peripheral to access the bus when there is data or control information on the bus for it.

Both the CCIS-DTF and the PUC-DL provide microprocessor-controlled, self-diagnosing data links. The CCIS-DTF has a hard-wired controller and a microprocessor-controlled terminal. The CCIS-DTF terminal's program is loaded from the central control when it is initialized. The PUC-DL has a microprocessor-controlled data-link con-

troller and terminal, each of which contains permanently resident programs. The functions performed by the microprocessor programs are described in Section 3.4.

The data-link hardware provides electrical interfaces and low-level signaling operations necessary to implement the CCIS protocol. These operations include parallel-to-serial conversion of CCIS signal units transmitted over the electrical interface between the data terminal and the modem and serial-to-parallel conversion of signal units received over this interface. The modems perform digital-to-analog and analog-to-digital conversion of the transmitted- and received-bit streams. They also maintain bit synchronization on the VFL.

3.4 Firmware

The firmware is the collection of programs that reside in the data-link hardware. The firmware implements the link-level CCIS protocol.* This level provides error-free data transmission over a signaling link in the CCIS network.

The CCIS-DTF and CCIS PUC-DL firmware formats CCIS signal units and messages into fixed-length blocks for transmission over the link. The firmware generates a cyclic redundancy check (CRC) code† used for detecting transmission errors on each signal unit, and it retransmits messages containing signal units received in error at the other end of the link.

The firmware provides priority-level queuing of messages waiting to be transmitted on the link and of messages received on the link that are waiting to be unloaded by the central control software. It buffers all transmitted messages until they are acknowledged so that they are available for retransmission if required. It also provides positive acknowledgment of all signal units received correctly and negative acknowledgment of all signal units received in error on the link.

The firmware collects message traffic counts and error statistics, such as the number of address messages transmitted and the number of signal units received in error. This information is provided to the central control software upon request. The firmware detects and reports problems such as circuit failures, buffer overflows, and exceeded-error thresholds. The firmware also responds to software requests for data-link control and maintenance actions such as initialization, reconfiguration, and diagnosis.

3.5 Data-link software

The data-link software layer is responsible for maintaining an op-

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* For a description of the CCIS system protocol, see Ref. 2.
† In the PUC-DL, the firmware computes the CRC code. In the CCIS-DTF, the hardware computes the CRC code under control of the firmware.

erational signaling subsystem. It is also responsible for providing signaling subsystem status and hardware-dependent I/O interfaces to the outer layers of software illustrated in Fig. 2. The major components of this layer are the link security and maintenance software. There are CCIS-DTF and PUC-DL programs in each of these categories.

Link security software provides CCIS data-link administration, which includes fault detection and automatic link recovery procedures. The objective of these procedures is to quickly remove faulty link components from service and to maintain an operational signaling subsystem by providing an alternate path for affected signaling traffic.

Link security maintains ESS signaling subsystem status and signaling network status for use in output message routing by the signaling software layer. This includes status reflecting the operational states of the data-link equipment in the ESS office. It also includes status of the operational states of other links in the signaling network that affect the routing of trunk-related (banded) messages that emanate from the ESS. Such signaling network status is received in messages from the STPs.

One of the principal link security procedures for maintaining an operational signaling subsystem is automatic link recovery. This procedure is initiated when link security detects a service affecting data-link fault or alarm. Since CCIS links are always equipped in pairs, the link recovery procedure begins by setting the failed link's operational status to out of service and placing the link in a faulty link mode of operation. This immediately causes banded messages destined for the failed link to be routed to its mate link and direct-signaling messages to be distributed over all other available links. It also causes change-over signals to be transmitted on the failed link, if possible, in order to notify the STP of the failure in the event that the STP had not already detected it. Link security then transfers all messages awaiting transmission or retransmission and unacknowledged transmitted messages from the failed link to its mate.

The part of the recovery procedure described above immediately restores the lost signaling capability. The next step in the procedure is to restore the lost link as quickly as possible. Since the most common source of link failure is the VFL, each CCIS link has a duplicate VFL as illustrated in Fig. 3. When both ends of a link have detected a failure, they will attempt to resynchronize on the backup VFL. If that attempt is unsuccessful, they will alternately attempt to resynchronize on the original VFL and then again on the backup VFL. The ESS alternates between VFLs every 5 seconds, and the STP alternates between VFLs every 10 seconds to guarantee intervals when both ends are attempting to resynchronize on the same VFL. In most cases, this procedure restores the link. Following a successful resynchronization on either

VFL, a 15-second prove-in period is entered to verify acceptable transmission quality on the link. Following a successful prove-in period, the link security software notifies the STP at the other end of the link that signaling traffic may be returned to the link by transmitting a load transfer signal. When the STP returns a load transfer acknowledgment signal, link security allows the ESS to resume signaling on the link by setting the link status to active. If link resynchronization is unsuccessful after 3 minutes of attempting, link security requests maintenance programs to diagnose the affected data-link equipment.

The software maintenance programs control execution of data-link diagnostic programs that reside within the data-link equipment. The diagnostic programs verify access to different points within the data-link equipment, and they also execute data-link equipment tests. Diagnostics can be requested by link security software or manually via a teletypewriter. The maintenance programs also support manual controls for data-link configuration and testing. For example, they respond to requests to remove data links from service, to switch VFLs, and to provide maintenance access to the VFLs for manual testing. These maintenance functions are done in conjunction with the link security software.

3.6 Signaling software

The signaling software layer provides hardware-independent signaling capabilities to the ESS applications software. This includes I/O interfaces for CCIS trunk-related (banded) signaling and direct signaling. The signaling software also provides automatic responses to signaling network congestion. The principal programs in this layer are a CCIS input processor, a CCIS output processor, and signaling network congestion control programs.

The CCIS input processor is a continuous process within the ESS central control. It executes at regular intervals, each time checking for input from the CCIS data links. When input messages are present, the input processor unloads the messages from the data links. Within the programs that unload the data links, there are short hardware-dependent segments of program code that are both logically and physically part of the data-link software layer. Each program or program segment resides in a software feature package. This concept is explained in Section 3.8.

The input processor distributes CCIS input messages to appropriate application programs. Included in the input processor is a finite-state machine (FSM) controller that provides inputs to application programs such as CCIS call processing, which uses an FSM-based software architecture. For these applications, the specific program that receives an input message is a function of the current state of the FSM at the time

the input is received. The FSM controller also performs state updates when the application program has completed processing of the input message. The call processing FSM is described in Section 4.3.

The CCIS output processor consists of macro-accessible subroutines which are called by the application programs when they wish to send a CCIS message to a different SPC network node. The output processor provides a high-level interface that permits the application programs to be concerned mainly about the application-oriented data content of messages and not about the low-level signaling protocol characteristics.

The output processor will optionally format user-specified data into CCIS message format. It then routes the messages to an appropriate signaling link based on data-link equipment status and signaling network status maintained by the data-link software layer and also based on a terminal load-balancing algorithm. The load-balancing algorithm strives to maintain an evenly balanced load among all available CCIS links. Banded messages are associated with a specific data-link pair; thus, such messages are evenly distributed to the two terminals of the pair. Direct-signaling messages may be routed over any available CCIS link; therefore, these messages balance the signaling load across terminal pairs. The output processor calls data-link-dependent output subroutines in the data-link software layer to transmit data. These subroutines execute peripheral orders to effect the transfer of data across the peripheral unit bus to the data-link equipment.

Signaling network congestion control programs automatically respond to signaling overload in the ESS data links and in the CCIS network STPs. Data-link overloads are detected as buffer-full conditions in the data links. Overloads in STPs directly connected to the ESS are reported to the ESS using processor signaling congestion messages. Because of the load-balancing algorithms used within the signaling network, it is assumed that whenever a data link or STP becomes overloaded that its mate is also overloaded. Thus, the response to either of these conditions is to reduce traffic to both of the affected links while such congestion lasts. Signaling traffic is reduced by preventing new call originations which would use the affected terminal pair and by preventing direct-signaling traffic from using that terminal pair. Overloads in STPs not directly connected to a particular ESS can still affect signaling for specific trunks in that ESS whose CCIS messages must be routed through the overloaded STPs. The ESS is notified of such overloads through group signaling congestion messages. These messages apply to specific trunk groups. The ESS response to one of these messages is to place a 10-second network management trunk group control on the affected group. This temporarily suspends signaling traffic for that trunk group by either canceling new call originations destined for the group or optionally skipping the group in the

call-routing sequence and permitting the call to complete on a different trunk group.

3.7 ESS applications software

The applications software consists of ESS programs that use the signaling subsystem for basic call handling, for implementing special features, etc. Two principal applications are CCIS call processing and System 800. These applications are described in Sections IV and V, respectively. There are also other important applications which use CCIS. For example, CCIS network management provides traffic controls on the CCIS portion of the trunking network. Trunk maintenance programs in switching offices at each end of CCIS trunks use the signaling network to exchange maintenance state information about the trunks. Trunk query is an interoffice trunk state audit which verifies that the operational and/or maintenance states at each end of CCIS trunks are consistent. Other ESS call-processing programs use the signaling subsystem for trunk-related signaling via the supervisory program interfaces described in Section 4.2.

In addition to application layer programs, signaling software and data-link software layer programs themselves use the signaling subsystem.

3.8 Software feature packaging

No. 1/1A ESSs serve a variety of purposes. They provide basic local, tandem, and toll switching, as well as a variety of network features such as CCIS and customer services such as System 800. Each office is individually engineered and equipped with the hardware and software required for the features and services provided by that office. Feature packaging is a mechanism used to permit an office to load that software, and only that software, needed to provide the office's particular combination of features and services.

A feature package is a collection of software associated with a particular feature, service, or piece of equipment. The software may include complete programs, program segments, and/or subroutines. It can also include fixed and variable amounts of temporary (call store) memory. A feature, service, or piece of equipment may require one or more feature packages to be loaded into an office. Also, a particular feature package may be used by one or more different features, services, or pieces of equipment. The following paragraphs describe the feature packages which provide CCIS capabilities in local and toll offices, the packages associated with the signaling system hardware, and the System 800 packages.

CCIS Common—This package contains software required by every

No. 1/1A ESS office equipped with the signaling capability. It includes hardware-independent signaling software and CCIS applications software, such as call-processing programs, which are common to local, tandem, and toll switching, trunk maintenance, network management, etc.

Local CCIS—This package contains CCIS call-processing logic required in local offices. It handles calls routed over CCIS interlocal, tandem, and toll-connecting trunks.

Toll CCIS—This package contains CCIS call-processing logic required in toll offices. It handles calls routed over CCIS intertoll and toll-connecting trunks.

CCIS Two-Wire—This package contains maintenance programs required to diagnose faults in two-wire CCIS trunks and continuity check circuits used with CCIS trunks. Two-wire networks are used mainly for local switching.

CCIS HILO—This package contains maintenance programs required to diagnose faults in HILO CCIS trunks and continuity check circuits. The HILO switching networks provide transmission quality equivalent to four-wire networks and are used for toll switching in No. 1/1A ESS offices.

2400DL—This package contains maintenance software for the 2400 b/s CCIS-DTF.

CCIS 2400DL—This package contains hardware-dependent I/O interfaces and link security logic associated with the CCIS-DTF.

PUC—This package contains maintenance software associated with the peripheral unit controller. This software is common to the DCT application and also to each of the PUC-DL applications.

PUC-DL—This package contains maintenance software associated with the PUC when it is used as a data-link controller. The software is required for any application that uses the PUC-DL.

CCIS PUC-DL—This package contains hardware-dependent I/O interfaces, link security logic, and maintenance programs associated with the CCIS configuration of the PUC-DL.

OSO—This package contains the software which comprises the System 800 originating screening office feature. It is used in all No. 1/1A ESS local and toll offices that have the CCIS signaling capability.

BISI—This package contains the software which comprises the System 800 busy/idle status indicator feature. It is used in local offices that serve System 800 customers.

The required combination of the above feature packages depends on the type of office, the data-link hardware subsystem used, and the features or services provided by that office. Figure 4 illustrates the feature package combination required for a typical local switching office with CCIS. It uses PUC-DL for its CCIS data links. It provides

originating office screening of 800 Service calls, and it serves customers that have 800 Service lines connected to the office.

Every No. 1/1A ESS has a collection of base software which provides basic call processing, maintenance, and switching office administration. Feature packages usually build on capabilities provided by the base software. As illustrated in Fig. 4, feature packages can also build on the capabilities provided by other feature packages. For example, the CCIS PUC-DL package adds data-link capabilities which are unique to CCIS onto the more general PUC-DL capabilities provided by the PUC-DL package. The PUC-DL package adds general data-link capabilities to the more general PUC capabilities provided by the PUC package. The PUC package, in turn, builds on basic maintenance capabilities provided by the ESS base software. Likewise, CCIS applications such as OSO and BISI use the signaling capabilities provided by the CCIS common package in order to implement their own features.

IV. CCIS CALL PROCESSING

4.1 Development environment

CCIS is sometimes referred to as a new signaling type to replace multifrequency (MF) signaling. While this may be partly true, address signaling (digit transmission) is certainly not the entire concept, nor the most difficult aspect, for call processing to implement. Digit transmission and voice path assurance for CCIS involve only a few messages and, as with MF signaling, comprise only the addressing portion of the call. It is the expanded capabilities of CCIS (e.g., backward call failure messages) that make CCIS difficult to integrate into existing systems which before only dealt with in-band signaling and supervision (e.g., trunk on-hook/off-hook signals).
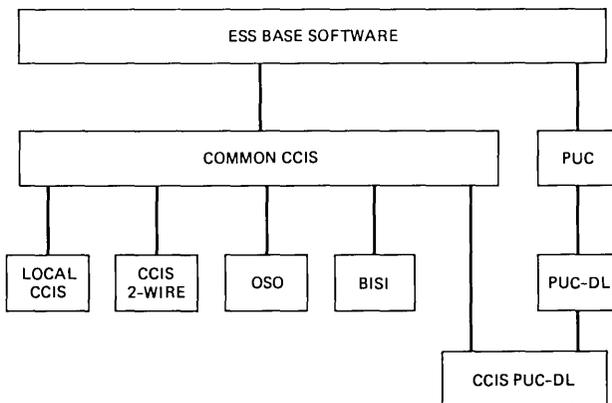

Fig. 4—Software feature packaging for an SPC network local office.

The CCIS call processing is involved in setup and teardown of calls utilizing CCIS trunks and mainly handles CCIS trunk-related (banded) messages. This processing involves supervisory messages such as trunk seizure, answer, and disconnect which have non-CCIS trunk on-hook/off-hook signaling counterparts. However, CCIS call processing also involves new nonsupervisory information messages such as specific call failure, trunk reset, and address messages which may not have non-CCIS trunk signaling counterparts.

The CCIS call processing is faced with other issues not previously dealt with by existing call processing. Because of signal transmission errors and resultant retransmission, CCIS signals can arrive out of sequence, be received twice, or even spill over from previous calls. Unexpected signals can arrive at any time, and special timing may be required to determine their reasonableness.

No. 1/1A ESS first developed CCIS for the toll environment. It was decided then that because of the number of signals and internal inputs to be processed during all phases of the calls, a finite-state machine structure would be best suited for the implementation. Also, since the toll environment is very limited in the types of connections required (i.e., trunk-to-trunk only), the processing logic could be mostly separate from the existing toll-processing logic. This eliminated extensive changes in the existing toll-call processing logic to handle supervision, out-of-sequence messages, new nonsupervisory messages, etc. As soon as the call-processing logic determines that a call involves a CCIS trunk, control is passed to the toll CCIS logic which then maintains control of the call through disconnect processing.

Local CCIS development was faced with an even larger and more complex environment. The local call-processing environment involves many program interfaces and types of connections requiring hundreds of thousands of program instructions. For example, besides basic calls such as line-to-trunk and trunk-to-trunk, there are interfaces with features such as coin, three-way calling, call waiting, etc. Duplicating this logic to process local CCIS calls would have been too costly initially and most likely would have incurred huge maintenance costs. Thus, it was clear that the existing logic had to process local CCIS calls and, further, coexist with the toll CCIS logic already deployed. Supervisory messages received would have to be converted to their on-hook/off-hook counterparts and passed through some interface to the existing logic. Similarly, trunk circuit state changes to send supervisory signals outward would require conversion to CCIS messages. Nonsupervisory messages (i.e., those with no on-hook/off-hook equivalent) would require special handling apart from the existing logic. This special handling would have to be confined to areas where signaling-type differences are recognized.

4.2 Supervision modernization

The call-processing logic which handles calls involving in-band signaling trunks must also be used to process calls involving local CCIS trunks. To accomplish this, the mechanisms for controlling supervision had to be changed. No longer could the application logic assume on-hook/off-hook supervision on the trunks. Application programs could no longer directly access I/O memory to change supervisory status. Turning off scanning of a trunk would not necessarily suspend supervision, nor would changing the supervisory state in a trunk circuit necessarily send a supervisory signal to the connected office. An interface between the application programs and the signal I/O programs to isolate supervision had to be developed.

The incoming signal control mechanism which existed had two levels of programs that communicated using shared memory. The I/O level programs detected trunk supervisory changes, updated I/O memory, and reported the changes to the application program level. Application programs controlled report generation by writing directly into I/O memory. The application programs had to be familiar with the use of the memory and the synchronization problems which arose from multiple access by both levels.

The objective of supervision modernization was to eliminate the tight coupling that existed among application programs, I/O processes, and I/O memory. Incoming signal control programs provide the primary interface between I/O and application programs. The application programs control which reports are generated by making requests to the supervisory control program. This control program accesses I/O memory when necessary. Knowledge of I/O memory use and synchronization problems is thereby confined to the signal-processing interface programs. These supervisory interface programs maintain per trunk supervisory status in dedicated memory. Incoming signals from CCIS trunks are recorded in this memory and delivered as logical reports to the call-processing programs. Implementation of this objective effectively isolates the details of supervision from the call-processing programs which allows CCIS and non-CCIS trunks to be treated identically by the call-processing software.

A second supervisory interface, the outgoing signal function, is used to generate outgoing supervisory signals. This interface is used whenever call processing is attempting to change the supervisory state of an interoffice trunk which could possibly be a CCIS trunk. The outgoing signal function allows the call-processing program to specify the logical supervisory message it wants to send and the trunk for which it should be sent. The outgoing signal interface causes the CCIS signaling logic to send the appropriate CCIS supervisory message for a CCIS trunk.

4.3 Structure

The CCIS call-processing logic structure is based on finite-state machines. Each state represents a condition or processing stage of a CCIS trunk involved in a call. The state of each CCIS trunk is stored in a per-trunk state word block of memory. The states are grouped into models which reflect call functions (e.g., continuity checking). All stimuli handled by each model come as inputs through the CCIS input processor where validity screening and state table execution take place.

The CCIS messages are unloaded from the data links by the input processor as described in Section 3.6. The trunk label from a call-processing message is translated to a trunk network appearance and a state word memory address. The message input is applied to the current state which specifies the model in control. The model controls all processing by calling any number of closed transition routines (i.e., those which return to the calling program), updating the state, and possibly calling an open interface routine (i.e., one which allows processing to pass to other application logic).

Models are of two basic types: processing models and conversion models (see Fig. 5). Processing models handle the parts of call processing which are unique to the signaling type. The CCIS address message processing and trunk-continuity checking are the primary examples. They have in-band signaling counterparts that are handled by separate programs. During these portions of a call, the processing models act as application programs and perform call-processing functions. These models are in control prior to sending or receiving the
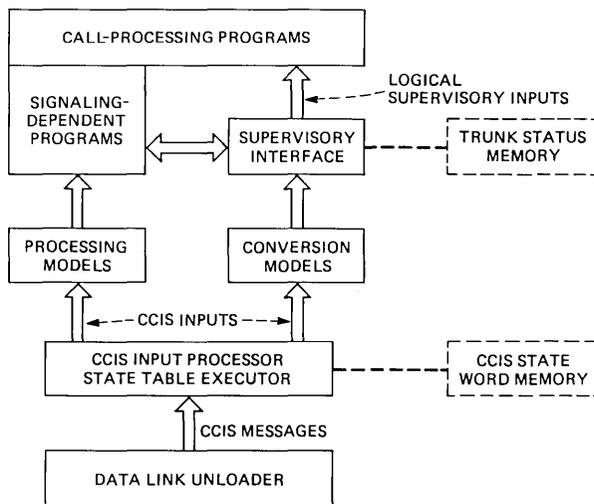
Fig. 5—Local CCIS call-processing structure.

address complete (ADC) message. The ADC message basically separates call setup from answer and disconnect processing. Since most nonsupervisory messages are exchanged prior to ADC, the processing of these messages is confined to the CCIS application programs. All supervisory and nonsupervisory inputs are handled directly by these models.

Conversion models are in control when the only messages to be processed are the supervisory messages. These models validate and resequence messages if necessary before passing them through the supervisory incoming signal interface to the call-processing programs. They also receive the stimulus from the outgoing signal interface to send the appropriate CCIS supervisory message. These models maintain trunk states for message-screening purposes only and provide no call-processing functions themselves. In essence, the states of these models are unaware of whether the CCIS trunk is connected to a line or to another trunk. This terminal processing concept enables local CCIS to interact with the majority of the application programs of the local ESS environment.

4.4 Call flow

The basic call types described in this section are those of the local office. A brief call flow of each type is given specifying the basic program interactions and message protocol. The toll office call-type descriptions have been previously given in other articles and are not repeated here for No. 1/1A ESS.[6]

4.4.1 Originating outgoing calls

An originating outgoing CCIS call begins the same as any originating outgoing call. Dial tone is given to the customer, digits are collected and analyzed, and an outgoing route is selected. When this outgoing route involves a CCIS trunk, the CCIS outpulsing logic receives control. The CCIS outpulsing finite-state model and associated transition routines perform the necessary call-processing functions and remain in control until the receipt of the ADC message. These functions include sending the initial address message (IAM), performing the continuity check if necessary, sending the continuity (COT) message, and handling any backward failure messages. Once ADC has been received or an error has occurred, control is returned to the call-processing programs to perform call setup or teardown as required.

During these and subsequent call functions, a conversion model handles the supervisory message inputs. The answer charge (ANC) message, for example, causes the conversion model to pass a logical answer via the supervisory incoming signal interface to the call-processing programs where answer processing occurs. Upon receipt of disconnect, the call-processing programs tear down the cross office

path and restore the outgoing trunk to the idle state. Here, interface logic for CCIS takes control of the outgoing trunk, sends a clear forward (CLF) message, and places the trunk in a processing model which waits for the release guard (RLG) message. When RLG is received, the trunk is returned to the idle state and made available for another call.

4.4.2 Incoming terminating calls

This call begins with the receipt of an IAM for a particular incoming CCIS trunk. A continuity check circuit is connected to the incoming trunk, if required, and the call waits for the COT message. This function is handled by the CCIS incoming call-processing model as a unique inpulsing-type application program which remains in control until the COT message is received. Upon receipt of the COT message, the ADC message is sent to the originating office. Then control is given to the call-processing programs to perform digit analysis and establish necessary connections. Giving up control means that a conversion model handles subsequent inputs. However, in the event that digit analysis determines that the terminating line is busy, the subscriber busy (SSB) message is returned in lieu of the ADC message so that the customer can be connected to busy tone in the originating office. If the called line is idle, the CCIS incoming trunk is connected to audible ringing tone and ringing is applied to the terminating line. The calling customer then waits for the called party to answer.

If the called party answers, the call-processing logic sets up the cross office path and puts the incoming trunk in the off-hook state. At this point, an outgoing signal interface to send logical answer allows the conversion model to send the ANC message. Upon receipt of a CLF message (i.e., calling party disconnect), the model passes a logical disconnect via the supervisory incoming signal interface to the call-processing programs. These programs tear down the cross office path and restore the incoming trunk to the idle state. An interface for CCIS in the trunk idle logic sends the RLG message, and the trunk is made available for another call.

4.4.3 Tandem calls

An incoming call which routes back out of the office on an outgoing trunk is a tandem call. This call proceeds as an incoming terminating call, except that digit analysis dictates that an outgoing trunk be selected. When the outgoing trunk is a CCIS trunk, the CCIS outpulsing logic receives control to handle the outgoing trunk processing as described in originating outgoing calls, Section 4.4.1. The tandem call-processing logic performs the call setup and teardown processing. Each CCIS trunk is independently associated with a finite-state model. The

models separately handle the CCIS messages and supervisory interfaces for each trunk.

V. NO. 1/1A ROLE IN SYSTEM 800

No. 1/1A ESS performs two important functions in System 800: the OSO function and the BISI function. The OSO function can exist in both No. 1/1A ESS local and toll offices. An OSO queries an NCP on all 800 Service calls to obtain a direct distance dialing (DDD) number for routing. The BISI feature, which monitors the busy/idle status of 800 Service customers and reports changes in status to an NCP, can reside in No. 1/1A ESS local offices. The busy/idle status can then be used by the NCP to provide alternate handling of 800 Service calls that would have received busy treatment. An overall description of the System 800 capability is provided in another article in this issue.[7] The following sections describe the No. 1/1A ESS implementation of the OSO and BISI features.

5.1 Originating screening office

The OSO feature provides single-number DDD calling and improved routing for 800 Service calls. This section discusses the functioning of a No. 1/1A ESS OSO as it applies to both local and toll offices.

5.1.1 Processing 800 service calls

A No. 1/1A ESS OSO processes both originating 800 Service calls and 800 Service calls which arrive over a trunk from a distant office. The 800 Service calls are recognized by examining the first three digits dialed by the customer or received from the distant office. After identifying a call as 800 Service, the OSO determines the identity of the originating Numbering Plan Area (NPA).

The NPA and the dialed 800 number are then formatted into an 800 Service direct-signaling message called QUERY which is sent to an NCP. The NPA is used by the NCP to determine if the call is allowed, based on the customer's purchased service area. The 800 Service call is suspended until a REPLY message is received from the NCP. The OSO saves the call data, while the QUERY is being processed by the NCP, and times for a response from the NCP.

When the OSO receives a REPLY from the NCP, it first determines which call the REPLY is associated with by accessing the saved call data. If the REPLY contains a 10-digit DDD number, the OSO routes the call as a normal DDD call. If a DDD number is not contained in the REPLY (e.g., because of all 800 Service lines being busy), the OSO routes the call locally to an appropriate tone or announcement.

The OSO also has the ability to manually test the OSO-NCP interface. The input of an 800 number and an NPA from a teletypewriter will

cause the ESS to send a QUERY to the NCP. The information contained in the resulting REPLY is then displayed on a teletypewriter at the OSO.

5.1.2 800 Service code controls

The 800 Service code controls are initiated automatically to prevent overloading the switching network, the CCIS signaling network, or the NCPs. Code controls restrict the number of queries sent to a particular NCP.

There are two types of 800 Service code controls:

(*i*) Network management-code controls—These controls can be initiated automatically by the NCP or manually at the OSO. When they are in effect, the OSO limits the number of queries sent to the NCP for a particular 800 number or for a group of 800 numbers.

(*ii*) CCIS failure-code controls—These are initiated automatically when the OSO is unable to successfully send a QUERY. They cause the OSO to restrict queries for a group of 800 numbers.

5.2 Busy/Idle status indicator feature

The BISI feature resides in No. 1/1A ESS 800 service terminating-end offices (TEOs). An 800 Service TEO is a local office which serves 800 Service customers. The BISI feature monitors the busy/idle status of 800 Service customer line groups and reports changes in busy/idle status to an NCP. The NCP can then use the busy/idle status information to provide alternate handling to 800 Service calls which would have received busy treatment.

5.2.1 Busy/idle monitoring and reporting

With the introduction of System 800, all 800 Service calls will be routed to the TEO using a 10-digit DDD number. In a No. 1/1A ESS TEO, each 800 Service DDD number has an associated Simulated Facilities Group (SFG). The SFG is used to limit the number of simultaneous calls to a group of physical 800 Service lines and to provide proper 800 Service band hunting and billing. An 800 Service band is a geographical area from which an 800 Service customer may receive calls. The DDD number also directs the incoming call to the correct physical facilities (i.e., lines).

An SFG is required for each service-area band that an 800 Service customer purchases, so that incoming calls can be billed based on band. Figure 6 illustrates an 800 Service customer setup at the TEO. This customer has seven physical lines and wishes to allow at most five of these lines to be used at any given time for incoming 800 Service calls. The customer wishes to permit three simultaneous calls from band 1 and two simultaneous calls from band 2, and to have band 1
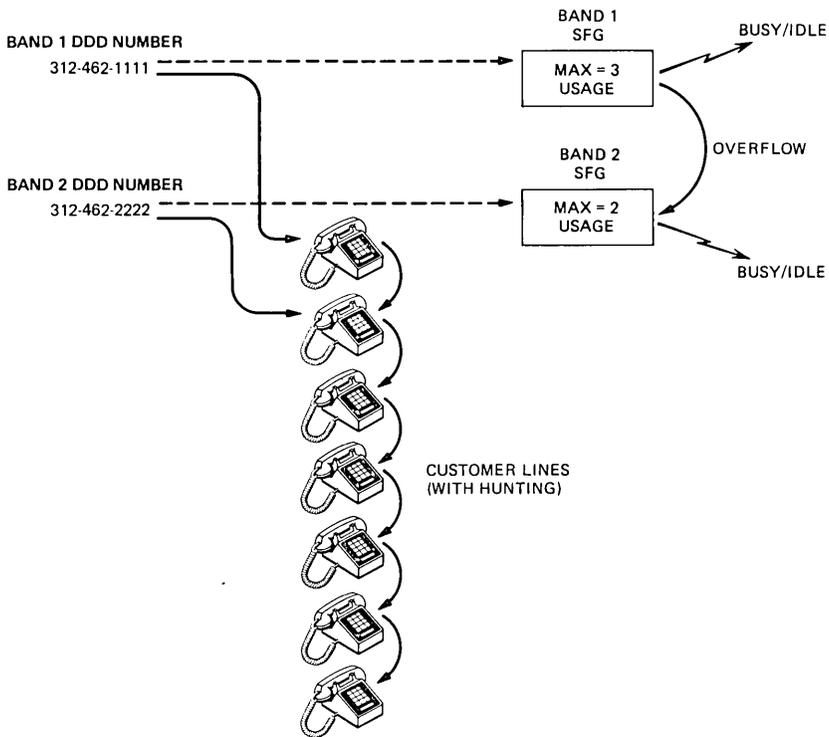
Fig. 6—800 Service customer line group arrangement.

calls overflow to band 2 lines if all band 1 lines are busy. In this case, two SFGs are required, and the band 1 SFG overflows to the band 2 SFG. There are three 800 Service lines in the band 1 SFG and two 800 Service lines in the band 2 SFG. A distinct ten-digit DDD number is required for each band.

The BISI feature monitors the busy/idle status of the 800 Service SFGs in a TEO. To perform the monitoring function, a count of the number of calls currently in progress for each SFG is maintained. This count is called USAGE. Also, for each SFG, a constant is stored which indicates the number of 800 Service lines for that SFG. This per-SFG constant is called MAX. The BISI feature monitors the activity on the SFG and increments or decrements USAGE when 800 Service lines are seized or released.

The BISI feature reports changes in SFG busy/idle status to a remote NCP via CCIS direct-signaling messages. Therefore, if USAGE becomes equal to MAX when an 800 Service line is seized, or if an 800 Service call is unable to complete because USAGE=MAX, a direct-signaling message is sent to the NCP that indicates BUSY. If USAGE becomes

equal to MAX-1 when an 800 Service line is released, an IDLE direct-signaling message is sent. The TEO continuously audits USAGE so that its value is correct at all times.

To assure that the BUSY and IDLE messages for a particular SFG are properly sequenced, the TEO performs a blind-period timing function. An SFG goes on blind period timing after a BUSY direct-signaling message is sent. While an SFG is on blind-period timing, no BUSY or IDLE direct-signaling messages are sent to the NCP. When the blind-period timing interval expires, an IDLE direct-signaling message is sent if the busy/idle status changed to idle while the SFG was on timing.

The NCP has the ability to query the TEO about the current busy/idle status of a particular SFG. When the BISI direct-signaling QUERY message is received at the TEO, the current busy/idle status is returned in either a BUSY or IDLE message. Using this mechanism, inconsistencies in busy/idle status between the NCP and the TEO can be corrected.

5.2.2 Activation and deactivation of busy/idle reporting

The TEO reports changes in busy/idle status to the NCP only if busy/idle reporting is activated for the SFG. Before busy/idle reporting can be activated for an SFG, common data between the NCP and the TEO must be verified, so that busy/idle reporting will function correctly. The data verification sequence is performed using direct-signaling messages and can be initiated from either the NCP or the TEO.

Under normal circumstances, the NCP controls the activation/deactivation process, but the TEO can also activate and deactivate busy/idle reporting for an SFG. As an example, when the TEO wishes to change some data (e.g., to add another line) associated with a particular activated 800 Service SFG, the SFG must first be deactivated. Next, a data verification process is initiated by the TEO. The NCP returns its data for that SFG, and the TEO verifies that the data returned agree with the data stored at the TEO. If so, the SFG is activated and busy/idle reporting resumes.

5.2.3 800 Service data for customers

The 800 Service customers can receive data concerning the activity on their lines. SFG attempt and overflow data are available using customer premises equipment. The counts can be sent to the customer as often as every 30 minutes. In addition, overflow counts are available on the customer's monthly bill.

Prior to the new System 800, all counts were kept solely at the TEO. With System 800, most overflows for customers served by TEOs with

the BISI feature occur at the NCP since the NCP screens all 800 Service calls.

To provide this overflow data to the customers, the NCP sends it to the TEO in a direct-signaling message either every 15 minutes or every day. The counts are then stored at the TEO so that the customer can continue to get an accurate picture of the activity on their 800 Service lines.

VI. SUMMARY

No. 1 ESS was the Bell System's first major commercial electronic switching system. Today No. 1 and 1A ESSs are an important part of the rapidly growing SPC network. The SPC network uses CCIS to provide rapid and efficient basic call handling. However, the network's full capabilities are just beginning to be realized now that the SPC network is being used for the development of services such as System 800. No. 1/1A ESSs play an important role in the SPC network because they provide direct interfaces to the subscribers and users of SPC network services. No. 1/1A ESSs serve nearly one-half of the Bell System subscriber lines. Thus, they have the potential to provide much customer-related service information and line status information to other SPC network switching offices and NCPs.

The No. 1/1A ESS uses a layered CCIS signaling subsystem that supports two types of data-link hardware at the innermost layer, while providing hardware-independent signaling capabilities to ESS applications software at the outer layers.

The CCIS call processing provides call handling over CCIS trunks in both local and toll offices. To do this, especially for local offices, the CCIS programs have to interface with numerous existing ESS call-processing programs which had previously used ingrained in-band signaling techniques. Changes to the ESS supervisory programs helped to provide new signaling interfaces to these programs.

The CCIS call processing must also respond to the many call-handling messages which are part of the CCIS protocol. It uses a finite-state machine program structure to respond to CCIS messages and, at the same time, to verify their reasonableness when received at different stages of a call.

No. 1/1A ESS performs two important System 800 functions. With the help of NCPs, it can screen 800 Service calls in either local or toll offices using its OSO feature. With OSO, System 800 NCPs are queried to obtain call-routing information for 800 Service calls. The OSO feature also provides code controls on 800 Service calls.

A System 800 BISI feature monitors System 800 customer line groups served by No. 1/1A ESS local offices and reports busy/idle line status changes to System 800 NCPs for use in call screening. The BISI feature

also provides 800 Service call attempt and overflow data to customer premises equipment. The System 800 features exemplify the types of SPC network and customer interfaces that No. 1/1A ESS can provide.

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Stored Program Controlled Network:

CCIS and SPC Network Performance

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Common-channel interoffice signaling (CCIS) represents a major advance in interoffice signaling speed and capability over current inband signaling systems. The introduction of CCIS between Stored Program Control (SPC) switching offices is reducing ineffective machine attempts (IMAs) caused by transmission and switching irregularities associated with inband signaling. Because signaling between CCIS-equipped switching offices is concentrated in a relatively small number of signaling links and signal transfer points (STPs), a high standard of performance for the signaling network is essential. Therefore, the design of the signaling network incorporates many features to assure a high degree of availability. Cumulative data on STPs and studies of signaling links are the principal measures of signaling network performance. Data on their performance are presented that confirm the high availability of the signaling network.

I. INTRODUCTION

Common-channel interoffice signaling (CCIS) was introduced to provide the advantages of greater economy, faster call setup, improved security from fraud, and improved flexibility. The initial CCIS implementation was limited to class 1 to class 4 toll offices, but was extended to class 5 end offices during 1981. Several companion articles provide detailed accounts of CCIS implementation and describe its characteristics.

At year-end 1981, over 160 toll switching offices were interconnected through the CCIS network, which then comprised 24 signal transfer points (STPs) and signaling links serving over 400,000 trunks. The signaling link consists of an analog voice bandwidth channel with a CCIS terminal at each end. These links currently operate at a data rate of 2400 b/second. Because of the increasing traffic in the network, higher-speed links (4800 b/s) are being introduced.

Supervisory and address signaling information for a conventional call is usually transmitted directly from one switching system to the next over the same communication channel used for talking. A CCIS call, on the other hand, uses the separate, duplicated, signaling network to carry its supervisory and address signaling information. Since CCIS-equipped switching offices access the signaling network through a pair of STPs, signaling for a trunk between two CCIS switching offices will typically be routed through one or two STPs and two or three signaling links, depending on whether the two switching offices are served by the same or different STP pairs.

Clearly, the concentration of CCIS into a small number of signaling links and STPs greatly increases the consequences of a signaling failure. The original CCIS system design recognized the importance of signaling path availability and provided link and STP redundancy, tolerance to transmission errors, and automatic response to signaling network failures to assure that SPC network completion objectives were not jeopardized. This paper describes the differences between conventional signaling and CCIS methods, examines both signaling network performance and SPC network performance, and discusses the reduced rate of IMA observed with CCIS between modern stored program control systems.

II. INTEROFFICE SIGNALING

Interoffice signaling conveys the supervisory and address information necessary to switch calls through the telephone message network. Supervisory signals are used to initiate and release connections and to control charging. Address signals route the called number to its destination.

Conventional interoffice signaling separates the supervisory and address functions. Supervisory signaling equipment is usually dedicated to each trunk, while address signaling equipment is shared in a common pool. Address signals are sent by either dial pulsing (DP) or multifrequency (MF) pulsing.

The CCIS network interconnects switching office processors. Interoffice signaling messages transmit supervisory and address information. This information is checked and errors are corrected by retransmission before they are accepted by the switching office.

III. THE SIGNALING NETWORK

3.1 Configuration and response to failure

The basic configuration of the signaling network for CCIS is shown in Fig. 1. Much of the inherent availability of the signaling network is a result of the architecture of this arrangement.[1,2] Switching offices in each signaling region have access to the signaling network through
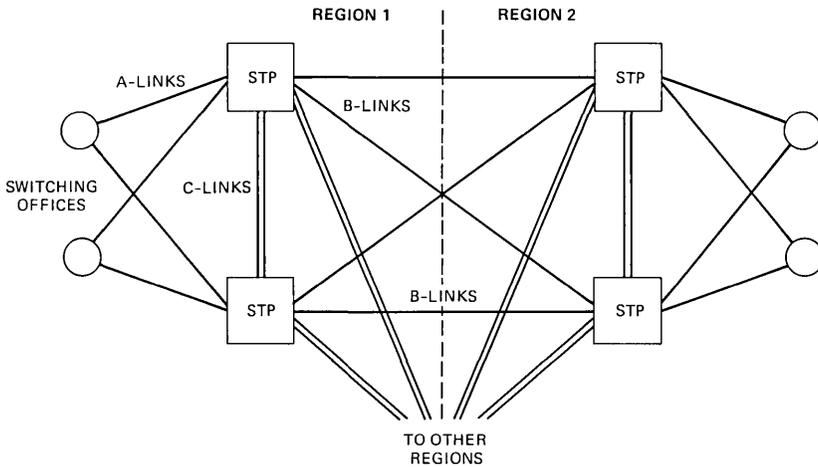
Fig. 1—The CCIS network.

access links (A-links). These links provide access to regional STPS. Switching offices may also be connected to other than home STP, and these access links are designated E-links. The STPS route signaling units to outgoing links based on address information contained in incoming signal units. For intraregional signaling, the outgoing link would be another A-link. For interregional signaling, messages are routed onto bridge links (B-links) that provide access to STPS in another region.

The signaling regions with a heavy volume of traffic are supplemented by area STPS. Switching offices access area STPS by A-links and E-links. Area STPS are connected to regional STPS by D-links and to area STPS by B-links.

This network is fully duplicated. Regional and area STPS are provided in pairs, and A-links or E-links from an office are duplicated with mates terminating at each STP of the pair. The B-links and D-links are duplicated from each STP to form a quad. Under normal conditions, traffic loads are balanced among the links and STP pairs. However, the loads are engineered so that in the event of a failure, the mate link or the mate STP can carry the full traffic load. The links connecting mate STPS (C-links) carry traffic only under certain transient failure conditions and are provided, after the first pair, in proportion to the number of A-links and E-links in a region.

The redundancies are provided so that alternate signaling paths are available in the event of link or STP failures in the network. One assumption that is implicit with redundant arrangements is that failures of mate pairs are independent. Physical diversity is one way of assuring independence. Diversity is achieved with STPS by locating

them in different cities. To the greatest extent possible, mate signaling links use separate transmission circuit facilities for their entire length.

Effective use of redundancies means that the signaling network must respond quickly and automatically to failures and reestablish signaling paths with little or no interruption to the signaling traffic. Two general classes of failures are expected. First, the links may experience hits or fades characterized by high error rates for short periods of time. Second, major facility outages or hard equipment failures may occur which could last for several minutes or longer. The ccis network is designed to handle these situations with minimal deterioration of signaling performance.

The ccis terminals at each end of a signaling link continuously monitor errors by decoding an 8-bit check code appended to each signaling unit. This code is designed to detect single errors and a large class of multiple errors and error bursts. In addition, the terminal can automatically detect loss of carrier or synchronization, while an improper sequence of signaling units is detected by the switching office processor through the use of reasonableness check tables.

Under normal circumstances, errors are corrected by retransmission. However, if a high error rate is detected for a relatively long period of time, about one-third of a second or longer, the terminal assumes that the link is faulty and initiates recovery action. Link recovery procedures can be illustrated by considering A-links. When the error threshold is exceeded, the terminal will alert its host processor to direct traffic to the mate link. Changeover signaling units are then sent to the far-end terminal to coordinate the changeover in case the problem affected signaling in one direction only. The STP temporarily routes traffic destined for the switching office over the C-link to the mate STP to avoid the failed A-link.

Terminals at both ends of the A-link then attempt to restore service. In the case of A-links, an extra level of redundance is provided through use of two voice frequency links (VFLs) per signaling link. When resynchronization is achieved on one of the VFLs, the terminals monitor the error rate for 15 seconds to prove in the link. If the error threshold is not exceeded, the link is restored to service and the normal routing of traffic is resumed.

If recovery cannot be effected within 3 minutes, the terminal is taken out of service. This is accompanied by alarm indications at the switching office and STP and automatic initiation of terminal diagnostic routines. The STP sends special control messages to other STPs in the network to route all traffic destined for the failed link directly to the mate STP and its A-link. This procedure avoids the use of C-links, except for short interruptions. It also minimizes total delay in signaling through the network when failures do occur.

Similar network reconfigurations are automatically invoked when an STP fails. In the event of an STP outage, the CCIS terminal for each signaling link detects the outage and autonomously signals this condition to the far-end terminal. Traffic destined for the A-links is automatically rerouted by the switching office to the mate STP, and distant STPs also reroute B-link traffic to the mate.

It can be seen from this brief discussion that the simultaneous occurrence of several unlikely events is required to isolate a switching office from the signaling network. One possibility is A-link pair failures. Other possibilities include B-link quad failures, an A-link plus a B-link pair plus all regional C-links, or an STP regional pair outage. The combined effect of all these possibilities is the unavailability of the network. By using actual field failure statistics, it can be shown that the probability of switching office isolation is very small, as will be discussed below.

3.2 Signaling network performance monitoring

All switching offices and STPs in the CCIS network have provisions for monitoring and reporting CCIS traffic and signaling link performance. Traffic and performance data are continuously gathered at the STPs by specialized minicomputer systems called peripheral bus computer (PBCs).[3]

Reports generated by the PBC are used mainly by the STP management and craft to assess traffic loads and link occupancy, to aid in maintenance activity, and to index the overall performance of the STP and signaling links. Many impending problems, characterized, for example, by high error rates or an unusual number of changeovers can be spotted and corrected by the craft before signaling performance is affected.

Data on signaling link performance have not been collected continuously for all links. The sheer mass of information involved would be unmanageable. However, each node monitors link performance to generate exception reports to guide ongoing maintenance activity. Occasionally, Bell Laboratories conducts special studies to assess link performance by examining data from a sample of links. Very little variation in the average characteristics of links has been observed in these studies.

3.3 Reliability of STPs and signaling links

The probability that a switching office will be isolated from the signaling network is equivalent to the probability of certain multiple failures in the network, as mentioned above. The probability of service-affecting multiple failures is, in turn, a function of the reliability of the STPs and the signaling links. However, it is important to recognize that

certain network failures would be more serious in their effect than others. For example, the simultaneous outage of a regional STP pair would take almost all CCIS trunks in the region out of service. (Some high-traffic trunk groups are homed on distant regional STPs for increased efficiency.) On the other hand, an A-link pair failure would take out of service only the trunks assigned to that pair (up to 2250 or 4500 trunks, depending on link speed). As will be shown, the probability of the former failure is orders of magnitude lower than the latter, although both probabilities are small.

The reliability of STPs and signaling links can be expressed in terms of their mean-time-to-failure (MTTF) and mean-time-to-repair (MTTR). In the case of STPs, these parameters can be estimated from outage records. From mid-1976, when the first STPs were cut to service, through 1980, 86 system years of STP service have been accumulated. There have been 14 outages and an accumulated downtime of 590 minutes. These numbers translate to an MTTF of 6.1 years and an MTTR (the average downtime per outage) of 42 minutes. Assuming that STP outages are independent, the probability of simultaneous regional outages can be computed. The probability can be expressed as a mean-time-to-pair-failure (MTTPF) or as an average downtime, D, in an interval of time T. From well-known results of availability theory:

$$\text{MTTPF} = \frac{\mu + 2\lambda}{2\lambda^2}$$

and

$$D = T \left(\frac{\lambda}{\lambda + \mu}\right)^2,$$

where λ and μ are the reciprocals of MTTF and MTTR, respectively, expressed in the appropriate units. Thus, for regional STP pairs, the estimated MTTPF is over 200,000 years and the estimated D is about 5 ms per year. In other words, the probability of a regional STP pair outage is negligibly small and has never yet occurred.

Estimates of MTTF and MTTR for signaling links have been generated from sample studies using PBC data available at STPs. In one representative study conducted in 1980, about 200,000 A-link hours of activity were monitored at ten STPs. For each link, changeover peg counts and out-of-service time were measured on a daily basis. The study showed that link failures are predominately caused by short hits or fades on the VFL. The mean out-of-service time was found to be 1.6 minutes. The mean time between changeovers was found to be about 17 hours. Taking these numbers to be the MTTR and MTTF, respectively, for an A-link, the MTTPF is estimated to be 0.6 year, while the downtime is estimated to be 1.3 minutes per year. Given this probability for pair

failure, the expectation for pair failures in the study data was 0.5 link hour. The observed incidence of unambiguous pair failures (those not related to switching office outages or interrupts) was 0.3 link hour. The agreement is good and indicates that the A-links do indeed behave as a redundant system.

IV. THE SPC NETWORK

The CCIS network performance just described has an increasing impact on the service provided by the SPC network as CCIS deployment expands. The volume and quality of service delivered by the SPC network is measured through a variety of traffic and switching equipment measurements. Their purpose is to provide sufficient information to monitor the rate of successful call completions and to help detect areas where maintenance activity is required.

Recent call completion studies indicate 69 percent of direct distance dialing (DDD) attempts are successfully completed. Major causes of unsuccessful attempts are busy or no-answer conditions encountered at the called customer's phone. These conditions represent 25 percent of DDD attempts. The remaining unsuccessful attempts (6 percent of DDD attempts) are considered to be ineffective attempts (IAS) caused by either the calling customer or the message network. The IAS are comprised of three subcategories that include ineffective traffic attempts (ITAS), ineffective network attempts (INAS), and IMAS. An example of an ITA is an 800 Service call that is blocked because it originates outside the band specified by the customer. An example of an INA is a call that is abandoned by the originator before it reaches the talking state. However, the principal IA component used to measure SPC network performance is the IMA which is described next.

4.1 Ineffective machine attempts

An IMA is defined at a given switching office as an incoming bid for service which is recognized by the switching office but which does not result in a completed call, a busy, or a no answer, as experienced by the customer. An IMA may result from a switching office or interoffice signaling malfunction, a lack of sufficient trunks or other switching resources, or a customer or operator dialing irregularity. The IMAS are classified into several broad categories as shown in Table I.

A summary of the IMA failure rate for each category, expressed as a percentage of total incoming attempts, less false starts, provides a uniform set of switching office performance measurements that are useful in directing management's attention and effort toward items requiring service improvement. The NC category reflects primarily the adequacy of outgoing trunk provisioning, although it is influenced by overload and network management controls and transmission facility

and switching equipment failures. Vacant codes are caused by dialing errors, erroneous or missing translation data at a switching office, or the loss of one or more digits by interoffice signaling. The RO category best reflects the quality of service provided by the toll switching, interoffice signaling, and transmission equipment, since it is relatively insensitive to dialing mistakes which are usually detected by the originating class 5 office. The switching system connects calls failing in this manner to a reorder tone or announcement.

4.1.1 Incoming reorder IMA

Incoming reorders are detected during digit analysis of the received address by the toll switching office and usually result from reception of fewer than the expected number of digits. Typically, interoffice signaling failures resulting from MF pulsing and CCIS are classified as shown in Table II. The DP failures are classified similarly to MF. Certain CCIS irregularities, such as reception of two conflicting initial address messages (IAMs) for the same trunk or an IAM identifying an unequipped trunk, are rejected by sending back a confusion (COF) or unequipped label (UQL) signal, and the call is either reattempted or treated as an outgoing IMA by the preceding office.

Toll offices equipped for centralized automatic message accounting (CAMA) include unique CAMA failures in the incoming reorder IMA. A

Table I—Ineffective machine attempts

IMA Type	Definition
Reorder (RO)	
Incoming	Failure to receive all address digits or to receive notification of successful CCIS continuity check.
Connecting	Switching office fault or insufficient resources.
Outgoing	Failure of interoffice integrity check or signaling.
Vacant code (VC)	Unassigned called number.
No circuit (NC)	All trunks busy to destination.

Table II—Incoming reorder IMA

Conventional RO	Definition
Permanent signal time-out—PST	No key pulse (KP) signal or address digits received.
Partial dial time-out—PDT	Received at least the KP signal, but not the start (ST) or an incomplete set of DP digits.
Pulsing error—PER	Received other than the expected number of digits, or an erroneous or invalid digit.

CCIS RO	Definition
Incomplete address detected—IAD	Received other than the expected number of digits.
Continuity time-out—CTO	Failed to receive the continuity (COT) signal after the IAM.

CAMA office provides billing information for customer-dialed DDD calls from class 5 end offices not equipped with the AMA function. Customers from step-by-step end offices are connected to the CAMA office, after dialing the DDD access digit (1) and then dialing directly into the CAMA office. These dial-pulsing, immediate seizure (DP-IS) trunks can be expected to have a higher reorder rate than MF trunks since the screening that is normally done at the class 5 office is now performed at the CAMA office. The CAMA office must also obtain the calling number identity from the end office, and if automatic number identification (ANI) is not available, a CAMA operator must be connected to obtain the customer's telephone number. Failure to connect an operator or to obtain the calling number are also counted as incoming reorders.

4.1.2 Connecting reorder IMA

Connecting reorders include those failures which are directly attributable to the switching office, either because of an equipment fault or unavailability of a traffic-sensitive resource, such as a call register, network path, or CCIS continuity-check transceiver.

4.1.3 Outgoing reorder IMA

Outgoing reorders result from failure of the interoffice verification checks or from detection of signaling abnormalities associated with the transfer of address digits to the next office. Detection of any of these problems during the first attempt, except for the CCIS address complete (ADC) time-out, results in a reattempt to complete the call on another outgoing trunk. If the reattempt also experiences any of the outgoing problems, the call is then routed to reorder. Table III summarizes the outgoing failure categories.

4.2 Stored Program Controlled Network performance studies

To determine how CCIS compared with conventional signaling performance, separate studies of call failure rates were performed in selected No. 4A ETS and most No. 4 ESS systems. The data from six 4A ETS systems with over 94 million incoming attempts were collected during June 1980. Forty No. 4 ESS systems with over 1.5 billion incoming attempts were studied during January 1981.

The signaling mix of the six No. 4A ETS and the 40 No. 4 ESS systems was virtually identical: 6 percent of the attempts were dial pulse, 64 percent MF, and 30 percent CCIS. A summary showing a comparison of conventional and CCIS reorder, NC, and VC rates is provided in Table IV. The detailed results of these studies are tabulated in Tables V, VI, and VII for incoming, connecting, and outgoing reorder rates.

Table III—Outgoing reorder IMA

Conventional RO	Definition
Integrity check failure—IKF	Failed to receive off-hook in response to seizure of delay-dial trunk.
No-start dial—NSD	Delay-dial signal not removed or wink signal not received.
Unexpected stop—UXS	Received unexpected stop (off-hook) during outpulsing.
Glare—GLR	Steady wink or delay-dial received after outgoing selection of two-way trunk (detected as NSD in No. 4A ETS*).
Expected stop time-out—XST	Expected stop received during DP outpulsing was not removed.

CCIS RO	Definition
Continuity check failure—CKF	Failure of interoffice continuity check of outgoing trunk.
Call failure detected—CFD	Received a BLK†, COF, UQL, or RST‡ signal after outgoing trunk selection.
Address complete time-out—ADC	Failed to receive the ADC signal after sending the COT signal.
Signaling network failure—SNF	Received an MRF§ or UQL signal or no signaling path was available after outgoing trunk selection.
Glare—GLR	Received an IAM at noncontrol office after outgoing selection of a two-way trunk.

* ETS—Electronic translator system.
† BLK (blocking)—Request the far-end office to remove a trunk from service.
‡ RST (reset trunk)—Return the trunk to the idle state.
§ MRF (message refusal)—Signaling network could not locate a signaling path.

Table IV—Study results—failure rates in per cent

System/Signaling Type	Reorder				VC	NC	Total IMA
	Incoming	Connecting	Outgoing	Total			
No. 4A ETS					0.725	0.334	
DP plus MF/EM }	0.482 (MF = 0.356)	0.017	0.061	0.560			1.619
CCIS	0.006	0.067	0.021	0.094			1.153
No. 4 ESS					0.621	0.228	
DP plus MF/EM }	0.612 (MF = 0.334)	0.001	0.046	0.659			1.508
CCIS	0.029	0.001	0.021	0.051			0.900

4.3 Discussion of results

4.3.1 General

A review of the study results in Table IV indicated that the reorder rate for CCIS attempts is substantially less than for traffic using conventional signaling. Consequently, it is clear that CCIS has not jeopardized network completions, but appears to have reduced the IMA caused by switching and transmission irregularities.

Several other observations are also apparent. One is that the No. 4 ESS and No. 4A ETS results are generally consistent, except for the connecting reorder and the CCIS incoming reorder categories. Both of these discrepancies will be discussed in detail later in this article. Some

of the other differences in results are caused by minor differences in some time-out intervals used in the two systems and a more extensive capability in No. 4 ESS to detect certain irregularities. As examples, No. 4A ETS systems generally do not count conventional signaling irregularities if the customer hangs up prior to being connected to an announcement, but the No. 4 ESS does. Also, the No. 4 ESS usually checks that the correct number of digits has been received to route a call to its ultimate destination; whereas, the No. 4A ETS often limits its check to the number of digits required to be translated for outgoing trunk selection, typically three or six digits.

The study results do not permit a true comparison of CCIS and conventional signaling because of differences in the trunking base for each type of signaling. The CCIS data are confined to CCIS intertoll trunks interconnecting No. 4 ESS, No. 4A ETS, and No. 1/1A ESS switching systems, while the MF and DP data include the remaining intertoll trunks and all toll-connecting trunks. Nonetheless, the study results demonstrate the performance of CCIS in a pure intertoll trunk environment.

4.3.2 Incoming reorder

The conventional signaling incoming reorder data shown in Table V for the study offices were heavily influenced by the presence of DP trunking. Although DP trunks initiated only 6 percent of the conventional signaling attempts, they were involved in 26 percent of the No. 4A ETS incoming reorders and 43 percent of the No. 4 ESS incoming reorders. One factor contributing to the DP error rate is CAMA traffic originating from step-by-step end offices. Customers from these offices dial DDD calls directly into the toll office after dialing the "1" access digit. The toll office is now subject to the same dialing irregularities

Table V—Incoming reorder data (percent)

| | Conventional Signaling | | | |
| | No. 4A ETS | | No. 4 ESS | |
Reorders	MF + DP	MF	MF + DP	MF
Permanent signal time-out	0.281	0.218	0.325	0.209
Partial dial time-out	0.118	0.057	0.119	0.020
Pulsing error	0.074	0.081	0.111	0.105
Miscellaneous	0.009	—	0.057	—
	0.482	0.356	0.612	0.334
	CCIS			
Reorders	No. 4A ETS		No. 4 ESS	
Incomplete address detected	0.005		0.026	
Continuity signal time-out	0.001		0.003	
	0.006		0.029	

normally experienced by the class 5 end office. The CAMA toll offices are also sensitive to subscriber loop irregularities, which can appear to the step-by-step office as the DDD access digit 1 and result in false seizures and permanent signal or partial dial time-outs at the toll office. The other significant source of DP traffic originates from class 4 step-by-step toll offices whose performance and maintainability do not match the more modern electromechanical common control and electronic switching systems. In view of the special nature and limited amount of DP traffic, it is appropriate to concentrate further discussion on the relative performance of CCIS and conventional signaling using MF pulsing.

Common-channel interoffice signaling shows an order of magnitude improvement over conventional signaling using MF pulsing with an incoming reorder rate measured at 0.029 percent for No. 4 ESS and 0.006 percent for No. 4A ETS. The CCIS reorder is almost entirely due to the IAD component. An explanation for the improved CCIS reorder performance is offered in the following discussion. Furthermore, a sampling of the CCIS IAD reorders indicates that the address digits for these attempts were incorrectly received from the conventional signaling source by the first CCIS toll office.

The MF incoming reorder data from Table V indicates that 75 percent of such IMAs are permanent signal or partial dial time-outs. Common-channel interoffice signaling eliminates the possibility of similar failures by combining the incoming trunk seizure signal and the called-number address digits in the IAM, which will be retransmitted if an STP or the incoming office detects an error during reception of the IAM. The remaining MF incoming reorders are pulsing errors which include reception of an erroneous, invalid, or an incorrect number of digits. The CCIS error checking and retransmission effectively eliminate the erroneous digit as a problem, while the reception of an invalid digit or other IAM format irregularity causes the incoming office to return a COF signal, which requests the outgoing office to reattempt as described in Section 4.1.1. This leaves reception of an incorrect number of digits, designated as incomplete address detected (IAD) by CCIS and pulsing error (PER) by MF, as the only incoming IMA common to both MF and CCIS.

Conventional signaling is susceptible to loss or mutilation of part or all of the address digit stream because of undetected outpulser and receiver faults and transmission system hits, fades, and noise. Such is not the case with CCIS. To determine the cause of CCIS IAD reorder, a total of 216 outgoing CCIS attempts, which were rejected by a subsequent switching office because of an incomplete address, were monitored at the Norway, Illinois and Toledo, Ohio No. 4A ETS switching offices using the procedures to be described in Section 4.3.3. Over 75

percent of the failures were DDD attempts of the form NPA+NXX+$XXXX$ ($N = 2 - 9, X = 0 - 9$) and were received at the No. 4A ETS with other than the required ten digits. Because of its address screening limitations, the No. 4A ETS routed these attempts over CCIS trunks, usually with the NPA digits deleted, to the next office where they were correctly blocked as IAD. Invariably, the far-end office detecting the IAD was a No. 1 ESS or No. 4 ESS, except when eight digits had been received by the Norway or Toledo office. The apparent inability of a destination No. 4A ETS to detect these IADs occurs because it translates a received six- or eight-digit sequence of the form NXX+$XXXX$ in a dedicated area (NPA) code table and, thus, blocks the attempt as a vacant code instead of an IAD. The remaining failures were a mix of alternate routed INWATS and operator-originated attempts that also arrived at the Norway or Toledo office as an invalid digit sequence. A total of four attempts arrived with the correct number of digits. Two of these were of the form NPA+11XXX and were incorrectly blocked at the destination office because translation data specified a six-digit instead of a five-digit translation for the 11X code.

The higher CCIS reorder rate experienced by the No. 4 ESS during the study results from its superior incomplete address screening capability and the misclassification by No. 4A ETS of certain incomplete address sequences as vacant code instead of IAD. The No. 4 ESS is able to store an acceptable digit count (ADC) value in the routing data block which specifies the characteristics and available trunk subgroups of the selected outgoing route. The ADC specifies the number of digits required to be received from the preceding office if the call is to successfully complete to the selected outgoing route. If only one ADC value is specified, as in the case of a toll completing route to a class 5 end office, the screening is totally effective. However, in the case of an intertoll route selected by a three-digit translation, several ADC values must be specified to accept valid digit sequences such as NPA+1X1, NPA+11XXX, NPA+0/1XX+XXX, and NPA+NXX+$XXXX$. Consequently, address screening effectiveness is compromised, unless six-digit translation is specified to create routing data blocks for each of the ADC values or combinations.

The No. 4A ETS, because of its memory constraints, employs much simpler checks which are generally effective for only the first seven digits. The first three received digits are translated in either an area (NPA) or office code table, depending on the total number of received digits. Three-digit codes of the form 0/1XX are always translated in the office code domain. Thus, when the first digit is N(2-9) and the received digit count is 3, 4, 5, or 7, the attempt is translated in the office code table; otherwise, if the received digit count is 6, 8, 9, 10, or 11, the attempt is translated in the area code table. Unless the three-

digit code is in dual use as both an NPA and office code, it will appear only in the appropriate table. Consequently, an office code sequence containing 6 or 8 to 11 digits is blocked as a vacant code, as are area code sequences containing 3 to 5 or 7 digits. The IAD classification applies only to digit sequences containing insufficient digits for the specified 3-, 4-, 5-, or 6-digit translation and office code sequences containing four or five digits.

Most of the other differences between the MF and CCIS incoming reorder rates occur because the IMA failure rate for conventional incoming attempts tends to be overstated, since it includes an unknown number of noncall-related failures. This inaccuracy results primarily from the PST incoming reorder component of IMA, since the toll office cannot distinguish between a PST time-out caused by a false trunk seizure and an outpulsing failure at the preceding office. As mentioned previously, analog carrier failures are a primary source of false noncall-related PST failures on SF-equipped trunks. Generally, the PDT and PER components of incoming reorder IMA are considered to be call-related failures resulting from signaling or switching faults. However, the PER component may include an unknown number of attempts which arrived from the class 5 end office without being screened for the correct number of digits.

4.3.3 CCIS backward failure signals

Common-channel interoffice signaling includes a set of backward signals which allows a subsequent switching office to report call setup failures back to the originating office so that it may connect the attempt to the proper tone or announcement. Another use of these signals is to alert the originating and intermediate offices to certain IMA so they may record pertinent call data in an analysis file. These data include the received-address digits and incoming- and outgoing-trunk identities associated with an attempt receiving an address incomplete (ADI) or vacant national number (VNN) signal. This process is useful in identifying incorrect translation data or conventional signaling irregularities which cause such IMAs and it was used to collect the sample IAD IMA data at the Norway and Toledo offices.

Other backward signals provide notification of attempts blocked by NC, switching congestion, and switching equipment failures. These signals may optionally be recorded to determine the source of these blockages.

4.3.4 Connecting reorder

Table VI shows connecting reorder results for both conventional signaling and CCIS. The No. 4 ESS data show almost no connecting reorder for either conventional signaling or CCIS. This is due largely to

Table VI—Connecting reorder data (percent)

Conventional Signaling		
Reorders	No. 4A ETS	No. 4 ESS
Switching equipment failure	0.013	0
No network path	0.004	0
Queue time-outs	—	0.001
	0.017	0.001

CCIS		
Reorders	No. 4A ETS	No. 4 ESS
Switching equipment failure	0.033	0
No network path	0.004	0
No call register/no outpulser	0.030	0
No transceiver, etc.	0	0.001
	0.067	0.001

the superior reliability of the No. 4 ESS hardware over the No. 4A ETS electromechanical circuits and the fact that No. 4 ESS has an essentially nonblocking network.

4.3.5 Outgoing reorder

Table VII shows outgoing reorder study results. Outgoing reorder is roughly an order of magnitude lower than incoming reorder for conventional signaling, and no disproportionate contribution was noted for DP signaling. The primary reason is that outgoing attempts encountering a failure are permitted a single reattempt. The No. 4A ETS data show a conventional signaling first attempt outgoing failure rate of 0.299 percent, or roughly the same order of magnitude as incoming attempts that fail at 0.356 percent. However, the second outgoing trial results in a final failure rate of only 0.061 percent, confirming that 80 percent of the second attempts did not experience an outgoing failure. This does not necessarily imply that all reattempts were successful since the reattempt may have encountered NC or may have been abandoned. Other factors are that most of the defensive checks in both No. 4A ETS and No. 4 ESS are on the incoming side; outpulsing failures may only be detected as incoming failures in the next office and that outgoing reorder is "controllable" in the sense that an outgoing office can identify and remove a suspect outgoing trunk or outpulser from service, until it is repaired more easily than the incoming office.

The CCIS outgoing reorder rate shows a relatively modest improvement over conventional signaling in No. 4A ETS. In No. 4 ESS, an improved CCIS glare treatment strategy allowed a similar modest improvement of CCIS over conventional signaling. The principal reason only small improvements were seen is that both conventional signaling and CCIS systems reattempt calls that fail. As mentioned earlier, the second attempt dramatically lowers the call failure rates for both signaling types, leaving CCIS less room for improvement.

Table VII—Outgoing reorder data (percent)

Conventional Signaling

Reorders	No. 4A ETS	No. 4 ESS
Integrity check failure	N/A	0.014
No-start dial	N/A	0.020
Unexpected stop	N/A	0.004
Glare*	—	0.006
Expected stop time-out and other	N/A	0.002
	0.061**	0.046

CCIS

Reorders	No. 4A ETS	No. 4 ESS
Continuity check failure	0.012	0.004
Call failure detected	0.006	0.002
Address complete time-out	0.002	0.006
Signaling network failure	0	0.003
Glare	0.001	0.006
	0.021	0.021

* No. 4A ETS does not detect glare on two-way trunks, but classified this problem as no-start dial.

** Outgoing second-attempt failure detail is not available for the No. 4A ETS; however, total conventional outgoing reorder is provided.

4.3.6 Glare

Heavy calling rates on two-way trunk subgroups will normally result in some level rate of glare on second trials. Common-channel interoffice signaling takes three to five times longer to accomplish a seizure than conventional signaling because of the need to transmit IAMs through the signaling network. Consequently, CCIS has a longer unguarded interval and is more susceptible to glare. (Despite this longer unguarded interval, CCIS still provides faster end-to-end address signal transmission than conventional signaling.) Trunk hunting and reattempt strategies mitigate the impact of this difference. The higher CCIS glare rate originally observed for No. 4 ESS was strongly affected by results from one study office.[4] After the original study data were collected, the No. 4 ESS retrial strategy was changed so calls encountering glare were retried in a different trunk subgroup. This strategy was based on the assumption that the second trial would be performed in a trunk subgroup that was more idle than the first, reducing the chances of encountering glare on the second trial. The new strategy reduced glare reorder from 1500 to only 100 occurrences per day in the No. 4 ESS most strongly affected during the original study, and the results presented in this article confirm that the modified strategy has been completely effective in reducing the rate of CCIS glare to a rate equivalent to conventional glare.

4.3.7 Common-channel interoffice signaling stable-call reset

The CCIS switching offices disconnect some small percentage of calls by means of CCIS RST signals because of certain internal switching

problems or time-outs. Calls disconnected by RST signals are counted as CCIS stable-call resets in automatic system performance measurements. Stable-call resets should be included when comparing CCIS with conventional signaling, despite the fact that many stable-call resets are not signaling problems, but switching office problems.

Examples of some of the causes of stable-call resets include:

(*i*) Switching office equipment failures in which transient calls and stable calls are cleared in the process of initializing system memory associated with failed trunks.

(*ii*) Situations detected by audits in which a switching office detects two CCIS trunks connected, but with inconsistent trunk states.

Unfortunately, the stable-call reset count does not give a very precise indication of CCIS performance because nonsignaling components dominate the count. Also, since a CCIS stable-call reset may propagate through several offices, combined measurements from several offices tend to overstate the incidence of this type of call failure since each reset may be counted in several offices.

Table VIII gives the rate of stable-call resets. Although the resets may occur on either a CCIS incoming or outgoing attempt, the reset rates shown in Table VIII are expressed only in terms of incoming CCIS attempts to more closely correspond to other IMA failure rates.

V. CONCLUSION

We have explained how IMA data are used to measure switching performance and have demonstrated, through data on 1.6 billion calls collected from 46 study offices, that the SPC network signaling performance for CCIS shows an improvement over conventional signaling. Common-channel interoffice signaling eliminates the possibility of permanent signals or partial dial time-outs by combining seizure and address information in the CCIS initial address message, which can be retransmitted if an error is detected. Common-channel interoffice signaling error checking and retransmission capabilities protect the signaling system from loss of information caused by hits, fades, and noise in the transmission media. These capabilities permit successful switching of 99.95 percent of all CCIS attempts. The largest component of the failures represents incomplete screening at the preceding offices rather than CCIS problems. These capabilities permit CCIS to complete calls that would be lost with conventional signaling and greatly reduce

Table VIII—CCIS call resets
(percent)

No. 4 ESS	0.013
No. 4A ETS	0.014
Composite	0.013

the incidence of IMA reports caused by phenomena not related to calls. These are the main reasons that IMA performance for CCIS is better than conventional signaling.

Common-channel interoffice signaling provides the capability for reporting problems to all affected offices through backward failure signals. The combination of a lower number of ineffective attempts and these failure signals allows a more efficient analysis effort.

Concentrating signaling information onto the CCIS network required the network to be highly reliable. The high degree of availability is assured by duplication of signaling links and STPs and automatic response to signaling network failures. Ongoing performance monitoring demonstrates that high reliability has been achieved.

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Stored Program Controlled Network:

Calling Card Service—Overall Description and Operational Characteristics

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Conventionally, operator assistance is required for most nonsent paid telephone calls (calls that are billed to a number other than the calling number). Examples of these calls include collect, credit card, and bill-to-third-number. These three types of calls currently represent about two-thirds of all operator-handled toll calls. To reduce the need for operator assistance, a new service, Calling Card Service, enables customers to make credit card calls by dialing in the billing information without the assistance of an operator; it also provides an alternative to operator-assisted collect and bill-to-third-number calls. This new capability is made possible through changes in the Traffic Service Position System (TSPS) No. 1, and uses the Stored Program Controlled (SPC) Network. By providing customers with an alternative to operator assistance, Calling Card Service is helping the Bell Operating Companies (BOCs) and independent telephone companies stabilize operator work force requirements. This paper gives a basic description of Calling Card Service and the customer interface. It also describes the implementation in TSPS, and other areas of the SPC network, and discusses some of the effects on telephone company operations.

I. INTRODUCTION

Telephone customers in the United States today may choose from a number of billing options. In addition to sent paid calls (calls for which the calling number is billed), several nonsent paid alternatives

exist. These include collect, credit card, and bill-to-third-number calls. Each of these billing operations requires operator assistance.

The widespread and efficient provision of these billing options has been made possible by the extensive use in the Bell System of the Traffic Service Position System (TSPS),[1,2] a stored program system first introduced for service in 1969 and now providing service to over 90 percent of the Bell System lines and to almost 6 million independent telephone company lines. In the last decade, the volume of calls requesting these three types of alternate billing has continued to increase. On an average business day, operators handle over 4 million such messages in the Bell System. Requests for these services are expected to continue to grow.

Concern about the growing expense of handling these types of calls and the market need to provide customers with an alternative to operator assistance led AT&T to press for the rapid development and widespread introduction of Calling Card Service.[3,4,5,6] This service permits a customer with a calling card (telephone credit card) to dial calls, including billing information, entirely without operator assistance. Calling Card Service capability will be available at stations using dual-tone multifrequency (DTMF) signaling. (This type of signaling is marketed in the Bell System as *Touch-Tone** service.) In addition to substantially reducing operator-assisted credit card calls, Calling Card Service provides an alternative to collect and bill-to-third-number calling. The development of Calling Card Service has been one of the major undertakings of the Bell System and the independent telephone industries.

Calling Card Service has been made possible through new capabilities of the Stored Program Controlled (SPC) Network.[7] This paper is the first of a series, in this issue of *The Bell System Technical Journal*, that discusses Calling Card Service and describes how key elements of the SPC network, such as TSPS and common-channel interoffice signaling (CCIS),[8] are being modified to provide the new service. This paper gives a general description of the service and discusses its operational characteristics. Implementation and plans for service introduction are also described. Subsequent papers in this issue consider the human factors and market aspects of the service and some of the more complex aspects of the implementation.

II. CREDIT CARD, COLLECT, AND BILL-TO-THIRD-NUMBER SERVICE PRIOR TO CALLING CARD SERVICE

Since its introduction, TSPS has provided an efficient method for handling credit card, collect, and bill-to-third-number calls. By allowing customers to dial these types of calls, TSPS provides faster service.

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* Registered service mark of AT&T.

To assist the operator in processing these calls, all administrative functions such as call timing, call supervision, and recording of the billing information are automatically handled by TSPS. Thus, with TSPS, the operator's interaction with the customer is more efficient and accurate and the operator is relieved of most of the routine manual operations required with cord boards.

In a typical TSPS, nearly two-thirds of all calls handled by operators are credit card, collect, or bill-to-third-number calls. Prior to Calling Card Service, the operator was required

(i) to determine the number to be billed for the call,

(ii) to enter it into the system (except on collect calls), and

(iii) to ensure acceptance of the charges.

To illustrate how these functions are handled by an operator at a TSPS, the following describes the processing of these types of calls.

To place a credit card, collect, or bill-to-third-number call, the customer typically dials 0, plus the called customer's telephone number. The local office receives the digits and determines from the 0 prefix that the call is to be routed to a TSPS. The local office then forwards the called telephone number, followed by the calling telephone number, over a trunk to the associated TSPS. The TSPS uses this information to connect the call to an operator position. While the operator is responding to the call, the called number is forwarded to the toll office (see Fig. 1).

When the call arrives at the position, the appropriate keys and lamps are lighted to indicate to the operator what type of call the customer dialed. The operator is then ready to help the customer.

If the customer wishes to make a credit card call, the card number
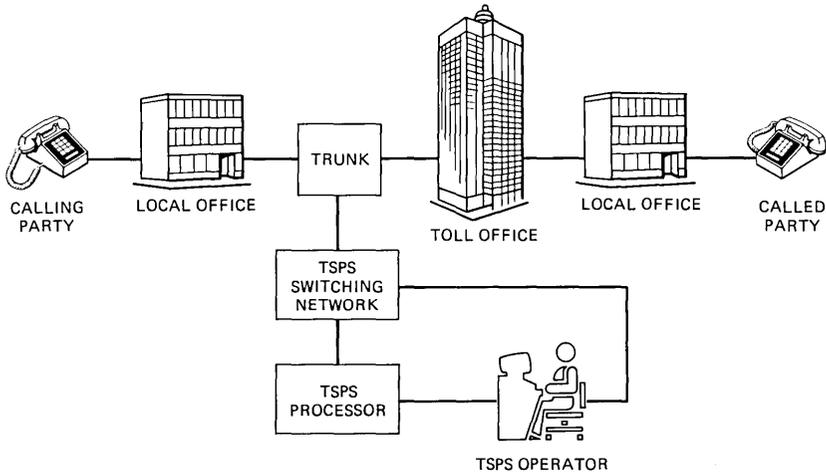
Fig. 1—Basic TSPS No. 1.

is given to the operator, who depresses a key to inform the system that this is a special billing call and enters the credit card number into the system. The system performs validity checks on the number entered by the operator, and if the card number is valid, the operator prepares the system for automatic billing of the call by indicating the type of billing requested and initiating the automatic timing of the call. The operator then allows the call to proceed. While this is taking place, the call is forwarded through the toll network. If the credit card number is invalid, the operator stops the progress of the call and asks the customer to make other billing arrangements.

If the customer desires to place a collect call, the operator indicates to TSPS that the call is to be billed to the number being called. When the called station answers, the operator obtains acceptance of the charges, initiates the timing of the call, and allows the call to proceed.

For bill-to-third-number calls, the customer gives the billing number to the operator, who informs the system that this is a special billing call and keys the third number into the system. The operator then contacts someone at the number being billed to obtain acceptance of the charges. If the charge is accepted, the operator indicates the appropriate type of billing, initiates the timing of the call, and allows the call to proceed.

III. CALLING CARD SERVICE OVERVIEW

Calling Card Service is based on the use of the calling card number, which is composed of a billing number and the customer's personal identification number (PIN). This number is assigned to a subscribing customer and is used to validate that a particular call can be billed to the associated billing number. The billing number usually corresponds to the customer's telephone number. However, in certain cases, a number that is not associated with an actual telephone number is assigned for special billing purposes; these numbers are often used for businesses.

With Calling Card Service, the customer has a number of options available for providing the billing information to TSPS. If the telephone is capable of DTMF signaling to a TSPS, the customer may directly dial the billing number for calling card calls without operator assistance. This is referred to as customer-dialed Calling Card Service.

A caller who has made a call and dialed the billing information may wish to place another call and bill it to the same calling card number. This may occur at the conclusion of a call or upon receiving a busy signal or no answer from a call. This new capability has been designed so that the customer does not need to reenter the billing information but may just signal TSPS that another call is to be billed to that same number. This is done by depressing the DTMF pushbutton with the

number sign (#) on it and then dialing the new call. This capability is referred to as sequence calling. There is no limit to the number of calls that may be dialed sequentially, but a request for a sequence call must be made within an appropriate interval following a call.

In those cases where the customer has dialed the called number but chooses not to dial the billing information, the billing information may be given orally to the operator. The customer can reach the operator by dialing 0, "flashing" (momentarily depressing) the switchhook, or waiting a few seconds. In addition, if the telephone is not equipped to send a DTMF signal to TSPS, the customer will be connected immediately to an operator. This is similar to the current credit card service and is referred to as operator-assisted Calling Card Service.

IV. COMPONENTS OF CALLING CARD SERVICE

Many changes were made to the existing switching network and supporting systems to accommodate Calling Card Service. These changes were particularly significant in TSPS. Further detail is provided later in this paper. In addition, a variety of new components and features are being introduced to provide the service. These include:

- Originating station treatment (OST)—A feature to determine when the originating station can be given the capability for customer-dialed Calling Card Service.
- Billing validation application (BVA)[9] and Data Base Administration System (DBAS)[10]—Two SPC components: the BVA is a processor-controlled data base that contains information about the calling and billing numbers and the DBAS is an associated administration system.
- Inward validation—An SPC capability that allows non-TSPS operators from both Bell System and non-Bell System companies to validate billing data through TSPS.
- Billed number screening (BNS)—An additional SPC network feature that enables the TSPS operator to determine if the collect or bill-to-third-number request is allowed for the particular billing number. The BNS data are stored in a BVA.

4.1 Originating station treatment

The OST determines the type of treatment to be given the calling station after a customer has dialed a 0+ call. The need for OST is based on the results of a human factors trial of this service described in a later paper in this issue.[6]

Basically, three treatments are provided:

(i) A prompting tone followed by a prompt announcement
(ii) A prompting tone only

(iii) Operator-assisted service (essentially the same service as before Calling Card Service).

The distinctive prompting tone indicates to the customer that the billing information may now be entered. The announcement provides an additional prompt for those not familiar with the service.

The first treatment, tone followed by announcement, is now being deployed for public and semipublic stations that have DTMF signaling capability. The second treatment, tone only, is now being deployed with most other DTMF phones. The third treatment, operator assistance, is provided for rotary-dial telephones. Provision has been made to allow changes in the above for cases where the recommended treatment is inappropriate.

4.2 Billing validation application and Data Base Administration System

The BVA is accessed by TSPS using a form of signaling called common-channel interoffice signaling/direct signaling (CCIS/DS). This signaling builds on the already available capability of the existing CCIS network.

The information in the BVA is used

(i) to determine the OST for the originating line so that the appropriate treatment can be given to the calling customer,

(ii) to provide security by validating the billing number and PIN combination provided by the customer, and

(iii) to alert the operators on collect and bill-to-third-number calls if the billing requested is not allowed for that particular billing number.

The computer-based DBAS, which currently administers the Automatic Intercept System[11] has been enhanced to administer the BVA. From the telephone company's viewpoint, the information in the BVA is stored primarily in an on-line data base at the DBAS.

In addition to initial data base loading and updating, the DBAS provides other base support functions. These include:
- Screening input data for possible errors
- Providing backup and recovery if a failure occurs at the BVA
- Providing user access restrictions for security
- Auditing the BVA for inconsistencies
- Transferring data from one BVA to another to balance the load over the SPC network
- Collecting measurements from the BVA
- Generating summary reports.

The interconnection of the various components of Calling Card Service is shown in Fig. 2.

4.3 Inward validation

Since most non-TSPS operators (for example, mobile, marine, and international operators) are unable to access the data base (the BVA),
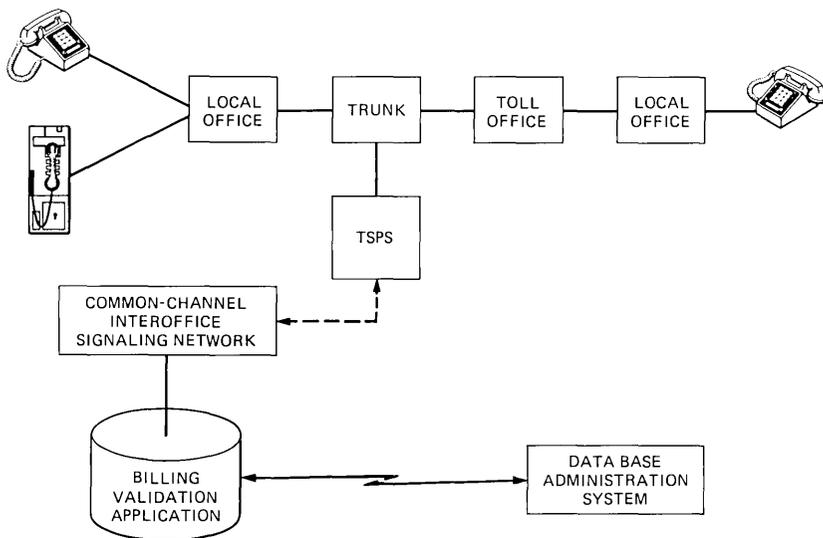
Fig. 2—Calling Card Service components.

other arrangements have been provided. The TSPS is capable of processing operator-requested calling card validations automatically if the operator has a DTMF or multifrequency key set. If not, the validation can be handled by TSPS on an operator-assisted basis.

In the case of operator-assisted validation, the non-TSPS operator quotes the calling card number to the TSPS operator. The TSPS operator keys in the information and a data base check is made. The TSPS operator is then given a display describing the results of the query, and this information is quoted to the non-TSPS operator.

In the case of automated validation, TSPS is reached by special codes that indicate either DTMF or multifrequency signaling. The non-TSPS operator receives a tone when the TSPS is ready to receive the billing information. The operator then dials the information, a data base query is made, and results announced automatically to the operator. No TSPS operator is required in this process. If a dialing error was made, the operator can redial the information.

4.4 Billed number screening

Another SPC feature, called billed number screening (BNS), is being added to TSPS along with Calling Card Service. The BNS feature applies to collect and bill-to-third-number calls placed through a TSPS operator. With this capability, the TSPS will perform a data base check whenever a customer attempts to place a collect or bill-to-third-number call. The data base query will be used to determine if the type of billing requested is allowed for the particular billing number. If the

requested form is not allowed, the operator will be alerted so that the customer can be asked to bill the call in an alternate manner.

The BNS feature is expected to save operator work time and eliminate network time spent processing calls for which third-number and collect calls are not allowed; it is also expected to reduce fraud.

The BNS feature will be automatically invoked by TSPS whenever an operator attempts to complete a collect or a bill-to-third-number call for a customer. After its activation, BNS will function as follows: On a collect call, the TSPS launches a data base query as soon as the called number is known and it has been determined to be a collect call. In most cases, the operator will be notified by a display that the call is allowed, and TSPS then completes the call. Upon answer, the operator announces the call and determines whether the customer will accept the call.

The BNS feature provides for two cases of denial for collect calls. In the first case, the operator is informed that collect calls are denied and requests alternate billing information from the calling party. The operator is also informed in the case where the called number is a public or semipublic telephone. Collect is not a valid billing alternative for these calls; therefore, the operator will attempt to obtain proper billing information.

For bill-to-third-number calls, the operator is either instructed that this form of billing is allowed or denied. For example, bill-to-third-number calls are denied when an attempt is made to bill to a public or semipublic telephone. When this type of billing is denied, the operator announces that different billing must be used and helps the customer with an alternate form.

V. CUSTOMER USE OF CALLING CARD SERVICE

The basic flow of a call placed through Calling Card Service is depicted in Fig. 3. To place a calling card call, the customer dials 0 plus the called number. The TSPS then determines whether the station should receive the treatment for customer-dialed service by launching an OST query to the BVA via CCIS/DS. Depending on the outcome of this data base check, the customer is either prompted to dial the calling card number, or an operator is connected to obtain the billing information. After TSPS has received the calling card number, a second data base query is made to check that the billing number is authorized for this service and that the PIN is correct for that billing number. The TSPS processing of the call is suspended until the results of the query are obtained. Based on a successful response, the call is then processed in normal fashion. The sections that follow explain the details of the various types of calling card calls:

- Customer-dialed
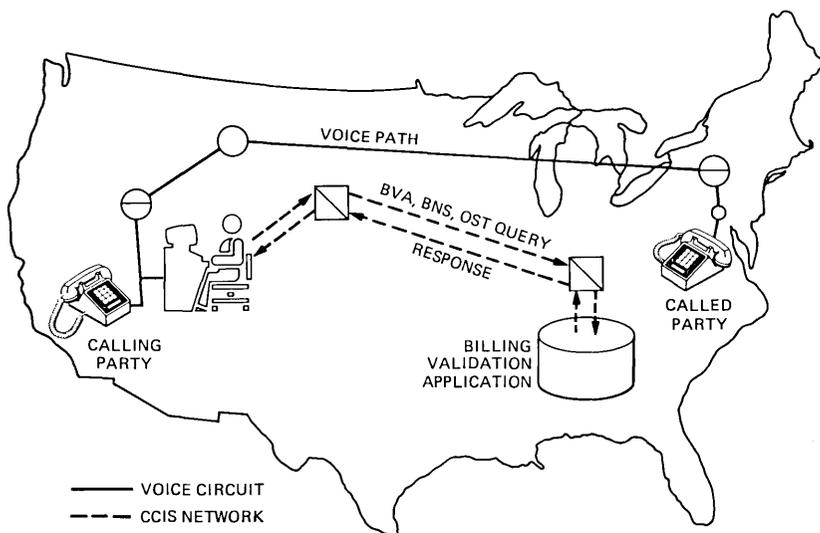
Fig. 3—Calling Card Service with CCIS direct signaling.

- Customer-dialed sequence
- Operated-assisted.

5.1 Customer-dialed Calling Card Service

A customer initiates a customer-dialed calling card call by dialing 0 plus the called number, just as is done today for a credit card, collect, or bill-to-third-number call. If the telephone is served by a TSPS equipped for this service, the TSPS will initiate an OST check to determine the proper station treatment for the call. If the results indicate that the line is equipped to provide customer-dialed Calling Card Service, TSPS prompts the customer with the proper treatment. In the case of public or semipublic telephones, a distinctive tone, which may be followed by an optional announcement, is used to provide the prompt. The announcement given by TSPS is

"Please dial your card number or zero for an operator now."

For most other telephones where the service can be provided, only the tone is given. As noted earlier, should the customer not wish to dial a card number, an operator can still be reached by flashing the switch-hook, dialing 0, or waiting a few seconds. If the OST check indicates that the telephone is not capable of customer-dialed Calling Card Service, the call is handled in the conventional manner.

The customer may begin dialing the 14-digit calling card number

following the prompt. If the customer begins to dial before the announcement starts, the announcement will not be given. This will allow customers familiar with the service to dial as soon as they hear the tone. If the announcement has started, it will be truncated as soon as the customer initiates dialing. The number sign (#) pushbutton may be depressed at the end of dialing to indicate that the customer has completed dialing the call.

After receiving the dialed billing information, TSPS will check its validity. If the billing information is valid, TSPS provides a "Thank You" announcement to the customer and proceeds to complete the call. If the information dialed is incorrect or the customers exceeds the timing threshold between digits, the following announcement is given:

"Please dial your card number again now. (Pause) The card number you have dialed is invalid."

If no dialing occurs within 3 seconds following this announcement, an alerting tone is given, followed by a prompt announcement. The customer has 5 seconds to begin dialing. If dialing is not started, a terminating announcement is given requesting that the customer reoriginate the call.

If a customer has twice dialed an invalid calling card number, the following announcement is provided:

"Please hang up and dial zero plus the number you are calling. (Pause) The card number you have dialed is not valid."

At this point, the customer must reoriginate the call.

5.2 Customer-dialed sequence call

The customer-dialed sequence calling feature allows a customer who has dialed a valid calling card call to originate additional calls to be billed to the same calling card number without redialing the billing information. The customer indicates the desire for a sequence call to TSPS by depressing the # pushbutton prior to dialing the new number.

A sequence call can be made at the conclusion of a call or upon receiving a busy signal or no answer from a call. To place a sequence call following a completed call, the calling party must wait until the called party hangs up. The # pushbutton must then be depressed. If there is a busy signal or no answer, another call can be attempted at this point by depressing the # pushbutton.

After the TSPS recognizes a sequence call attempt, the customer receives this announcement:

"You may dial another number now."

The customer can then dial the new called number, and if valid, TSPS replies with a "Thank You" announcement. If the number is invalid, the customer is requested to hang up and reoriginate the call. Any number of successful sequence calls can be made and charged to the calling card number.

5.3 Operator-assisted Calling Card Service

For customers dialing from rotary dial stations or for those who are unsure of how the service works, operator assistance is available to place calling card calls. Essentially, this service functions much like the current credit card service. The customer dials 0, plus the called number. If this telephone is not to be given the station treatment for customer-dialed Calling Card Service, the customer will be connected immediately to an operator. If the station is given the customer-dialed Calling Card Service treatment, the customer must either flash the switchhook, dial 0, or wait a few seconds for the operator. The customer then quotes the number to the operator, who enters it into the system. The TSPS performs a check on the number and allows the call to proceed if valid. If the number information is rejected as invalid, the operator informs the customers and requests new billing information. The operator is given an indication on those calls in which the OST check indicates that customer-dialed service was available. This permits the operator to provide dialing instructions to the customer.

Other types of calls can be billed to the calling card number. For example, a customer may dial a 1+ toll call from a coin station and, upon receiving the charge, wish to bill the call to a calling card number. The customer can reach the operator by either timing out or flashing the switchhook; the operator then keys in the new billing data. Operators will continue to handle noncalling card calls in the same manner as they do today.

VI. IMPLEMENTATION OF CALLING CARD SERVICE

The implementation of Calling Card Service requires changes to many parts of the switching network and supporting systems. Many new TSPS capabilities had to be instituted, including:
- Reception of DTMF and multifrequency signals
- New call types and announcements
- Signaling to the data base
- Provision of an interim OST data base
- Modified coin signaling to allow DTMF signaling.

In addition, local office and coin station changes are required to allow DTMF signaling to TSPS.

Calling Card Service also requires the deployment of the BVA data bases in the CCIS network. The DBAS was modified to provide telephone

companies with the ability to create and modify new distributed data bases, the BVAs, as well as the interim data bases at the TSPS. Modifications are also required in the customer record information and service order processing systems of the telephone companies to provide the data for initially loading and subsequently updating the information in a form suitable for DBAS.

6.1 Traffic Service Position System implementation

The TSPS software and hardware changes required to provide Calling Card Service and BNS build on capabilities previously provided in TSPS. One of the major building blocks is the Station Signaling and Announcement Subsystem (SSAS)[12] used to provide Automated Coin Toll Service.

6.1.1 Dual-tone multifrequency signal detection and announcement capability

The SSAS was previously added to TSPS to provide the capability to prompt coin customers with announcements and to record coin deposits. This system uses a programmable controller to control the coin detection and announcement circuits and the announcement store, which stores the announcement phrases.

To provide Calling Card Service, the SSAS was extensively modified. Additional speech phrases were added for the Calling Card Service announcements. The SSAS capability to detect both DTMF and multifrequency signals was also developed. These modifications required major changes to microcode in the programmable controller to provide the new capabilities and to maintain the new hardware.

6.1.2 Common-channel interoffice signaling/direct signaling

The CCIS/DS feature was introduced to query the data base for OST, calling card number validation, and BNS checks. Hardware and software developed for the No. 4A toll crossbar application of CCIS and adapted for the TSPS CCIS/DS environment were used in the design of CCIS/DS.[13]

6.1.3 Interim data base for originating station treatment

Within TSPS, a limited interim data base for OST data was provided, thereby allowing telephone companies to offer Calling Card Service before the BVA was fully deployed. With this data base, telephone companies could provide an appropriate OST treatment to all public and a limited number of nonpublic stations.

6.1.4 Other changes

Several other changes were also introduced in TSPS for Calling Card

Service. As described in detail in Section 6.4, changes were required to allow the DTMF dial at coin stations to be activated when a customer enters the billing information. To achieve this, a new signaling arrangement between TSPS and certain local offices, known as expanded inband signaling, was introduced.

Major changes in the TSPS operational and maintenance software were also required to provide Calling Card Service. For example, software was needed to handle the new automated service and provide operator assistance if needed. A complete description of these changes is presented in Ref. 14.

6.2 Data bases

The BVA data bases were designed to store customer- and station-related information and are located at signal transfer point nodes on the SPC network.[15] These distributed data bases contain information about the calling and billing numbers and are accessible to TSPS by means of CCIS/DS during the processing of calls.

The routing of messages between a TSPS and BVA is done by the CCIS network. The CCIS signal transfer points contain information required to ensure that query messages launched by TSPS are routed to the proper BVA and that reply messages are routed to the TSPS that sent the query.

The SPC network is arranged to allow this nationwide distributed data base to be evolutionary in nature. As use of Calling Card Service increases, new BVAS can be introduced in the network and data can readily be moved from one location to another to balance the load over the network.

6.3 Data base administration

Since BVAS contain customer- and station-related information, which changes frequently with customer movement, a high volume of updates is expected. Moreover, as the service attracts new customers, these data bases are expected to expand. For these reasons, a mechanized means of keeping these data bases current is essential. The support system that provides mechanized administration of the BVA is the DBAS.

The computer-based DBAS provides a secure interface between the telephone company service order systems and the BVAS (see Fig. 4). The DBAS is connected to each BVA that it administers by a pair of data links (primary and standby). Although a DBAS can administer up to four BVAS, each BVA is administered by only one DBAS for data integrity purposes.

The DBAS receives initial load data via magnetic tapes from telephone company customer-record information systems. Update data
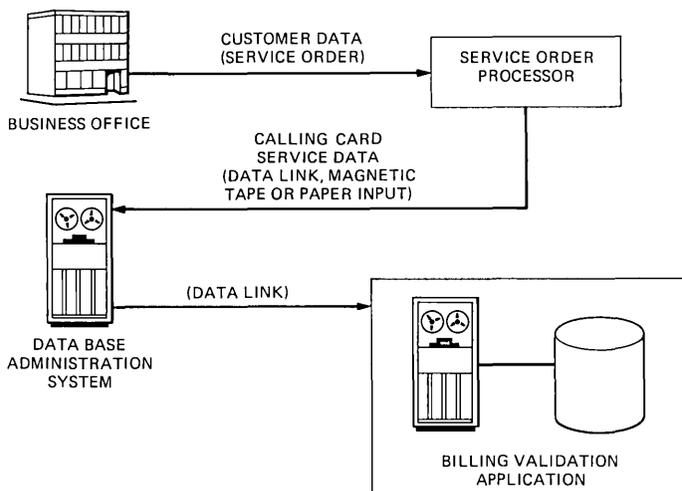
Fig. 4—Data Base Administration System.

are received from telephone company service order systems via data link, magnetic tape, or direct input from a terminal. The DBAS checks input data for logic and syntax errors prior to updating its own data base. Normally, updates are batched and transmitted to the BVA at a specified time of the day via data link. However, critical updates can be sent immediately if required.

6.4 Coin station enablement

Prior to the introduction of automated coin toll service,[12] it was necessary for local offices to disable the DTMF signaling dial on coin stations before a call was connected to TSPS. This was to prevent fraud, and was true for both dial-tone-first and coin-first coin lines. With Calling Card Service, the coin station dial must be enabled for the customer to enter the billing information.

The implementation of this capability requires substantial effort not only in TSPS but also in local offices and the public station area. Where economical, changes are provided in the local offices to implement this capability for all coin stations served by that office. Otherwise, per-station changes are required. In the case of local office changes, two methods of enablement are available: multiwink signaling and expanded inband signaling.

6.4.1 Multiwink

Multiwink signaling is currently available for use by many electro-mechanical and some ESS local offices to perform coin signaling with

TSPS. A series of one to five short-duration on-hook winks are used by the TSPS to signal the local office.

For a dial-tone-first call, the local office disables the DTMF signaling dial on the coin station immediately before making the connection to TSPS. If TSPS determines that this is a 0+ call and that the customer can dial a calling card number, TSPS sends a signal to the local office, which enables the dial. If the customer is subsequently connected to an operator, another signal is sent to notify the local office to disable the dial and allow coin signals to be transmitted.

In the case of coin-first stations, the dial is disabled as soon as the initial deposit is collected or returned. Before the introduction of Calling Card Service, the local office returned the coins prior to connecting the call to TSPS. To enable the dial, a limited form of coin retention has been developed. On calls connected to TSPS, the function of coin return has been moved to TSPS. On 0+ coin calls, TSPS retains the initial deposit until it is determined whether this is to be a customer-dialed Calling Card Service call. If it is, the deposit is retained until the end of the call, thus enabling the dial. If it is not, the initial deposit is returned before an operator is connected. In some electro-mechanical offices, coin retention will require minor hardware changes.

6.4.2 Expanded inband signaling

Prior to the need for DTMF signaling dial enablement, inband signaling has been used between TSPS and many types of ESS local offices. This form of signaling employs on-hook winks from TSPS to alert the local office that multifrequency tones will be transmitted. With inband signaling, three combinations of multifrequency tones are used to perform normal coin signaling (such as coin collect or coin return). Expanded inband signaling (EIS) provides three additional signals to provide DTMF signaling dial enablement. In addition, certain timing changes are incorporated in the signaling arrangement for enhanced reliability.

With EIS, the local office now enables the dial for calls dialed 0− or 0+; no EIS signal is required to perform this function. However, as soon as the call goes to an operator, TSPS must send one of the new signals to disable the dial and allow coin signals to be transmitted. A second signal is sent as soon as the operator disconnects so that the dial is again enabled. Enablement of coin-first coin stations with EIS uses coin retention in the same manner as multiwink signaling.

The implementation of EIS requires hardware and software changes in TSPS. Software changes are required for EIS in all ESS offices; in some cases, trunk designs must be modified. The activation of EIS requires a coordinated retrofit procedure between TSPS and the local office.

6.4.3 Coin station change

In some cases, it is not economical or practical to make local office changes for dial enablement, especially in areas where there are few coin stations. Three alternative methods are available for these cases: a complete new coin station with a new totalizer can be used, a new totalizer can be added to the existing set, or a newly designed polarity guard kit can be added to the station. These modifications make the station insensitive to battery polarity and, thus, allow the dial to be enabled at all times.

These station change techniques are applicable to only dial-tone-first coin lines; no station change procedures are available for coin-first lines.

VII. SERVICE INTRODUCTION

The introduction of Calling Card Service is affecting many areas of telephone company business, and a large coordinated effort is being applied to implement it throughout the industry. Because of the magnitude of such an undertaking, the service is being implemented in phases.

The initial phase began in July 1980. During this phase, BVAs were not deployed to provide billing validation and OST capabilities. Instead, TSPS performed internal validation checks in place of BVA queries.

In addition, since the OST capability (which relates to the customer's capability to dial the billing information) is essential to providing this service in an acceptable manner, an interim OST feature was provided in TSPS for use prior to BVA availability. The interim OST feature determined which public stations were equipped with DTMF signaling so that these stations could be given tone and announcement treatment. It also allowed a specified treatment (tone, tone and announcement, operator assistance) to be given to selected nonpublic stations. All rotary-dial public stations and other nonpublic stations for which tone or tone and announcement treatments were not specified received operator-assisted treatment.

The interim OST data were loaded and updated in TSPS by standard input messages. The DBAS administered and transmitted the data in the proper format to the TSPS administration center for subsequent input into TSPS.

Through the use of this interim OST feature, Calling Card Service was selectively introduced prior to BVA deployment. During this introductory phase, customers who were at public and selected nonpublic stations equipped with DTMF signaling could dial their billing information without operator assistance. The remaining customers gave their billing information to the operator, as with conventional credit card service.

Subsequently, the BVAs are being deployed nationwide, and Calling Card Service is being introduced into all TSPSs. Customer-dialed service can be extended to customers at all nonpublic and public stations equipped with DTMF signaling. As the service capability is introduced to TSPS offices, they will launch billing validation and OST queries to BVAs in lieu of local processing.

Billed number screening is being introduced for public telephones. The TSPSs in which the feature has been introduced will launch BNS queries to BVAs prior to the completion of collect and bill-to-third-number calls to ensure that the billing number is not a public telephone.

VIII. SYSTEM BENEFITS

The introduction of Calling Card Service benefits both the customer and telephone companies. For example, the service reduces operator involvement on calls, improves service, and increases customer billing protection.

Moreover, Calling Card Service calls for significant effort on the part of telephone companies and the Long Lines Division at AT&T to accommodate the modifications and additions to the network that it requires (refer to Section VI). Although these changes in the network are significant, the benefits of Calling Card Service are substantial and lie largely in the following areas:

(i) Decreased operating expenses resulting from the reduced need for operator services as customers more frequently dial their own billing numbers.

(ii) Reduced losses because of fraudulent calling and customer or operator error with billing information.

Economic analysis has shown that the reduction in operating expenses resulting from the use of Calling Card Service is particularly significant. This results from the rapidly rising operating expense and the high labor intensity of today's alternate billing arrangement. It has been estimated that at the anticipated growth rates in collect, credit card, and bill-to-third-number calls, the demand for operators could, without Calling Card Service, have increased by more than 50 percent within the next 20 years. It is expected that the new service will assist in stabilizing the operator force.

Another important area to consider when evaluating the benefits of Calling Card Service is customer reaction. Considerable data exist on customer acceptance of and performance with Calling Card Service. The first evaluation of customer experience with the new service was obtained in a Human Factors and Marketing Trial conducted between November 1977 and June 1978 in Milwaukee, Wisconsin.[6] In that study, a variety of tests were conducted on ways of providing the

service. Further information has also been obtained from initial experience with the service both in Buffalo, New York, and in Jacksonville, Florida, since cutover in 1980.

The basic measures of success on Calling Card Service are customer acceptance and performance. Most customers with calling cards (or their predecessor, the credit card) who make calls from stations equipped to receive the customer-dialed protocol, have attempted to dial their billing numbers and have done so with considerable success. The high acceptance rate has been essentially unaffected by the successive addition of new user population and can be taken as an indication of the overall success of the new service.

IX. CONCLUSIONS

We have given an overview of the Calling Card Service. Subsequent papers in this issue examine in more detail the changes required for the new service. The introduction of Calling Card Service is having a significant and positive impact on the telephone industry. Moreover, the service is one aspect of a new dimension in customer control of network telephone services; the key to this dimension is the capability of the customer to dial billing information in addition to the destination number. This, coupled with real-time access to distributed data bases, results in security and service improvements that are appealing to the customer and to the telephone companies. With Calling Card Service, customers are provided an alternative to operator assistance, while the telephone company is offered relief from the rapid increase in demand for operators.

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Stored Program Controlled Network:

Calling Card Service—TSPS Hardware, Software, and Signaling Implementation

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New hardware and software were developed for the Traffic Service Position System (TSPS) No. 1 to provide Calling Card Service and related capabilities. These developments allow TSPS to provide prompting announcements to calling card customers, to receive customer-dialed billing information, to verify the received billing information utilizing the data base capabilities of the Stored Program Controlled Network, and to provide operator assistance for calling card customers when required. The implementation includes new TSPS operational and maintenance software, dual-tone multifrequency* (DTMF) and multifrequency digit detection and announcement circuits, access to the Stored Program Controlled Network, and new local office interfaces.

I. INTRODUCTION

Calling Card Service enables customers to make calls billed to their calling card number without the assistance of an operator.[1] Customers originating O+ calls to the TSPS are prompted to dial their calling card number, or are connected to an operator based on the originating station treatment (OST) data specified at a billing validation application (BVA) data base.[2] Customers calling from stations with dual-tone multifrequency* (DTMF) signaling capability may dial their calling card number directly. The TSPS validates the billing number by initiating a

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* *Touch-Tone* is the AT&T registered service mark for dual-tone multifrequency signaling.

query to the BVA, and then completes the call. Sequence calls (subsequent calls billed to the same calling card number) may be made by keying the number sign (#) character prior to dialing the new telephone number.

Operator-assisted Calling Card Service is available to customers calling from stations not equipped for DTMF signaling to the TSPS and to customers requiring operator assistance. Validation of calling card numbers is provided on an inward basis to non-TSPS operators capable of DTMF or multifrequency signaling to TSPS. Billed number screening (BNS), a related Calling Card Service capability, enables the TSPS operator to determine if bill-to-third-number or collect requests are allowed for a particular billing number.

The functions needed in TSPS for Calling Card Service and BNS are provided by new hardware and software. These new services are provided by TSPS Generic 1T10, which establishes TSPS as a node on the Stored Program Controlled (SPC) Network. New hardware is needed to provide: automated announcements and collection of customer-dialed digits; Common-Channel Interoffice Signaling/Direct Signaling (CCIS/DS)[3] to send queries to BVA data bases; and special local office interfaces which activate DTMF signaling from coin stations when calls are connected to TSPS. New software is needed to provide automated and operator-assisted Calling Card Service interfaces for customers and to maintain new TSPS hardware.

II. HARDWARE IMPLEMENTATION

Implementation of Calling Card Service required changes and/or additions to a number of TSPS peripheral circuits. Major changes were made to the Station Signaling and Announcement Subsystem (SSAS) of TSPS to provide necessary announcements and customer prompts, as well as the ability to register billing information transmitted via DTMF or multifrequency signaling. Additional equipment was introduced to interface with the CCIS network and provide the TSPS with access to the BVA. Other TSPS changes were implemented to activate the DTMF signaling capabilities of certain telephones through expanded inband signaling and to provide required maintenance functions.

2.1 Changes in the SSAS

The SSAS is a program-controlled peripheral subsystem of the TSPS which was originally developed to provide Automated Coin Toll Service (ACTS).[4] The SSAS constructs customer announcements and prompts from a prerecorded vocabulary of announcement phrases, directs them to the telephone customer, and detects customer coin deposits. The SSAS consists of duplicated controllers and announce-

ment stores, and up to 239 traffic-engineered coin detection and announcement (CDA) circuits (see Fig. 1).

The SSAS announcement vocabulary consists of digitally encoded half-second phrases which are stored in the semiconductor announcement store. The SSAS controller retrieves announcement phrases from the announcement store and directs the appropriate phrases to each equipped CDA circuit. A digital-to-analog decoder within the CDA circuit converts the digitized announcement phrases into an analog announcement for the customer.

Customer coin deposits are identified by dual-frequency coin deposit signals, which are detected by a coin tone receiver within each CDA circuit. The received coin deposit information is monitored and acted upon by the SSAS controller. Amplifiers, four-wire terminating sets, and other transmission components within the CDA circuit protect the coin tone receiver from potential interference caused by the SSAS announcements and permit an operator to be connected to the call if necessary (see Fig. 2).

To provide Calling Card Service, two new SSAS circuits were developed: the tone detection and announcement (TDA) circuit and the multifrequency detection and announcement (MDA) circuit. The TDA
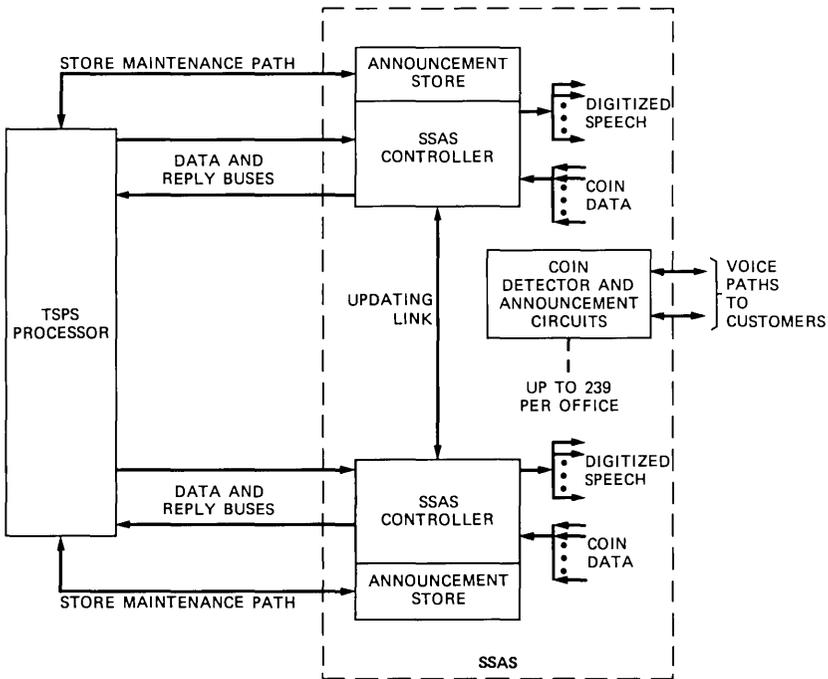
Fig. 1—Station Signaling and Announcement Subsystem block diagram.
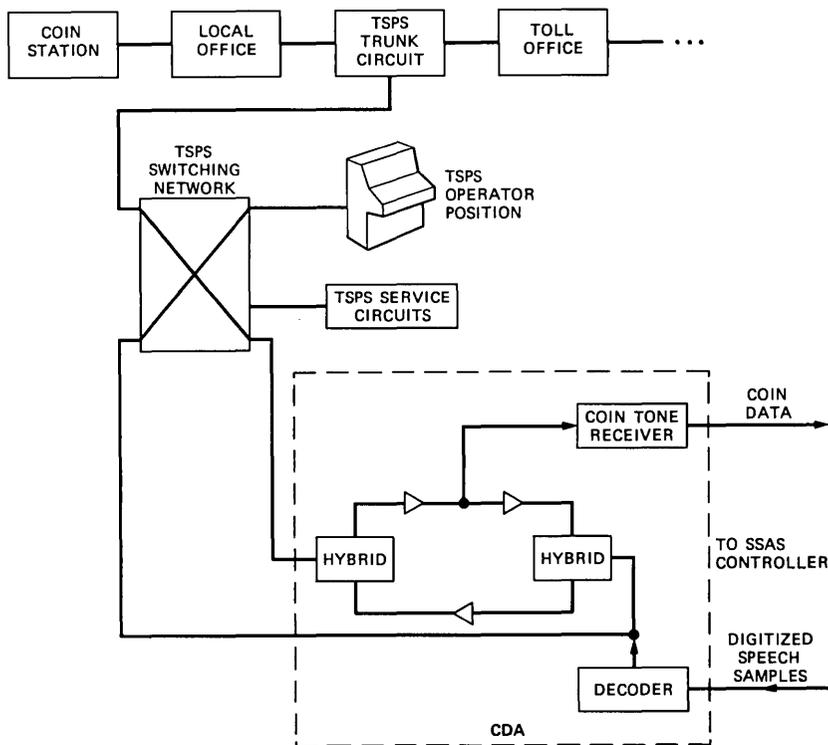
Fig. 2—Connection of SSAS CDA into TSPS.

circuit provides prompts and registers billing information transmitted via DTMF signaling on customer-dialed and certain automated inward validation calling card calls. The MDA circuit is utilized on automated inward validation calls when the billing information is transmitted using multifrequency signaling.

Implementation of the operational and maintenance functions associated with Calling Card Service required significant program additions to the SSAS controller. The capacity of the controller program store was increased to accommodate the added program. The SSAS announcement store was also equipped with additional memory to provide the new announcements and prompts required for Calling Card Service.

2.1.1 Tone detection and announcement circuit design

The design of the TDA circuit is similar to the CDA circuit used for ACTS, except that a DTMF receiver replaces the CDA coin tone receiver (see Fig. 3). The DTMF receiver provides the following functions:
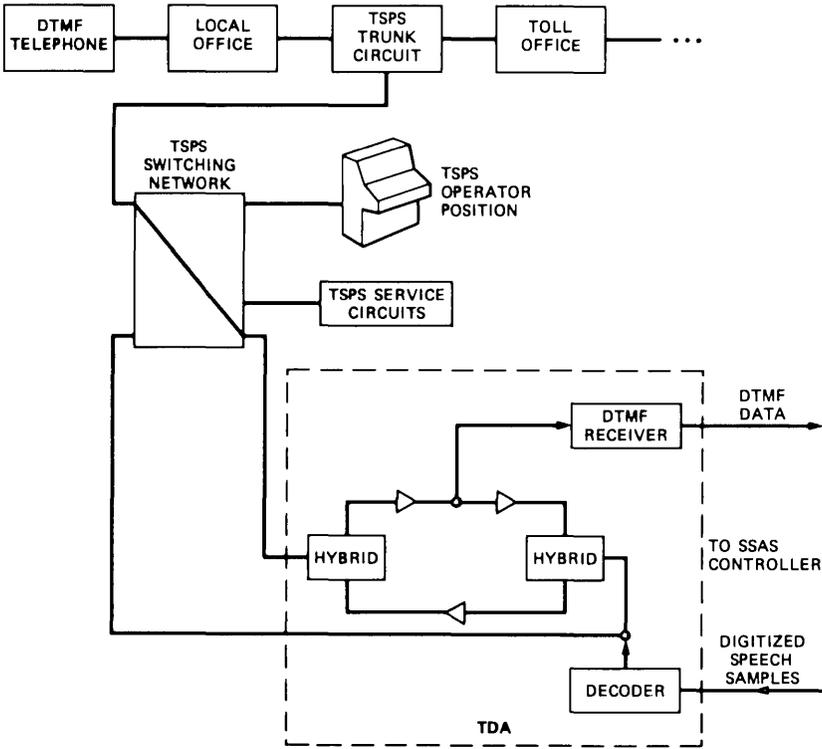
Fig. 3—Connection of SSAS TDA into TSPS.

(*i*) Detection of the standard DTMF signals used to transmit billing information during call setup (see Table I)

(*ii*) Rejection of speech simulations of DTMF digits

(*iii*) Buffering of detected digits

(*iv*) Enhanced detection of the # DTMF character while awaiting call completion.

These functions are achieved through the use of a modified local office DTMF receiver.

Table I—Dual-tone multifrequency codes

Low-Group Frequencies in Hertz	High-Group Frequencies in Hertz			
	1209	1336	1477	1633
697	1	2	3	A^*
770	4	5	6	B^*
852	7	8	9	C^*
941	*	0	#	D^*

* Currently unused.

The first two functions are shared in common with local office applications and are provided by the basic receiver. New circuitry was added to provide the other two functions which are required to implement Calling Card Service. Buffering of the detected DTMF digits permits the digits to be received at a 250-ms rate. Detection of the # character in the presence of audible ringing signals, busy signals, and network announcements, while awaiting call completion, is required to provide sequence calling.

As with the detection of coin deposit signals for ACTS, DTMF signal detection for Calling Card Service must be performed in the presence of speech and other interfering signals. Speech may contain components at the DTMF signaling frequencies that are subject to interpretation by the receiver as valid digits. To protect against errors of this type, the receiver employs a technique called "limiter guard action" (described later). However, this technique makes the receiver susceptible to the rejection of valid DTMF signals that are coincident with speech, and other techniques are required to provide protection against interference of this type. Protection against interference from coincident customer speech is provided by the design of the telephone itself, which disables the voice transmitter when a key is depressed. Protection against interference from coincident SSAS announcements is provided by isolating the DTMF receiver from these announcements through the use of four-wire terminating sets within the TDA circuit. However, since this isolation is not complete, the SSAS announcements are truncated at the earliest indication of a received DTMF signal to provide increased protection against interference from the SSAS announcements.

Figure 4 shows the SSAS DTMF receiver. The receiver incorporates an input transformer and amplifier to provide necessary impedance matching and signal gain. Input bandpass filter A shapes the incoming signal by suppressing interference at 60 Hz and its harmonics, as well as any energy above 3 kHz. When detecting the # character in the presence of audible ringing signals, busy signals, and network announcements, additional shaping is provided by input bandpass filter B which is inserted under TSPS control.

Two band-elimination filters follow the receiver input filter section. One filter rejects only frequencies in the high-group DTMF band; the other filter rejects only frequencies in the low-group DTMF band. Each band-elimination filter is then followed by a zero-crossing limiter, four channel filters, and their associated detectors. The channel filters each consist of a narrow bandpass filter centered at one of the nominal DTMF frequencies.

When a DTMF signal is introduced into the receiver, the two single-frequency components of the received signal are separated by the
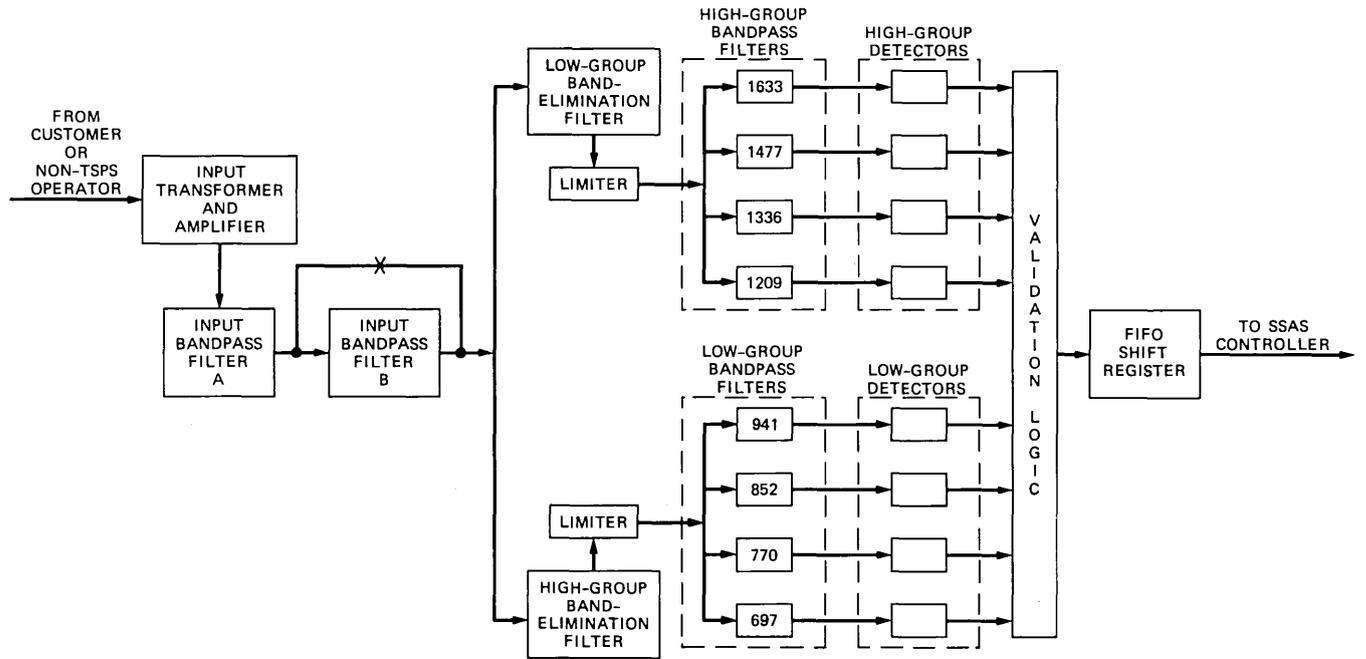
Fig. 4—Dual-tone multifrequency receiver block diagram.

band-elimination filters. If no additional interfering signals (e.g., speech) are present, each limiter will be driven by a single-frequency input signal, producing a fixed-amplitude square wave output signal of the same frequency. The fundamental frequency component of the square wave will pass through the channel filter corresponding to the specific DTMF frequency and turn on the associated detector. The detector outputs are processed by validation logic which verifies that the detected signals exceed the minimum required duration and converts the two-out-of-eight DTMF code to a binary-coded-decimal (BCD) format. The BCD information is loaded into a first-in-first-out (FIFO) shift register, which buffers the data until they are retrieved by the SSAS controller.

If the receiver is exposed to speech, the fixed-amplitude limiter output signal will be a nonperiodic waveform, rather than a periodic square wave. Any DTMF frequency components present in the limiter output signal will not contain sufficient energy to turn on the detectors and no output will be generated. This arrangement—limiter guard action—minimizes speech simulations of digits. However, as described previously, other measures are required to protect the receiver from speech energy during the reception of digits to avoid blocking valid receiver outputs.

The entire DTMF receiver is contained on four 4- by 8-inch plug-in circuit packs located in the SSAS service circuit frame.[4] Each service circuit frame can accommodate up to 16 TDA circuits, 16 MDA circuits, or any combination of the two circuit types. The SSAS service circuit frames can be arranged to provide a combined maximum of 239 CDA, TDA, and MDA circuits.

2.1.2 Multifrequency detection and announcement circuit design

The design of the MDA circuit is also similar to the CDA circuit, except for the receiver used (see Fig. 5). The MDA circuit uses a newly designed multifrequency signal receiver which performs the following functions:

(i) Detection of the 12 standard multifrequency signals used by non-TSPS operators to validate billing information (see Table II)

(ii) Protection against false operation

(iii) Buffering of detected multifrequency digits.

The SSAS multifrequency receiver is based on the design of existing central office multifrequency receivers, and takes advantage of modern integrated circuit and microcomputer technologies which allow it to be implemented on a single 6- by 7-inch plug-in circuit pack.

The standard arrangements used for the transmission of multifrequency signaling information minimize the potential for digit simulation and speech interference, thereby simplifying the receiver design.
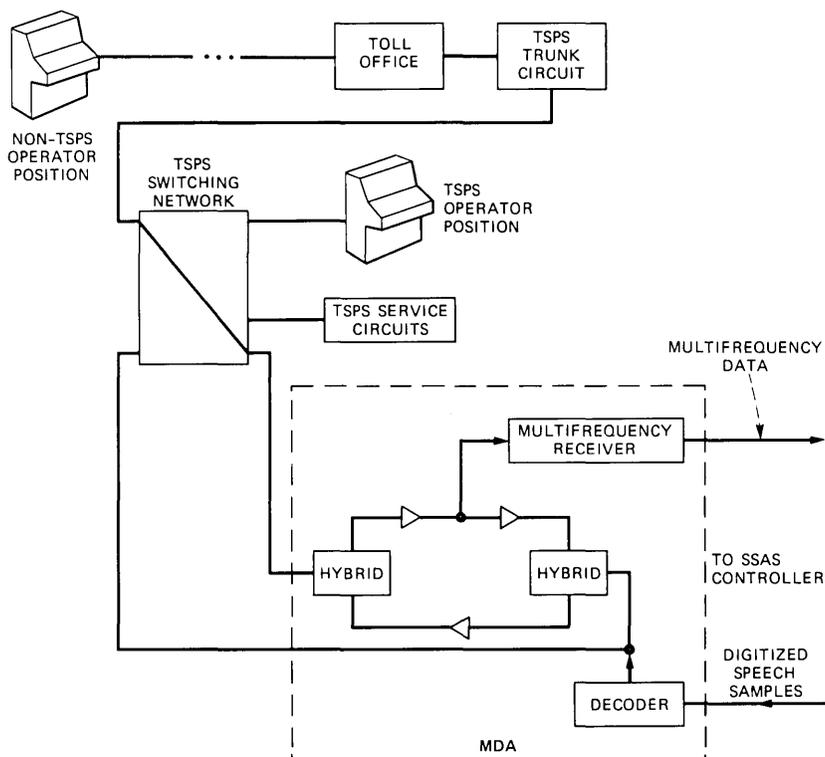
Fig. 5—Connection of SSAS MDA into TSPS.

Multifrequency signaling utilizes the KP (keypulse) and ST (start) codes to identify the beginning and end, respectively, of a multifrequency digit sequence. Depression of the KP key by a non-TSPS operator disconnects the operator's voice transmitter from the transmission

Table II—Multifrequency codes

	Frequencies in Hertz					
Code	700	900	1100	1300	1500	1700
1	×	×				
2	×		×			
3		×	×			
4	×			×		
5		×		×		
6			×	×		
7	×				×	
8		×			×	
9			×		×	
0				×	×	
KP			×			×
ST					×	×

path and provides a quiet background for the reception of multifrequency signals.

Prior to detection of the KP code, the multifrequency receiver remains in a "locked" mode in which it will only respond to the KP code; all other codes are ignored. A longer recognition time is required for the KP code than for other multifrequency codes to provide protection against false receiver operation caused by speech. Once the KP code has been detected, the receiver is switched to the "unlocked" mode in which it will respond to the remaining multifrequency codes. The detection of the ST code at the end of the digit sequence switches the receiver back to the "locked" mode.

The SSAS multifrequency receiver is depicted in Fig. 6. The input amplifier and automatic gain control (AGC) circuitry provide isolation and impedance matching for the receiver input, and provide a controlled input signal level to the channel filters. The six channel filters each consist of a narrow bandpass filter centered at one of the nominal multifrequency signaling frequencies. Each channel filter is followed by a threshold detector whose output is monitored by a microcomputer. The microcomputer provides overall control of the receiver, including timing of the received signals, code validation, mode control, and buffering of the detected multifrequency codes.

A valid multifrequency code consists of exactly two single-frequency signals. These two single-frequency components will be passed by two of the six channel filters in the receiver and trigger the associated detectors. The resulting two-out-of-six code is checked for validity by
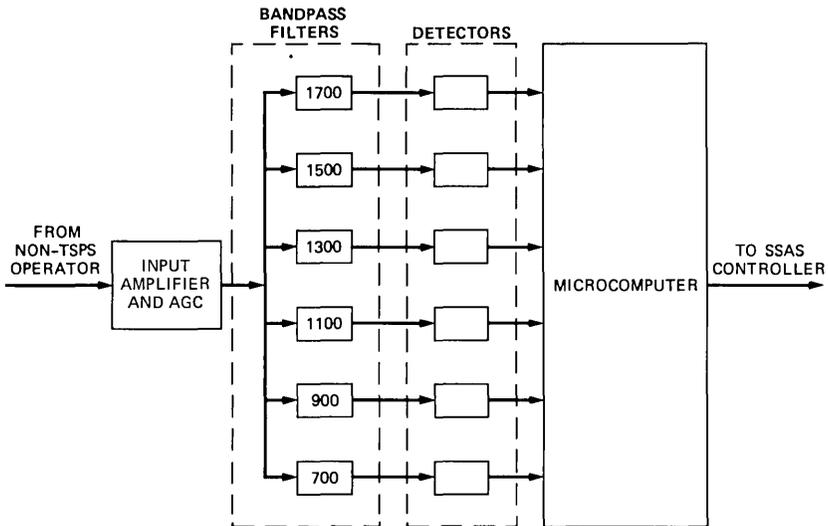
Fig. 6—Multifrequency receiver block diagram.

the microcomputer and buffered until it is retrieved by the SSAS controller.

2.1.3 Station Signaling and Announcement Subsystem program store expansion

The SSAS programmable controller, PROCON, has a basic addressing capacity of 16K program words. To accommodate the increased program requirements for Calling Card Service and subsequent features, the effective program store capacity was increased to 32K words. This was accomplished by implementing a block memory management arrangement.

Under the memory management arrangement, the 16K addressing range of PROCON is divided into a permanently active block of 12K words and a "paged" block of 4K words (see Fig. 7). Four additional 4K blocks of physical memory are provided and are paged into the 12 to 16K address range as required. Newly designed SSAS circuitry selects which one of the five 4K paged blocks is active, under control of a hardware register loaded by PROCON. This register is loaded by PROCON instructions located in the base 12K memory block. The hardware implementation ensures that one and only one 4K paged block is
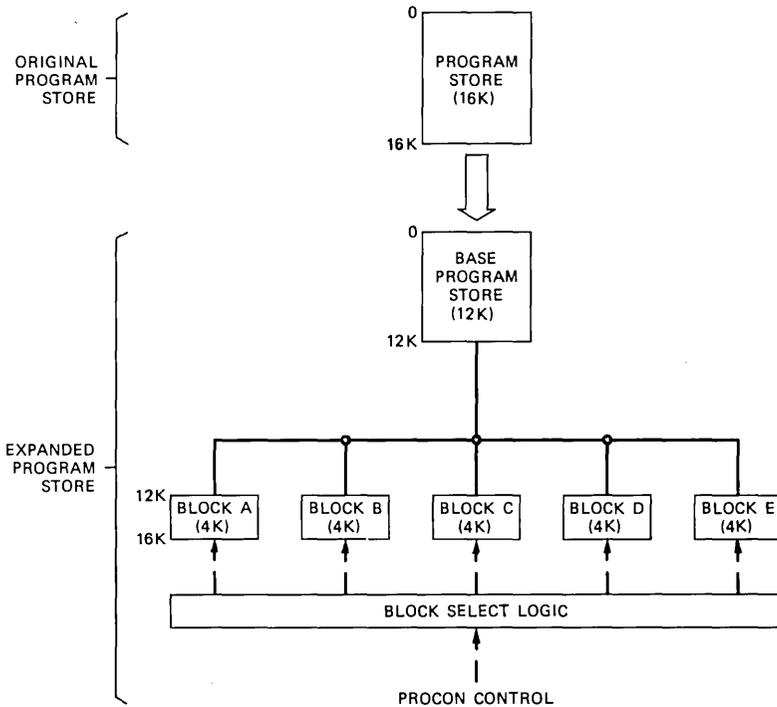
Fig. 7—Station Signaling and Announcement Subsystem program store expansion.

active at a time, and a software check is performed to verify that the correct block has been selected.

2.1.4 Station Signaling and Announcement Subsystem vocabulary expansion

The SSAS announcement store can be equipped with a maximum of six memory modules, each accommodating 80 half-second phrases, to yield a total vocabulary of 480 phrases. The implementation of ACTS required only 95 phrases, located in two memory modules. These phrases contained the speech segments used to generate announcements, as well as test tones and timing data used to perform automatic self-testing.

To provide the additional announcement vocabulary required for Calling Card Service, plus the test tones needed for the TDA and MDA circuits, the SSAS announcement store was equipped with one additional memory module. The necessary speech segments were recorded by a professional announcer, digitally encoded, and then edited to produce natural-sounding announcements. The test tones were recorded using laboratory signal generators.

2.2 Common-channel interoffice signaling hardware organization

The TSPS utilizes CCIS/DS to query BVA data bases and interconnects to the CCIS network via A-links to mate signal transfer points (STPs) in the same switching region.[5] Early in the development of CCIS/DS capabilities for the TSPS, it was recognized that CCIS equipment originally developed for the STP and No. 4A/CCIS systems could be utilized by TSPS to interconnect to the SPC network.[5,6] This is possible since both the STP and No. 4A/CCIS systems use SPC 1A processors, the same processor used by TSPS. Also, much of the maintenance software developed for those systems is adaptable to the TSPS application. The use of No. 4A/CCIS hardware and maintenance software provides an SPC network interface nearly identical to that of No. 4A/CCIS. However, even though the TSPS utilizes No. 4A/CCIS equipment, it does not perform CCIS call setup functions; instead, it utilizes only the direct-signaling capabilities of the CCIS network to communicate with BVA data bases on the SPC network. Figure 8 shows the TSPS interface to the CCIS network.

2.2.1 Signaling links

The A-link between the TSPS and the STP consists of a terminal unit at each end of a voice frequency link (VFL).[5] The VFLs are duplicated for reliability; one is normally in service, while the other VFL provides a switched backup. Because direct-signaling messages are not logically associated with individual signaling links, the TSPS distributes its
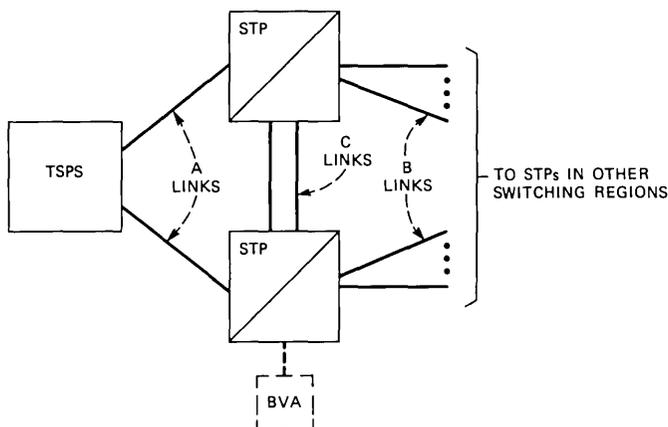
Fig. 8—Traffic Service Position System—CCIS network interface.

direct-signaling messages evenly over all in-service signaling links. When a signaling link is removed from service, because of a fault or manual action, the direct-signaling messages are distributed evenly over the remaining links. In this way, the in-service links constitute a common pool of signaling links available for direct-signaling messages. The TSPS may be equipped with a maximum of 16 A-links.

2.2.2 Common-channel interoffice signaling functional units

Figure 9 is a functional block diagram of the CCIS equipment configuration for TSPS. For simplicity, duplication of buses and controllers is not shown. For an explanation of the No. 4A/CCIS configuration see Refs. 5 and 6. The circuits added for TSPS/CCIS are the CCIS terminal group frame and the VFL access circuit. Modification of the TSPS office was required to interconnect the new circuits to the TSPS peripheral bus and to TSPS peripheral circuits.

2.2.2.1 Terminal group frame. The terminal group frame contains the signaling terminal units and data modems for up to 16 signaling links, as well as duplicated terminal access circuits (TACs) for processor communication with each terminal unit. The TSPS can be equipped with one terminal group frame.

The terminal unit is a special-purpose stored program processor which maintains data communication over the signaling link. Synchronization, error detection, and retransmission of signal units received in error are all handled by the terminal unit, independent of the TSPS processor.

The modem is the interface between the terminal and the VFL. One modem is associated with each terminal. The modem has two VFL ports which are used to switch between mate VFLs under TSPS processor
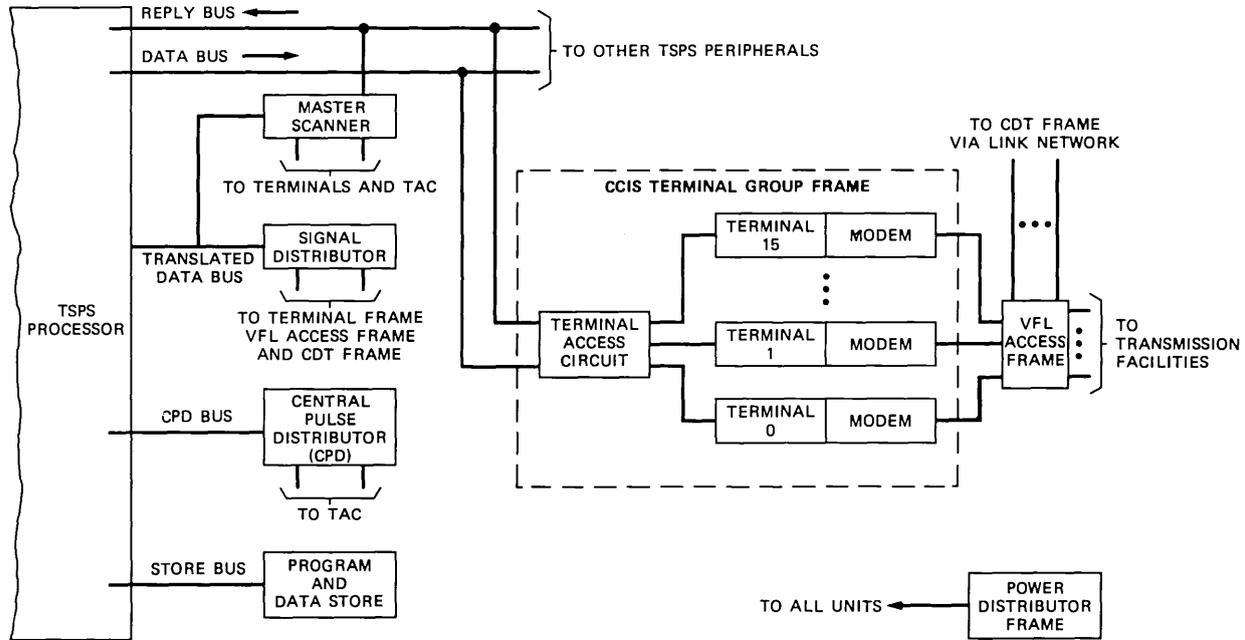
Fig. 9—Block diagram of TSPS/CCIS equipment.

control. One terminal-modem unit is associated with each signaling link. Backup capability for terminals is provided by requiring that signaling links be provided in pairs: one to the STP and one to its mate.

The fully duplicated TACs provide redundant and independent access for each terminal unit via the TSPS peripheral buses. The TAC has no autonomous functions and only one TAC is active at a given time. The TSPS processor periodically polls the TAC to determine which terminal units, if any, contain waiting signal units.

Modification of the TSPS office was required to interface the terminal group frame to the TSPS peripheral bus. Even though both No. 4A/CCIS and TSPS use SPC 1A processors, the two systems utilize different peripheral bus structures. Because of this, the TSPS peripheral buses were modified to provide the processor signals and bus lengths necessary to control the frame.

2.2.2.2 VFL access circuits. The VFL access circuits connect the terminal units to the signaling facilities to provide VFL test access. In addition, the VFL access circuits contain adjustable transmission pads which provide the proper transmission levels at the modem and test points.

2.3 Other TSPS hardware changes

Changes were made to other TSPS circuits to implement an expanded inband signaling interface with the local office and provide necessary maintenance functions.

As described in Section IV, expanded inband signaling uses six multifrequency codes to control a variety of local office functions, including activation of coin telephone DTMF dials. Expanded inband signaling is based on an earlier multifrequency signaling system which used three multifrequency codes. The multifrequency signals are applied by a TSPS service circuit called the coin control and ringback (CCR) circuit. Under control of the TSPS processor, the CCR circuit is connected to the incoming trunk from the local office via the TSPS switching network. Multifrequency tones are supplied to the CCR circuit by a common signal source. Timers and program-controlled relays within the CCR circuit then apply the appropriate controlled-duration tones toward the local office.

To provide the three additional codes and new timing parameters required for expanded inband signaling, the CCR circuits were modified by incorporating additional program-controlled relays and timing circuitry. The modified CCR circuits are bimodal and can be used to provide both expanded inband signaling and the earlier multifrequency signaling interface with the local office. The CCR circuits are automatically diagnosed using an existing multifrequency test circuit and new TSPS maintenance software. In addition, the control, display, and test

(CDT) frame and the test and display circuit (TDC), which are used to perform trunk maintenance tests, were equipped with three new keys.[7,8] The three keys control application of the additional multifrequency signals and can be used by the craftsperson during manual trunk tests.

Other modifications to the CDT frame were also required. One of these was the addition of indicator lamps to the CDT status panel. These lamps summarize the in-service/out-of-service status of the CCIS, TDA, and MDA circuits consistent with the status indications provided for other TSPS peripheral circuits.

The CDT frame and its associated TSPS processor software were also modified to permit manual transmission testing of the CCIS VFLs. Under control of the TSPS processor, each VFL can be connected to the CDT frame via the TSPS switching network. The CDT frame modifications were required to permit both transmit and receive paths of the VFL to be simultaneously connected to transmission measuring equipment located within the frame. Two-person manual transmission testing of the VFLs can then be performed as required between the CDT frame and the CCIS STP office.

III. PROGRAM IMPLEMENTATION

New software was developed to provide maintenance of SSAS enhancements and other new TSPS hardware arrangements, and to provide TSPS processing of automated and operator-assisted calling card calls and BNS calls. Additional software provides CCIS/DS capability.

3.1 Maintenance programs

3.1.1 Expanded SSAS PROCON memory

Paging a 4K memory block is done via a memory-block select register in PROCON. Since there is overhead required to select a block, paging must be kept to a minimum. To cut down overhead, a new software structure was designed to allow for efficient and simple growth of new features. The active and standby monitor programs, the scheduler, and operational programs for features developed prior to Generic 1T10, reside in the base 12K words of PROCON program store. All new 1T10 feature PROCON programs reside in memory blocks A and B. Future feature programs will be assigned to memory blocks C, D, and E as required.

Diagnostics of the block-memory select circuits are provided as a part of the SSAS controller diagnostics currently resident in the TSPS and SSAS processors. The block-memory select diagnostics generate test patterns which cause multiple memory blocks to be selected. The block-memory select circuit also has an odd parity checker which reports multiblock select errors.

Since all block-memory management circuitry is on one circuit pack, fault resolution capability is optimized. Only a few typical circuit-interface-type faults may involve two or more circuit packs in the controller.

3.1.2 Tone detection and announcement and MDA circuit diagnostics

The system configuration for testing MDA and TDA circuits is shown in Fig. 10. The CDA test circuit which was originally designed to test CDA circuits is also used to provide diagnostic test access to analog portions of the TDA and MDA circuits.[9] Transmission paths are set up by the TSPS processor, and the CDA test circuit generates and detects the required analog test signals. Additional tests are performed on the digital portions of the TDA and MDA circuits by way of their interface with the SSAS controller.

Actual tests are run by the standby SSAS. The standby SSAS receives commands from the TSPS processor, performs the tests, and returns the results to the TSPS processor.

There are 22 test phases for testing the MDA circuit and 21 test phases for the TDA circuit. Tests one through eight are the same as the



TLN - TRUNK LINK NETWORK
PLN - POSITION LINK NETWORK
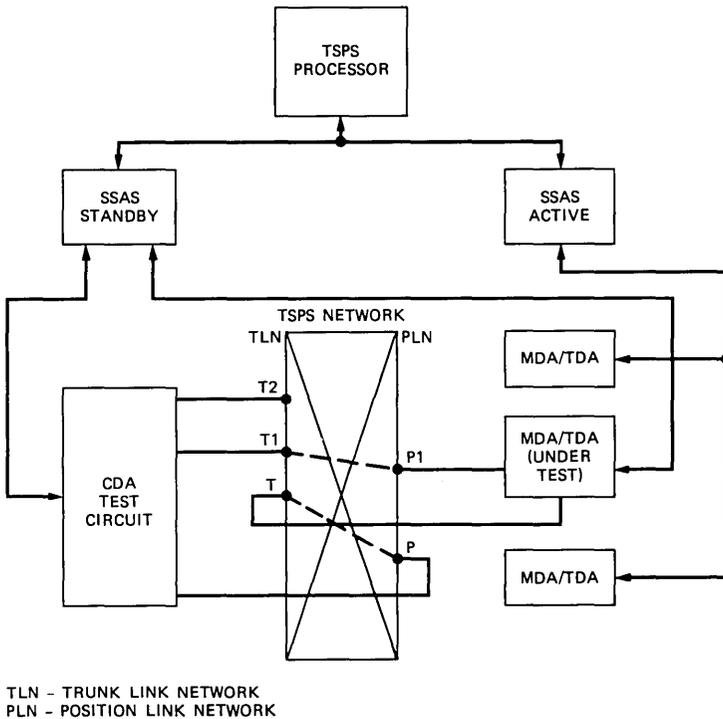
Fig. 10—Basic MDA/TDA test configuration.

original tests designed for the CDA circuit and they verify the digital and analog circuitry, as well as dc and ac transmission through the TSPS network. Phases 9 through 21 verify the proper operation of the receiver itself. These later phases check the receiver's ability to detect nominal input signals (i.e., nominal frequency, duration, and level). The phases also verify the receiver's response to various combinations of in-tolerance and out-of-tolerance signals. Phase 22 tests the MDA receiver's ability to automatically return to the "locked" mode if an ST signal is not received after a 35-second delay.

3.1.3 Common-channel interoffice signaling maintenance software

The TSPS maintenance software for CCIS is adapted from No. 4A/ CCIS maintenance programs and provides the same diagnostic and fault-recognition functions. The design goal was to make the maintenance of No. 4A/CCIS and TSPS/CCIS similar to expedite craft training and to permit sharing of craft expertise between systems. Maintenance for No. 4A/CCIS is described in Refs. 5 and 6.

3.1.3.1 Terminal group frame maintenance. The CCIS TAC and terminal hardware contain extensive self-checking circuitry. The terminal is a stored program unit with a self-test exercise program which runs continuously, interleaved with signal unit processing. Routine exercises are run on the TAC and terminal automatically on a daily basis to detect nonservice-affecting faults.

Faults detected in a TAC or terminal unit will cause a processor interrupt when the unit is next accessed by the processor. This causes the terminal fault-recognition program to be entered. This program determines which unit is faulty and then reconfigures the system to isolate the faulty unit. The faulty unit is removed from service and scheduled for diagnosis. Whenever a terminal is removed from service, the signaling network must be reconfigured to use the mate signaling link.

Faults which cause an excessive signaling link error rate lasting longer than 3 minutes will cause the link security program to request diagnostics on the suspected terminal unit. If the subsequent diagnostics at the TSPS and STP find no trouble, a VFL trouble is assumed.

3.1.3.2 Diagnostic Programs. Diagnostics and Trouble Locating Manuals (TLMs) developed for No. 4A/CCIS are used by TSPS. They provide TSPS craftspeople with the location of suspected faulty circuit packs in the TAC and terminal units. The results of a diagnostic are printed on the TSPS maintenance teletypewriter in the form of a trouble number. The TLM for each unit type associates the trouble number with one or more suspected faulty circuit packs. The terminal diagnostic includes a complete test of the modem and its interface to the VFL access circuit. Diagnostics for the TAC and terminal units are

invoked automatically by fault-recognition and automatic exercise programs, or manually by TSPS craftspeople via the maintenance teletypewriter.

3.1.3.3 *Signaling link security.*

Link security programs monitor the integrity of working signaling links, invoke link recovery procedures on faulty links, and provide maintenance access for TSPS craftspeople.[5] Link security programs respond to signaling link messages received from the STP, internal fault recognition, manual inputs from the maintenance teletypewriter, and frame key actions.

Terminal units check each signal unit received and detect unacceptably high error rates. The terminal notifies the processor if the link is not suitable to carry traffic. Link security programs initiate a change-over procedure which removes all direct-signaling traffic from the link and attempts to synchronize the link on the standby VFL. When the signaling link is resynchronized, the TSPS and STP processors measure the error rate to determine if direct-signaling traffic can resume. After a sufficient prove-in period, the TSPS and STP exchange load transfer and load transfer acknowledgment signals, which causes traffic to be returned to the signaling link.

3.1.3.4 *Voice frequency link testing capability.*

The error performance of signaling links is continuously measured by the terminal units at each end concurrent with normal service. The standby VFL may be tested with a special maintenance terminal at the STP. The test requires the TSPS to loop back the standby VFL via the VFL access circuit. When the link is active, the TSPS and STP can exchange signals to schedule a standby VFL test. The STP maintenance terminal measures the error rate on the looped-back standby VFL and signals the TSPS of the pass/ fail results. This test may be requested manually from either end, and is scheduled automatically by the STP several minutes after a signaling link failure to determine if the VFL should be reported to maintenance personnel.

The TSPS provides manual test access to VFLs through the CDT. Under control of the TSPS processor, the VFL test port of the VFL access circuit is connected to the CDT through the TSPS switching network. Connection of VFLs to the CDT is requested by teletypewriter message or by key action at the CDT itself. Figure 11 shows the TSPS VFL access circuit arrangement. No. 4A/CCIS and STP use dedicated VFL test positions for manual VFL testing.

3.1.3.5 *Signaling link measurement.*

Signaling link measurements are accumulated by the terminal program and the TSPS processor. The terminal program maintains counts on a short-term basis. Every 5 minutes a TSPS program retrieves these counts from the terminal and administers the long-term accumulation of those data. Other counts are maintained directly by the TSPS processor.

TLN - TRUNK LINK NETWORK
PLN - POSITION LINK NETWORK
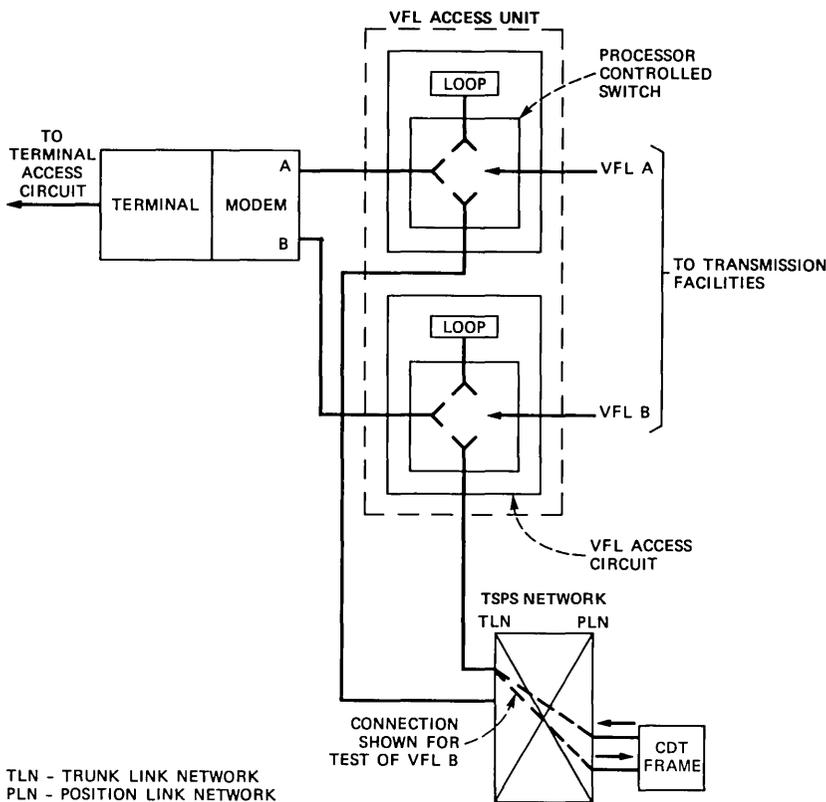
Fig. 11—Voice frequency link access circuit arrangement.

A daily summary report and a 30-minute exception report are printed on the TSPS maintenance teletypewriter for use by maintenance personnel. The daily report provides maintenance data for all signaling links on a 24-hour basis and may be printed on demand. The exception report is triggered whenever the value of a key measurement reaches a threshold value within a specific period of time. Exception reports alert maintenance personnel to possible deteriorating signaling link conditions that may warrant investigation.

3.2 Calling Card Service and BNS operational software

Calling Card Service and BNS are provided by adding new software to the TSPS processor and new firmware to the SSAS. The SSAS programmable controller, PROCON, uses read-only memory (ROM) for program and random-access memory (RAM) for transient data. Communication between the TSPS processor and for SSAS is effected over the TSPS data and reply buses (see Fig. 1).

3.2.1 Calling card number

A calling card number consists of a 10-digit billing number, plus a four-digit personal identification number (PIN). The billing number may be the directory number to which the call is billed, and is of the form:

$$NPA\text{-}NXX\text{-}XXXX.$$

Alternatively, the billing number may be a special number of the form:

$$RAO\text{-}(0/1)XX\text{-}XXXX,$$

where RAO is the Revenue Accounting Office which assigned this billing number. The fourth digit (0/1) indicates that the number is a special billing number.

The PIN is any four digits ($YYYY$) and can be designated as "restricted" or "unrestricted." Basic Calling Card Service requires an unrestricted PIN and is valid for calls to all destinations and for station or person calling. If the called number is the billing number, the calling customer need only enter the four-digit PIN. Only an unrestricted PIN may be associated with a special billing number.

A restricted PIN is used to bill station-to-station calls placed to a directory number which is the same as the billing number.

3.2.2 Customer-dialed calling card call

3.2.2.1 Service access treatment. Customers initiate calling card calls by dialing 0, plus the called number. This information, plus the calling number, is outpulsed to the TSPS by the local office. The TSPS applies OST to the call to determine the treatment the customer should receive, based on the characteristics of the originating station. Depending on OST, the customer may be routed directly to an operator, may receive an alerting tone, or may receive an alerting tone, plus an announcement, "Please dial your card number or zero for an operator now."

After the TSPS receives the called and calling number and the calling party has received OST for customer-dialed service, the TSPS processor connects a TDA circuit through the TSPS network to the local office and sends a message to the SSAS to process this call. The SSAS returns an alerting tone (or an alerting tone followed by an announcement) to the customer by utilizing an encoded tone and announcement in the announcement stores and the decoding circuits in the TDA circuit assigned to this call. The customer then has 1 second in which to begin dialing a calling card number or take action to get an operator. An operator is obtained by dialing 0, 0#, or by flashing the switchhook. Customer dialing during the announcement truncates the announcement. If no action is taken, the customer is given the announcement "Please dial your card number or zero for an operator now." The

customer is given an additional 5 seconds to begin dialing or take action to get an operator. If no action takes place after 5 seconds, the call is brought to an operator.

There are four possible dialing sequences for a customer-dialed calling card call. They are:

$$NPA\ NXX\ XXXX\ YYYY,$$

$$RAO\ (0/1)XX\ XXXX\ YYYY,$$

$$YYYY,$$

$$YYYY\#,$$

where $YYYY$ is a 4-digit PIN and $\#$ is the optional end-of-dialing indicator.

If the customer wishes to dial billing information, either the 14-digit calling card number or four-digit PIN is dialed. The digits dialed by the customer are processed and checked by the SSAS.

A number of timing sequences are performed by the SSAS to interpret the dialed information. If no digits are dialed within 2.5 seconds after the initial 0, then it is assumed that no further dialing will take place and the call is connected to an operator. Two-second timing is initiated after the first four digits to check if a PIN only was dialed. If time-out occurs after four digits, validation is initiated. If a customer dials another digit (other than a $\#$) within the next 3 seconds, the validation is terminated, and it is assumed that the customer intends to dial 14 digits. If no additional digits are received within 3 seconds and the PIN is determined to be invalid, an interdigit time-out is assumed.

After digit reception is complete, the SSAS sends the digits to the TSPS processor through the SSAS output FIFO buffer. If the customer has only dialed a four-digit PIN, TSPS forms the calling card number by prefixing the called number.

3.2.2.2 Service exit treatment. After the number has been received, TSPS performs a format check. If the customer only dialed a PIN, the called number is rejected if it is an INWATS, directory assistance, or an overseas number. After fraud checks, TSPS interrogates the BVA. If the billing information is accepted, the TSPS processor instructs the SSAS to return the "Thank You" announcement and outpulses the call.

If the billing number is rejected, a failure count is incremented. If the failure threshold is reached, SSAS gives the announcement, "Please hang up and dial zero plus the number you are calling. The card number you have dialed is not valid," and the call is ended.

If the threshold is not reached, the customer is given the announcement "Please dial your card number again now. The card number you have dialed is not valid." If no dialing has occurred within 3 seconds after the announcement, an alerting tone is returned to the customer.

The customer now has 3 more seconds to dial. If no dialing occurs after 3 seconds, the customer is given the announcement "Please dial your card number." If the customer does not dial after 5 more seconds, SSAS gives the announcement, "Please hang up and dial zero plus the number you are calling," and the call is ended.

3.2.2.3 Failures and restarts.

Hardware errors or failures—Hardware errors are detected by routine error-detection programs or fault-recognition programs. One example of such a hardware error is the inability of a TDA circuit to detect digits properly. If a hardware error occurs before a customer starts dialing, the call is routed to an operator. If the error occurs after dialing starts but before validation, the customer is given reorder. If the error occurs after validation, and the call is outpulsing, the call is treated normally, with the exception that "Thank You" may not be announced.

Customer flashes—If a customer flashes after dialing the called number, but before the alerting tone, the flash is treated as a disconnect. A flash after the alerting tone, but before dialing any calling card digits during an initial seizure, or after an initial 0 is dialed, results in the call going to an operator. Flashes are ignored from the time a customer starts dialing calling card digits to before outpulsing begins. If a flash occurs during outpulsing, the call is ended.

3.2.3 Customer-dialed calling card sequence call

3.2.3.1 Service access treatment. A calling card customer may initiate a sequence call by remaining off-hook and depressing the # key prior to called customer answer or after the called party goes on-hook. The calling customer has approximately 11 seconds after the called party disconnects to request the sequence call. After the # character is received, the forward connection is released.

When a sequence call begins, the SSAS gives the customer the announcement "You may dial another call now." The customer has 10 seconds after the announcement to start dialing. Customer dialing during the announcement truncates the announcement.

3.2.3.2 Service exit treatment. If the new called number is valid, "Thank You" is announced and the call is outpulsed. The use of the "Thank You" announcement is optional—it may either be provided or not. If the number is invalid, an error count is incremented. The number of errors allowed for dialing a new number is a changeable parameter.

If the number of attempts to redial a new number exceeds the allowable threshold, the announcement, "Please hang up and dial zero plus the number you are calling," is given and the call ended. If the

threshold has not been reached, the announcement, "Please dial the number you are calling again now. The number you have dialed is not correct," is given. This allows the customer to redial the new called number. If the customer does not start dialing within 5 seconds, the announcement is repeated.

3.2.3.3 Failures and restarts.

Effects of customer dialing a number sign (#) character—The # character has the following implications for a sequence call:

(*i*) Receipt of a # from the calling customer after outpulsing, but before answer or after answer while the called party is on-hook, is interpreted as a sequence call request.

(*ii*) If seven or ten digits are dialed (or at least the minimum number of digits expected on an international call) followed by a #, the received digits are treated as the called number, i.e., # acts as delimiter, and are validated.

When the system is expecting seven or ten digits, the new number is validated immediately after the seventh or tenth digit is received. During outpulsing of a valid number, the number sign is ignored. After outpulsing is complete, a number sign initiates a new sequence call.

(*iii*) If a number sign is dialed after other than seven or ten digits (or before the minimum number of digits required on an international call), the number is considered invalid and the error announcement for a rejected called number is given.

(*iv*) If a customer dials multiple number signs in a row, only the first number sign is recognized.

(*v*) If the number sign is dialed during the announcements, "You may dial another number now." "Please dial the number you are calling again now. The number you have dialed is not correct," or, "Please dial the number you are calling," the announcements are aborted. The number sign is ignored if received during the announcements: "Please hang up and dial zero plus the number you are calling. The number you have dialed is not correct;" "Please hang up and dial zero plus the number you are calling;" or "Please hang up and dial direct. This number cannot be dialed as a sequence call."

Asterisk (*) or invalid DTMF signals—An asterisk (*) or an invalid DTMF signal is ignored and does not invalidate the digit sequence nor does it reset the interdigit time-out interval. If an insufficient number of digits are received, a time-out will occur.

Calling customer disconnect or flash—If a calling customer disconnects or flashes during a sequence call attempt, a billing record of the previous call is made if it has not already been done, and the call is ended. Customer-dialed calling card calls do not have flash privileges.

3.2.4 Operator-assisted calling card calls

A 0+ call is brought to an operator position when one of the following conditions occurs:

(*i*) The TSPS does not receive automatic number identification (ANI) digits from the local office. This may occur because the local office is not equipped to send the digits or because there was a failure.

(*ii*) The calling customer is dialing from a station from which calling card calls are not permitted.

(*iii*) The OST information indicates that the call should receive operator handling.

(*iv*) The caller does not want to enter a calling card number. This may occur because another form of billing is desired or because person service is required. In this case, the calling customer flashes, dials 0, or times out after hearing the tone or announcement.

3.2.4.1 Operator-assisted calls dialed 0+.
When the call is brought to a position, the customer quotes billing information to the operator (calling card number or PIN only). The operator enters the number into the system as given. The operator receives validation information via lamps and displays, then relays this information to the customer (see Fig. 12). The operator may reenter the number in case of errors. When the billing information is valid, the call is automatically out-pulsed and the operator may release the call.

If OST indicates that customer-dialed Calling Card Service is available on the originating line, a display, 999, is given to the operator. This display tells the operator to give dialing instructions to the customer if calling card billing is requested.

3.2.4.2 Operator key actions

Proper calling card class of charge—The proper class of charge for an operator-assisted calling card call is either STATION SPECIAL CALLING (STATION SPL CLG) or PERSON SPECIAL CALLING (PERSON SPL CLG). The latter requires an operator to handle the call to determine that the proper called party was reached. The class of charge is entered by the operator before or after the calling card number or PIN is keyed.

Keying sequence for calling card number or PIN—An operator enters a calling card number or a PIN by depressing the KP SPL key, plus the digits, and then the START (ST) key. If incorrect digits are keyed, the KP SPL key flashes.

The PIN is rejected if the called number is an overseas, INWATS, or directory-assistance number. In addition, it cannot be inward numbers which are used by operators. If the check fails, the PIN is rejected, the program displays the incorrect number, and flashes the KP SPL lamp at the position. If the format check passes, the billing number is checked against the BVA.

4 COMPARTMENT TICKET BOX
NEW | CANCEL
SCRATCH | COMPLETED

| 2 | 1 | 2 | | 2 | 4 | 3 | | 1 | 2 | 3 | 4 |

CHARGE ✻ HOURS ✻ MINUTES ✻ SECONDS ✻

—— NONCOIN ——   —— COIN ——   —— HOTEL ——

VFY | OVER SEAS | SCRN | INWD | EMER INIT

STA | 0+ | DIAL 'O'

STA | 0+ | DIAL 'O' | POST PAY | TONE

STA | 0+ | DIAL 'O' | GST

—OUTGOING TRUNKS— RING RELEASE

DA | R&R | SWB | OGT

BACK | FWD | CALL BACK | T&C | NFY | CHG DUE | KEY CLG

BACK | FWD

SR | MAKE BUSY | MTCE | POS TRFR

CW

—————— AMA ——————

STATION | PAID | COL | SPL CLG | SPL CLD | AUTO COL | DDD

PERSON | PAID | COL | SPL CLG | SPL CLD | NO AMA

MULTI-LEAF BULLETIN TRAY

COIN   AMA TIMING

COL | RET

CNL TMG | ST TMG

CA CALL | REC MSG

POS RLS

TIME | CHG MIN | CLG NO | CLD NO | SPL NO

— DISPLAY —

CLG | CLG | CLG

CLD | CLD | CLD

HOLD | HOLD | HOLD

ACS | ACS | ACS

KP TRBL | KP RATE | KP HO

KP NFY | KP SPL

KP BACK | KP FWD

Q 1 | ABC 2 | DEF 3

GHI 4 | JKL 5 | MNO 6

PRS 7 | TUV 8 | WXY 9

Z 0

ST

POS NO PLATE

LEGEND

ILLUMINATED KEY

LAMP

NONILLUMINATED KEY

✻ THESE DESIGNATIONS ARE NOT VISIBLE UNLESS SIGNIFICANT

Fig. 12—Traffic Service Position System operator position.

Key actions during BVA query—Only certain key actions are allowed by an operator while a BVA validation of the PIN versus billing number is in progress. The following key actions are acceptable during a query:

(*i*) Display keys: Calling Number (CLG NO) Called Number (CLD NO), Special Number (SPL NO).

(*ii*) Appropriate class of charge keys: PERSON SPL CLG; PERSON SPL CLD, or STATION SPL CLD; DDD; NO AMA (for inward validation only); STATION or PERSON COLLECT.

(*iii*) Miscellaneous keys: Time and charge (T&C), MAKE BUSY, Cancel Call (CA CALL) (in initial period access), Position Release (POS RLS) (in interim access only). The actions CA CALL and POS RLS abort the BVA query and allow the operator to terminate the call attempt.

If the BVA query indicates that the calling card number is not accepted, the failing number is displayed and KP SPL is flashed. The operator may rekey the call. If the number is accepted, the KP SPL lamp is extinguished and outpulsing proceeds. After outpulsing is complete, the operator depresses the START TIMING and POS RLS according to local operator practices.

3.2.4.3 Display of the calling card number

Display of a rejected calling card number—When a BVA validation fails, the billing information keyed by the operator is displayed automatically. Since the 14 digits of a calling card number are more than can be displayed on the console, the display is broken into two pieces:

(*i*) 312 690 5441 (billing number)

(*ii*) 1234 (PIN).

When the number is rejected, TSPS displays the billing number immediately. The operator may then depress the DISPLAY SPECIAL NUMBER key to display the PIN. A second depression darkens the display.

If the operator entered the PIN only, a rejection results in the display of the PIN only. The operator knows that the called number is the billing number.

Display of an accepted calling card number—Once billing information is accepted the calling card number is still available for display to the operator. The first display is the same as in (*i*) above. The second portion of the display contains the RAO returned from the BVA and the PIN. Hence, if a PIN only was entered, the display is:

$$091 \qquad 1234$$
$$(\text{RAO}) \qquad (\text{PIN})$$

3.2.4.4 Automatic number identification failures or ONI calls

Calls dialed 0+ with operator number identification (ONI) or ANI

failures (ANIF) cannot be customer dialed. These calls are routed directly to an operator.

The position display is the same as a 0+ call with the addition of the KEY CALLING lamp lit steady (ONI) or flashing (ANIF). The operator actions are the same as before with the addition of keying a calling number.

3.2.4.5 Operator-assisted calling card, non-0+ type calls

Hotel, 1+ coin—A customer does not have to dial 0+ to bill a call to a calling card number. A coin customer may dial 1+, but after listening to an announcement, may decide to bill the call differently. The customer may flash or time out to access an operator. The operator may change the class of charge from STATION PAID to STATION or PERSON SPL CLG. This drops the charge and minutes display and the operator proceeds as previously described.

Incoming 1+ hotel seizures are brought to the position as STATION PAID, waiting for the hotel room number. The operator may change the call to a calling card call as described in the case of the 1+ coin call. The operator proceeds in the same way.

Non-coin, 0– coin, or hotel—A 0– customer may wish to place a calling card call. If the operator keys a 14-digit calling card number before keying the called number, validation is attempted immediately. If the number is rejected, KP SPL is flashed and the number is displayed. If the number is accepted, KP SPL is extinguished. The operator then asks the customer for the called number and keys it. Outpulsing occurs when the operator depresses the START key.

If a PIN only is keyed, BVA validation cannot start until the called number is keyed by the operator. If before this is done, the operator depresses the DISPLAY SPECIAL NUMBER key, the four-digit PIN is displayed. The call proceeds as described on 1+ coin calls.

Special called class of service—A call of any kind which starts out as a collect call, can be changed to a calling card call. This can occur at the called customer's request. The operator depresses STATION or PERSON SPL CLD as the class of charge and keys in the billing information. Acceptance or rejection of the billing information is the same as described for 0+ calls, which have a SPL CLG class of charge. Only an unrestricted PIN can be used to accept person collect calls.

3.2.5 Operator-assisted sequence calls

Conditions leading to an operator recall—A customer may recall an operator by flashing during a call which is in a talking state, provided that the call has flash privileges. Operator-assisted calling card calls are in the class of calls with flash privileges.

Service Descriptions—When a customer requests that an operator place a sequence call, the operator first terminates the current call by

depressing the Record Message (REC MSG) key, which causes a billing record of the current call and allows a subsequent call to be made. The operator then keys the new called number and class of charge. On calling card calls where the class of charge is STATION or PERSON SPL billing, and the PIN is unrestricted, the operator does not have to enter the calling card number if the same type of billing is desired on the second call.

Operator key action: REC MSG *key*—Prior to Calling Card Service, depression of the REC MSG key terminated the current conversation, released the forward connection, and made an AMA record of the call. Records of the called number were erased and the class of charge lamp was extinguished. The calling party's calling card, third number, or hotel room was retained.

With the introduction of Calling Card Service, the special number information is retained if the class of charge on the first call was STATION or PERSON SPL CLG and the call was billed to a number with an unrestricted PIN, to a 10-digit special billing number, or to a third party. This frees the operator from rekeying a validated number on sequence calls.

However, if the call was placed with a restricted PIN, the class of charge and billing number are deleted, and the operator must enter a new billing number or charge the call another way. If the class of charge was STATION or PERSON SPL CLD, the class of charge is deleted and the billing number is also deleted, regardless of the type of PIN. This is because the billing number was specified by the called customer, and it is presumed that the new sequence call has a different called party.

Operator key action: Key forward new called number—Once the REC MSG key is lit, the operator must key in a new called number. The operator does this by depressing the KP FWD key, keying in the new number, and then depressing the ST key. If the billing number has not been deleted, the called number is outpulsed. After depressing STATION or PERSON SPL CLG, the operator depresses the Start Timing (ST TMG) key and the POS RLS key, according to usual practices.

Operator key action: New class of charge—If a customer does not wish to place another calling card call, but prefers to bill the call another way, the operator depresses the other class of charge key and handles the call according to usual practices. In the cases where the billing information was deleted, the operator is required to enter new class of charge information before the call can proceed.

3.2.6 Inward validation

Non-TSPS operators must dial one of three inward codes to gain access to the TSPS to perform calling card validation. The validation

can occur on an automated basis if the operator has a DTMF or multifrequency dial available. Otherwise, inward validation will be done on an operator-assisted basis.

3.2.6.1 Operator-assisted inward validation. For operator-assisted validation requests, TSPS connects the call to a TSPS operator. After the non-TSPS operator informs the TSPS operator that a validation is requested, the TSPS operator depresses the KP SPL key and enters the number. In all cases, 14 digits are entered. If the customer only specified a PIN, the non-TSPS operator gives the called number to the TSPS operator for use as the billing number.

After keying in 14 digits, the TSPS operator depresses the ST key. The KP SPL key remains lit, while the BVA inquiry is in progress. If the number is good, KP SPL is extinguished, and a special display is given to the TSPS operator indicating the type of PIN. The non-TSPS operator is informed of the RAO and the type of PIN.

3.2.6.2 Automated inward validation. A non-TSPS operator may validate a number without TSPS operator assistance. The TSPS returns an alerting tone. The non-TSPS operator has 1 minute to start dialing the 14-digit calling card number to be validated.

After a format check, TSPS initiates a BVA inquiry for validation of the number. There are four possible outcomes of a validation attempt:

(*i*) Calling card number accepted; PIN unrestricted: Announce "Valid number, unrestricted PIN, RAO XXX."

(*ii*) Calling card number accepted; restricted PIN: Announce "Valid number, restricted PIN, RAO XXX."

(*iii*) Calling card number accepted; RAO unknown: Announce "Valid number, unrestricted PIN, unknown RAO."

(*iv*) Calling card number rejected: Announce "Invalid number, please dial again."

After cases (*i*), (*ii*), and (*iii*), the connection to the non-TSPS operator is dropped by TSPS. After the announcement in case (*iv*), the alerting tone is given again and the non-TSPS operator may redial.

If an operator is using DTMF signaling, the # character has the same meaning as described before. It can be used to terminate dialing and restart dialing of another number. If a * or an invalid digit is received, it is ignored. A flash ends the call.

If the operator is using MF signaling, the start (ST) signal is treated as a # and is required after the 14th digit. The KP signal must precede dialing the 14 digits. Any error in keying results in the error announcement sequence.

Any digits dialed before the initial alerting tone, after termination announcements have started, or after the 14th digit when using DTMF signaling, is ignored. If a termination signal (# or ST) follows the 14th

digit and dialing follows, the BVA inquiry is aborted and the following digits are considered a new number.

The reception of digits truncates announcements in progress. The termination announcement is restarted as soon as possible, but the error announcement is not restarted. Digits dialed during an error announcement are considered a new number.

3.2.7 Operator actions—BNS

Collect calls—When an operator places a collect call on behalf of a customer, the BNS feature checks if collect billing is allowed for the called number. First, a preliminary format check is made on the forward number. The number plan area (NPA) must be a legal NPA. No BVA query is attempted if the NPA is illegal. While a query is in progress, the COLLECT (COL) key remains lit. In general, keying of a COL key darkens any lit or flashing KP key lamp, except KP FWD.

The BNS/collect reply indicates one of four collect billing states for the called number and results in the following actions:

(*i*) Collection not denied—The number is outpulsed and the collect key remains lit. When the customer answers, the operator informs the customer that the calling customer wishes to bill the call collect and attempts to procure acceptance of the call.

(*ii*) Public telephone—The called number is outpulsed, the COL key remains lit, and the called number is displayed to the operator. Collect calls to public telephones must be billed in an alternate manner by the called customer, or originated by the called customer if the called party wishes to accept the call on a sent-paid basis and pay with coins. The operator informs the called party of collect call and attempts to procure alternate billing.

(*iii*) Collect denied—No outpulsing occurs and the COL key flashes. The operator informs the customer that collect calls are not accepted by that number.

(*iv*) Indeterminate (a possible public telephone)—No outpulsing occurs and the COL key stays lit. The operator may check with a Directory Assistance (DA) or Rate and Route (R&R) operator. If it is not a public telephone, the operator depresses ST to initiate outpulsing.

Bill-to-third-number calls—After an operator places a third-number call, the BNS feature checks if the number accepts third-number billing. No class of charge is needed. Format checks and BNS inquiry are performed as described for collect calls. Replies and their actions are as follows:

(*i*) Third number not denied—The KP SPL lamp is extinguished, and the called number is outpulsed. The operator may release forward

and seek acceptance by the third party, or allow the call to outpulse and seek acceptance in parallel.

(ii) Third number denied—The KP SPL lamp is flashed and the third number is displayed. No outpulsing occurs and the operator announces that the number is unacceptable for billing.

(iii) Indeterminate—The KP SPL lamp is extinguished. The operator may check with a DA or an R&R operator to check if the third number is a public telephone. If not a public telephone, the operator attempts to get third-party acceptance of the charges. Outpulsing is initiated by the operator by depressing the ST key.

3.3 Common-channel interoffice signaling/direct-signaling operational software

The CCIS/DS operational software provides the TSPS software interface to the CCIS network. This interface is provided by the CCIS/DS message handler program which formats and sends direct-signaling messages for calling card, OST, and BNS data base queries. It also receives and processes direct-signaling replies from the data base queries. Additionally, the message handler provides direct-signaling traffic volume controls when there is congestion or blockage in the CCIS network and when the BVA is overloaded. A cache memory of recently processed calling card numbers is also maintained to protect the network from focused overload of frequently used calling card numbers.

3.3.1 Call-processing interface

Call-processing programs may request that a query be sent over the CCIS network. The requesting program specifies the type of query to be sent (calling card, OST, or BNS), the location of the trunk administration register which contains various data about the call being processed, and the location to which control should be transferred when the data base reply is received. If the state of the call changes before the reply is received, the call-processing program may change the location to which control is transferred. Requests for queries during periods of CCIS network failures result in control being immediately returned to the requesting call-processing program, with an indication of the reason for failure.

Call-processing programs may also request that a CCIS query be canceled. This request would be made, for example, if the calling party hung up before the reply to a query was received. The message handler ignores the reply to a canceled query.

3.3.2 Sending direct-signaling messages

When a query is requested, the message handler obtains the necessary call data, then formats direct-signaling messages into signal units

for transmission to terminal units. To associate each reply with the call requesting the query, a call identification number (call ID) is assigned to each query. The call ID is included in the CCIS query message and returned in the reply message. Timing for replies is initiated for each query sent. If no reply is received within two seconds, the reply is considered lost.

3.3.3 Message routing

The CCIS/DS messages have three address fields which are used for routing.[3] The domain field indicates the type of data in the other two fields. The TSPS uses two domain values. Domain 0 indicates that the other address fields contain a function number. A function number uniquely identifies nodes or processes on the Stored Program Controlled (SPC) Network. The BVA replies are routed to TSPS by function number.

Domain 2 is used to route calling card, BNS, and OST queries to BVA data bases. These queries contain NPA and NXX information in the two remaining address fields. The network may route the queries on the basis of NPA alone or on both NPA and NXX. Calling card queries may also be routed on the basis of RAO using domain 2. The RAO addresses are identified by setting the NPA address field equal to 1000.

3.3.4 Traffic volume controls

The TSPS automatically reduces the number of CCIS/DS messages sent when the network is congested, when messages are blocked, and when the BVA data bases are overloaded. When processor signal congestion (PSC) signals are received from an STP, the TSPS stops all outgoing messages to that STP and its mate for 10 seconds to allow the network to recover. Network problems beyond the first STP pair are detected when a query cannot reach its intended destination and is returned to the TSPS with an indication of the reason for failure. If network congestion or blockage is indicated, TSPS immediately initiates a complete cutback of all queries with the same NPA or RAO destination as the failing query.

Replies from BVA data base queries contain an overload indicator which, when set, directs the TSPS to reduce the number of queries to that data base. This indicator causes traffic reduction to be invoked for a specified interval of time. Subsequent requests for traffic reduction received during the reduction interval cause the timing interval to be restarted.

A cache of replies to recently validated calling card numbers is maintained at the TSPS to protect the network against a focused overload of BVA queries that may result from frequently used calling card numbers. Replies to calling card queries are saved in a memory scratch area which is used as a cache. A hash algorithm is used to map

calling card numbers into cache locations. The hash algorithm is time-dependent and periodically changes the location used for any particular calling card number. This ensures that only recent replies to queries can be found in the cache. Before a calling card query is sent, a check is made to determine if the reply for that query is in the cache. If it is, the reply data in the cache is used to process the call and the query is not sent.

3.3.5 Traffic sampling

To monitor the use of the SPC network for division of revenue and special studies, the TSPS collects on a sampled basis the NPA and NXX of the calling and called numbers on calls using the network. These call data are transmitted to a network data collection node in the form of a supplemental query data (SQD) message. The SQD message indicates the type of query, the address used in the query message, the function number of the TSPS processing the call, the SQD sampling rate, and the NPA-NXX of the calling and called numbers.

3.3.6 Direct-signaling translation test

The direct-signaling translation test (DSTT) verifies the integrity of routing data between nodes on the SPC network.[3] This test is manually initiated and consists of a series of special data network messages which test the translation data in each signal transfer point (STP) on the path between the origin and the specified destination. The TSPS is capable of originating DSTTs and responding to translation tests originating from other nodes on the SPC network.

The TSPS originates a DSTT by sending a Data Translation Test (DTT) message over one of its A-links. The STP receiving the DTT checks its own translation data and then advances the test by transmitting a Compare Translation Test (CTT) message to its mate STP. After checking its translation data, the mate STP transmits a DTT message over the route determined by its translation. The SPC network function that ultimately receives the DTT responds with Reply to Test Messages (RTTs). If the function reached is the one specified in the DSTT, a success message is returned; if some other function is reached, RTTs indicating a routing error are returned to the originating node.

3.4 Administrative software

Changes to TSPS administrative programs were made to provide support for the new SPC network features. Recent change programs are used to administer TSPS resident data. New recent change programs were provided to activate CCIS/DS, Calling Card Service, OST, and BNS. In addition, new recent change programs administer trunk group signaling data for DTMF signaling enablement of coin stations and

locally define Calling Card Service announcement protocol prior to OST data base availability. New interface programs for the No. 1A Service Evaluation System, which provides service evaluation of TSPS calls, allows Calling Card Service and BNS calls to be evaluated. Automatic Message Accounting (AMA) record changes were made to facilitate billing of Calling Card Service and BNS calls.

3.5 Measurements

Extensive new measurements include maintenance, traffic, and CCIS/DS query measurements. Maintenance measurements provide data on hardware failures, out-of-service intervals, and other indications of the service provided, and the overall system performance. Traffic measurements detail usage of Calling Card Service and other types of calls. This information is used to forecast future traffic capacity requirements and engineer equipment additions, administer the operating force, and to assess the grade of service to the customer. The number of CCIS/DS queries, replies, and failures are also measured to give an indication of CCIS/DS and BVA usage and performance.

IV. LOCAL OFFICE INTERFACES

New local office interfaces were provided at the TSPS to permit coin telephone customers to use DTMF signaling to enter billing information and place sequence calls associated with Calling Card Service. Prior to the implementation of these interfaces, the DTMF dials of both dial-tone-first and coin-first telephones were disabled by the local office upon connection of the call to the TSPS. The new interfaces extend control over activation of the DTMF dials to the TSPS.

Two signaling interfaces are provided for dial-tone-first telephones: multiwink signaling and expanded inband signaling. For coin-first telephones, a new coin-retention protocol is provided. The use of a particular interface is specified in TSPS program memory (office-dependent data) on an individual trunk-group basis. Some trunk groups may require the application of both coin-first and dial-tone-first protocols.

A new signaling arrangement was also provided to permit DTMF customers served from certain step-by-step local offices to enter billing information using the DTMF dial.

4.1 Background

4.1.1 Dial-tone-first telephones

When a customer at a 1C-type dial-tone-first telephone goes off-hook, the local office applies negative battery towards the telephone (i.e., the ring lead is negative with respect to the tip lead), dial tone is received, and the DTMF dial is activated. Upon connection of the call

to the TSPS, the local office applies positive battery towards the telephone (i.e., the ring lead is positive with respect to the tip lead). This disables the dial and places the telephone in a mode in which individual coin deposits are identified by coin deposit signals.[4] The telephone must be in this mode for the customer to place a sent-paid call (i.e., one in which the customer pays for the call by depositing coins).

To activate the DTMF dial and permit the entry of the billing information required to place a calling card call, the local office must reapply negative battery towards the telephone.* However, this prevents the generation of individual coin deposit signals required for sent-paid calls. To accommodate either type of call, the TSPS must be able to control the application of positive and negative battery by the local office.

4.1.2 Coin-first telephones

The DTMF dial of a coin-first telephone is not activated until an amount equal to the initial rate has been deposited by the customer. If the initial rate is collected or returned to the customer, the dial is once again disabled.

To place a TSPS call, the customer at a coin-first telephone must first deposit the initial rate. Prior to the introduction of the coin retention protocol, the local office would return the initial rate deposit upon connection of the call to the TSPS. This was consistent with no charge being incurred to reach an operator; it also simplified the charge calculation in the event that the customer wished to place a sent-paid call. However, it disabled the dial and prevented the entry of billing information for calling card calls.

4.1.3 Step-by-step offices with DTMF service

Certain step-by-step local offices provide DTMF service through the use of DTMF-to-dial-pulse converters located within the office. These converters translate the DTMF signals received from the customer's telephone into dial-pulse signals which are used directly to establish a connection through the step-by-step switching system. These converters must be disabled, once the call reaches the TSPS, to permit DTMF billing information to be transmitted through the step-by-step office.

4.2 Multiwink signaling

Multiwink signaling consists of a series of one to five short duration on-hook "winks" sent from the TSPS to the local office. It is used by

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* Alternatively, the telephone itself can be modified to permanently activate the dial.[1]

the TSPS to control the traditional functions of coin collect, coin return, and ringback (i.e., application of ringing signal), as well as the selective activation of DTMF or coin deposit signaling.

The multiwink signaling codes are shown in Table III. "Operator-attached" and "operator-released" are historical terms which identify the multiwink signals used to control the application of positive and negative battery, respectively, by the local office; their use does not necessarily coincide with the attachment or release of an operator. The last three codes are identified by the functions which they perform ("collect," "return," and "ringback").

Multiwink signaling has been available for several years between the TSPS and No. 5 Crossbar, Step-by-Step, and No. 3 Electronic Switching System (ESS) local offices. However, Calling Card Service represents its first system-wide application for providing DTMF signaling beyond the local office.

With multiwink signaling, the local office continues to apply positive battery toward the coin telephone upon connection of all calls to the TSPS. At the TSPS, incoming 0− and 1+ calls are connected to an operator or CDA circuit as appropriate. With positive battery applied, coin deposit signaling is available to handle sent-paid calls. Upon release of the call to a talking state (no operator or CDA circuit attached), the TSPS sends an operator-released signal to reverse the battery applied to the telephone. This activates the DTMF dial, thereby permitting its use by the customer for end-to-end DTMF signaling.

On sent-paid calls which require intermediate coin deposits, the TSPS sends an operator-attached signal, prior to connecting a CDA circuit, to enable coin deposit signaling. After the necessary charges have been collected and the CDA circuit is released, the TSPS sends an operator-released signal to once again permit end-to-end signaling by the customer.

On 0+ calls, the TSPS sends an immediate operator-released signal to enable the DTMF dial for the entry of billing information on calling card calls. If the customer subsequently decides to place a sent-paid call, the TSPS sends an operator-attached signal and the call proceeds in the same manner as a 1+ call. Otherwise, the DTMF dial remains

Table III—Multiwink signaling codes

Number of On-Hook Winks	Function
1	Operator released
2	Operator attached
3	Coin collect
4	Coin return
5	Ringback

activated for the duration of the call with no additional multiwink signals being sent.

4.3 Expanded inband signaling

Expanded inband signaling provides the TSPS with control over the same local office functions as multiwink signaling. Expanded inband signaling was developed to circumvent inefficiencies associated with scanning for multiwink signals in ESS local offices. It can be used between the TSPS and No. 1/1A ESS and No. 2/2B ESS local offices.

Expanded inband signaling is based on an earlier inband signaling system which utilized an alerting wink, followed by one of three multifrequency codes, to initiate the coin collect, coin return, and ringback functions. Expanded inband signaling incorporates three additional multifrequency codes to provide efficient control over the activation of DTMF and coin deposit signaling. Additional changes were made to the timing parameters of the earlier inband system (e.g., wink duration, delay, and tone interval) to enhance signaling reliability.

The multifrequency codes used for expanded inband signaling are identified in Table IV. Expanded inband signaling provides signals equivalent to the five multiwink signals. In addition, it provides a sixth signal which combines the coin collect and operator-released functions. The sixth signal is used following intermediate coin deposit requests on sent-paid calls and eliminates the need to send the coin collect and operator-released signals back-to-back.

One other difference between multiwink and expanded inband signaling is the state in which calls are connected to the TSPS. With expanded inband signaling, 0+ and 0− calls are initially connected to the TSPS with negative battery applied toward the coin telephone. Therefore, the DTMF dial is activated and remains so unless the customer subsequently decides to place a sent-paid call. In that event, the TSPS sends an operator-attached signal to enable coin deposit signaling.

As with multiwink signaling, the local office initially connects 1+ calls using expanded inband signaling to the TSPS with positive battery applied toward the coin telephone. The handling of these calls is similar to those using multiwink signaling, except that the sixth ex-

Table IV—Expanded inband signaling codes

Frequencies in Hertz	Function
900 + 1500	Operator released
1300 + 1500	Operator attached
700 + 1100	Coin collect
1100 + 1700	Coin return
700 + 1700	Ringback
1500 + 1700	Operator released/coin collect

panded inband signal is used in place of separate coin collect and operator-released signals following intermediate coin deposit requests.

4.4 Coin retention

The newly established coin retention protocol permits the entry of billing information and the origination of sequence calls from coin-first telephones. With this protocol, the return of the initial rate deposit, which was previously performed by the local office, is now initiated under control of the TSPS.

On 0− and 1+ calls, the TSPS sends a coin return signal to the local office prior to attaching an operator or CDA circuit. However, on 0+ calls the coin return signal is delayed. This leaves the DTMF dial enabled and permits the entry of billing information. If the customer successfully enters a calling card number, the return of the initial deposit will not be performed until the customer hangs up. This permits the customer to originate one or more sequence calls using DTMF signaling. If the customer flashes, keys 0 for an operator, or simply waits instead of entering a calling card number, the TSPS will send a coin return signal prior to attaching an operator.

4.5 Control of DTMF-to-dial-pulse converters

The distinctive tone used by the TSPS to prompt customers at the beginning of calling card calls also provides the TSPS with control over the DTMF-to-dial-pulse converters used in certain step-by-step local offices. The tone incorporates a # DTMF character which disables the converters when the call reaches the TSPS. Once disabled, the converters will not interfere with the transmission of DTMF billing information or the origination of sequence calls.

V. ACKNOWLEDGMENTS

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Stored Program Controlled Network:

Calling Card Service—Human Factors Studies

By D. J. EIGEN and E. A. YOUNGS

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Many new telephone services involve more customer-system inter-action than ever before, and making these services easy to use and error-free is a major development goal. Properly designed dialing plans, announcements, timing, tones, and instructions increase cus-tomer acceptance and minimize errors. These new services are de-signed from systematic analyses of present services, interviews with customers, laboratory studies of user-system interactions, field trials, and product follow-ups. Calling Card Service automates credit card service and allows the customer to bill a call to a special billing number, without an operator, from Touch-Tone* dialing phones. Based on a series of studies, the market need for Calling Card Service was established and the customer-machine interface was designed. An analysis of operator-assisted credit card service indicated that credit card calls could be automated. Interviews with customers verified an interest in, and a need for, Calling Card Service. More-over, laboratory studies indicated that customers could use the Call-ing Card Service successfully. In turn, these studies led to the design of a field trial, which combined and extended earlier studies and verified Calling Card Service performance and acceptance by cus-tomers.

I. INTRODUCTION

The introduction of Calling Card Service is in response to the Bell System's goals of providing improved services, stabilizing the operator work force near current levels, and minimizing increases in operating costs. Calling Card Service is automated and replaces current credit

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* Registered service mark of AT&T.

card service, which requires operator assistance.* The automated service is a preferred alternative for some collect and third-number calls.

Calling Card Service allows a customer at a *Touch-Tone*† dialing station to bill a long-distance call to a telephone number other than the one from which the call originates, without an operator—just as direct distance dialing allows billing of a long-distance call to the originating telephone without an operator. This is accomplished when the customer dials a billing number in addition to the called number— Calling Card Service. Such a service is expected to control costs and help serve the growing volume of credit card and other specially billed calls. Customers at unequipped *Touch-Tone* stations or at rotary stations will receive operator-assisted Calling Card Service.

Companion papers in this issue of *The Bell System Technical Journal* discuss in more detail the rationale for developing Calling Card Service.[1,2] This paper focuses primarily on a coordinated series of studies to measure customer reaction to Calling Card Service and to refine the customer-system protocol. Each study is discussed. Section II discusses the initial analyses of credit card calling, customer interviews, and laboratory studies. The field trial was by far the largest of the studies and is the principal subject of this paper (see Section III). Section IV describes the recommended protocol and discusses briefly the follow-up study of actual service.

II. EARLY STUDIES‡

2.1 Characteristics of operator-handled credit card calls

More than 80 percent of Bell System credit card calls are now handled by operators using Traffic Service Position System (TSPS). Operators enter the credit card number, given verbally by the customer, into the TSPS console. In automating credit card calls, it is useful to understand operator handling of credit card calls.

2.1.1 Operator work time on credit card calls

To assess the potential for automating credit card calls (Calling Card Service) the service observer records of 1538 credit card calls were analyzed.§ These calls were sampled from 25 representative TSPSs.

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* Where the automated Calling Card Service cannot be used, such as at rotary dial phones, operator assistance will still be available.
† Registered service mark of AT&T.
‡ Early in the planning for these studies, AT&T conducted interviews to test the concept of Calling Card Service. This study indicated that customers agreed with the utility of the Calling Card Service concept.
§ Service observers use a paper form (or computerized equivalent) to describe operator and customer actions during the initial phase of a call. As soon as the call completes, both the operator and the service observer leave the connection. Service observing is done on a very small sample of calls to verify that high-quality service is being maintained.

Each call record was examined for circumstances that would have made automating that call difficult. For example, person-to-person calls require an operator to assure reaching the proper party.

Figure 1 shows the operator work-time distribution, taken from the service observing records, and indicates which calls were considered automatable. The average time to handle a credit card call was about 20 seconds, but work time was highly variable. In contrast, those calls considered to be automatable averaged about 15 seconds work time, with low variability. The remainder, considered nonautomatable, averaged over 50 seconds work time, with very high variability. The general nature of this last finding was anticipated since operator assistance was often required in these cases. Person-to-person calls accounted for about one-half the nonautomatable calls, and their average work time was about 70 seconds.

The work-time analysis indicated that, if Calling Card Service were used on all possible calls, 15 percent of present credit card calls would still require operator assistance and 36 percent of present call-handling work time would still be used. Some additional saving might be expected if customers continue to migrate from collect and third-number calls, both of which require more operator time to handle than credit card calls.

2.1.2 Originating stations

Knowing what proportion of credit card calls originated at *Touch-Tone* dialing stations is another key determinant of the work-time savings, since the Calling Card Service would be available only at *Touch-Tone* dialing stations. A representative sample of credit card
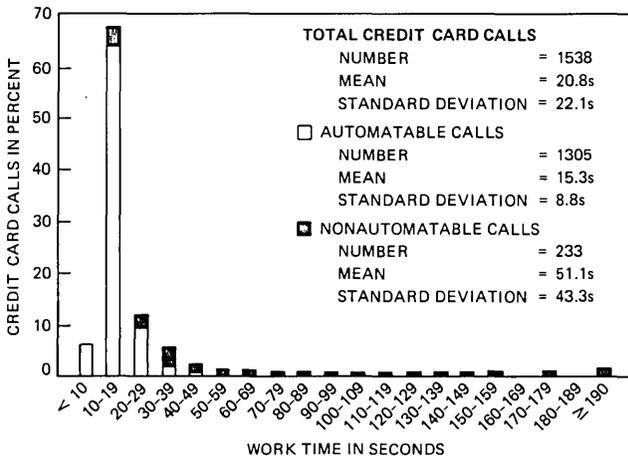

Fig. 1—Traffic Service Position System operator work times for credit card calls.

calls was traced to the types of stations from which the calls were made. Then, using the fraction of person-to-person calls and the fraction of nonautomatable calls mentioned earlier, the approximate fraction of automatable calls by originating station type was estimated. The results strongly supported the introduction of Calling Card Service at *Touch-Tone* dialing stations.

2.1.3 Distribution of calls among callers

The estimated potential for Calling Card Service has thus far been based on the premise that callers are willing and able to use the service. The degree of caller success and acceptance might be expected to depend on (*i*) how frequently users place calls, (*ii*) why they place calling card calls, (*iii*) where they originate calls, and (*iv*) how available the service is.

The success and acceptance of Calling Card Service is expected to grow with practice. Distribution of credit card calls is concentrated among a small number of credit card users. This leads us to expect rapidly increasing success rates initially (because of continuing user experience), slowing with time until an equilibrium success rate is reached. This equilibrium will reflect a balance between failures, attributed to less experienced users, and successes, attributed to more experienced users.

2.2 Opinions on potential Calling Card Service

So far we have discussed potential Calling Card Service users only in aggregate terms. To obtain additional detailed information and user opinions, frequent users of operator-handled credit card service were interviewed in two Bell Operating Company areas. When asked why they use credit card service, the most frequent answers were

(*i*) for accounting purposes, allowing the call to be billed to the appropriate bill payer,

(*ii*) for the ease and convenience of credit card service, and

(*iii*) because credit card service is preferable to paying with coins (at coin stations).

In fact, about one third of the respondents indicated that they would not have made their most recent credit card call had they not had the convenience of a telephone credit card.

Even though nearly 90 percent rated operator-assisted credit card service as good or excellent on a four-point scale (excellent, good, fair, poor), most customers preferred to dial the credit card number (Calling Card Service) rather than to use operator-assisted service. Most customers also indicated that they made several credit card calls in succession, at least "some of the time"—a finding which led to the

development of a protocol for placing sequences of calls, billed to the same calling card account, without having to reenter the calling card number for each new call. (See Section 2.3 below.)

2.3 Laboratory studies of Calling Card Service protocols

2.3.1 Placing a single calling card call

To obtain "hands-on" experience with a proposed Calling Card Service protocol, a laboratory minicomputer was programmed to control special-purpose hardware to simulate the service. Using the simulator, the proposed protocol timing and wording of announcements were adjusted and appropriate user instructions were developed. Then tests were run in which Bell Laboratories employees placed simulated calls. Calling Card Service procedures were systematically varied. These tests produced two important results:

(i) It was important to give users a tone to indicate when they could begin dialing their calling card numbers. Otherwise, even practiced callers frequently dialed too soon. That is, they dialed while simulated call control was being passed from the local office to the TSPS. During this switching interval, digits cannot be received. Without the tone, even experienced customers would have to listen for an announcement before dialing or risk having the attempt fail, resulting in slower service.

(ii) Overall, the procedure was acceptable and the brief instructions, designed to be printed on the calling card itself or on the public telephone instruction card, were adequate.

2.3.2 Placing a sequence of calls

Since many credit card users indicated during interviews that they sometimes place several credit card calls in succession, a procedure was devised to allow a sequence of calls to be placed without reentering the calling card number for each new call. In late 1979 and early 1980, simulation of this multiple call procedure was prepared on the laboratory minicomputer. Several conclusions about placing calls in sequence were reached on the basis of tests with this simulation:

(i) Callers were able to make a sequence of simulated calls, each beginning with the *Touch-Tone* telephone dial "#". Since successive calls may follow a call attempt terminating in ringing or busy, it is important to demonstrate that the presence of these network tones does not disturb users, nor strongly affect their success. Test callers, all Bell Laboratories employees, recovered quickly and naturally when network tones occasionally blocked initiation of the next call.

(ii) Callers were able to comprehend and follow the brief dialing

instructions, suitable for printing on the calling card itself or on public telephone instruction cards.

(*iii*) Callers followed the calling procedures correctly on about 90 percent of attempts, and they recovered from about 20 percent of their errors, yielding an overall success rate of more than 92 percent.

Figure 2 shows the resulting recommended protocol. Briefly, callers initiate a new call by dialing # either when the called party goes on-hook, or when they reach a busy or nonanswering line. If no digits are received or an error is detected, an error announcement requests a second attempt which, if unsuccessful, results in TSPS dropping the call after a suitable announcement.
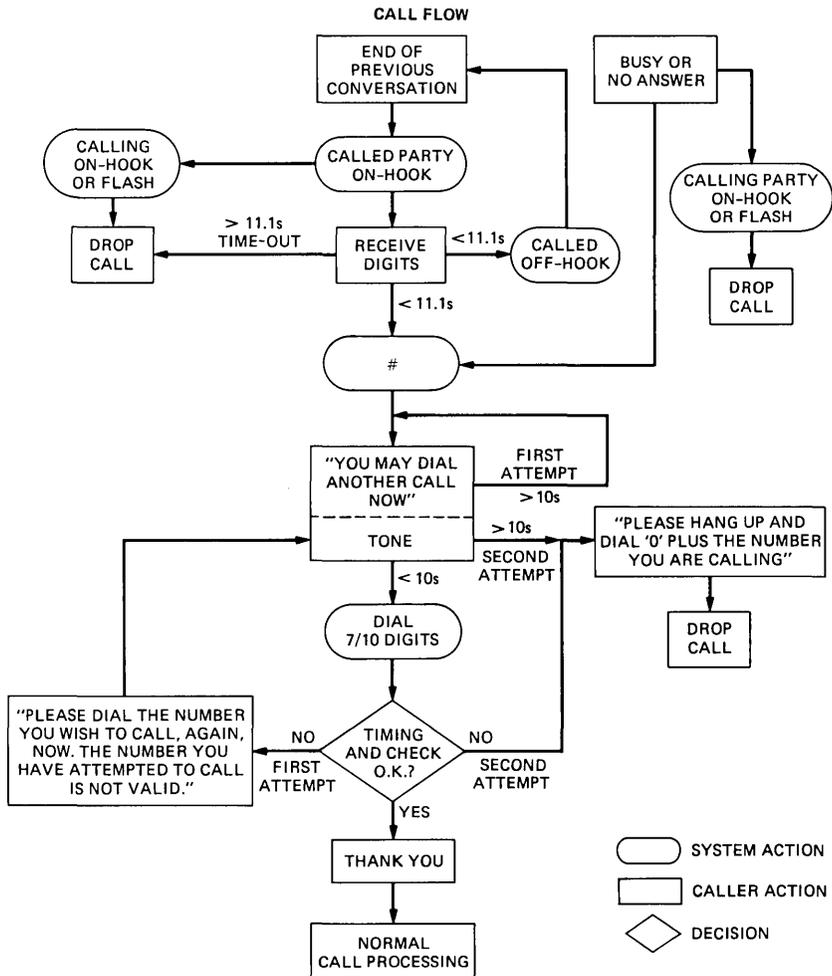

Fig. 2—Proposed sequenced calling protocol.

III. FIELD TRIAL

3.1 Trial overview

The Calling Card Service field trial was conducted in Milwaukee, Wisconsin, from November 1977 to June 1978.[3] Permission to conduct the trial was obtained from the Wisconsin Public Utility Commission prior to its start. Customers making the most credit card, collect, and third-number calls and responding to a mailed brochure describing Calling Card Service, were invited to participate in the trial. Four hundred twenty-five business and residential customers participated. Each customer received a unique 14-digit calling card number. In addition, regular telephone credit card numbers could also be dialed and they, in fact, provided most of the trial calls.

Calling card numbers or regular credit card numbers could be used to place automated calls from about 3000 noncoin phones in the Milwaukee area, and from 70 coin phones at Milwaukee's airport (General Mitchell Field), two downtown hotels, and a few local restaurants. Bell Operating Company marketing representatives distributed brochures giving instructions on how to use the service. Also, customers received additional instructions on special Calling Card Service cards. At some coin phones, placards were placed instructing customers on how to use the automated credit card calling service with the Bell System credit card. Moreover, operators were trained to assist callers and to answer questions.

To use the simulated Calling Card Service, customers first dialed zero, plus the number. Special programs in the TSPS routed these incoming 0+ calls from trial stations to a small team of specially trained operators who helped simulate Calling Card Service. In addition to a TSPS console, each operator had a terminal linked to a minicomputer (see Fig. 3).

When a call arrived from a trial station (see Fig. 4), a trial operator, using the console, notified the minicomputer. The minicomputer then delivered a tone to prompt the customer to dial a calling card number. (Calls from unequipped stations were handled by operators as usual.) Detectors received the dialed digits and sent them over a data link to the minicomputer for verification. Calls with valid calling card or credit card numbers proceeded and were billed appropriately.

Depending on the version of the protocol being tested, the minicomputer displayed appropriate step-by-step instructions on the terminal screen to guide the operator in handling each call. For example, to encourage customers to redial after making errors, the minicomputer might display to the operator: "Please hang up and dial zero, plus the number you are calling." The operator, in turn, read the message to the customer. By making simple changes in the minicomputer program, the operator's treatment of calls could be altered, often without
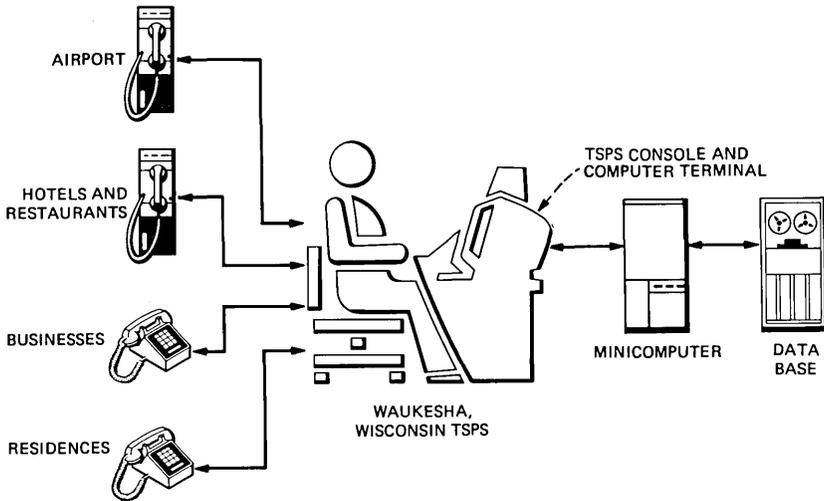
A TEAM OF OPERATORS HANDLED 0 + CALLS FROM THE TRIAL STATIONS. EACH OPERATOR HAD A
TSPS CONSOLE AND A VIDEO DISPLAY TERMINAL. THE TERMINAL WAS CONNECTED TO A
MINICOMPUTER, WHICH COLLECTED DATA ON EACH CALL AND PRESENTED GUIDELINES—VIA
THE TERMINAL SCREEN—TO DIRECT THE OPERATOR IN PROCESSING THE CALL, AND IN
SIMULATING RECORDED ANNOUNCEMENTS. IN AN ACTUAL SERVICE, NO OPERATORS ARE USED.

Fig. 3—Trial setup.

additional training. This flexible arrangement allowed for easy testing
of many protocol variants and rapid changes among them.

As noted, operators simulated recorded announcements by relaying
them orally to the customer. This method of communication was
chosen not only because it was flexible, but also because a previous
study indicated that customers strongly preferred natural-sounding
announcements.[4] In a trial environment, operators were able to provide
high-quality, flexible announcements.*

The minicomputer recorded the time and details of each call. These
records were analyzed rapidly to determine how the protocol could be
improved. Throughout the trial, protocols were varied by changing
announcements, timing, access to operators, error-correction proce-
dures, etc. In all, 24 variations of the protocol were tested at trial coin
phones and 14 were tested at noncoin phones. Each variation was run
long enough to establish its salient performance characteristics.

3.2 General trial results

Customers used the service successfully, repeatedly, and indicated
that they liked it. Quality of service was also maintained for those who

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* For trial purposes only, operators simulated the Calling Card Service to evaluate
user behavior, reaction, and acceptance of automated Calling Card Service. During
actual automated service, no operator is connected.

Fig. 4—Trial coin station placard.

did not wish to use the automated Calling Card Service. Different protocols were tested to determine the effects of varying operator accessibility, wording of announcements, and written instructions. The overall goals in testing the different protocols were to increase customer performance, usage, and satisfaction. Customer dialing performance and customer satisfaction are discussed in Sections 3.2.1 and 3.2.2, respectively. Section 3.3 gives an analysis of the effects of Calling

Card Service on other users. Also, specific service manipulations and findings are related in Section 3.4, and Section 3.5 gives some supporting information on sequenced calling.

3.2.1 Customer dialing performance

3.2.1.1 Frequency of customer dialing attempts. Customer-dialed credit card calls reached 60 to 70 percent of all credit card calls at trial coin phones for the most successful protocols. Customers were more apt to dial when an announcement requesting the caller to dial the card number followed an alerting tone. When only the alerting tone was transmitted, 40 to 50 percent dialed.

Results were similar at noncoin phones: Nearly 80 percent of credit card calls were customer dialed when the announcement was given; about 70 percent were dialed when only the tone was given. In addition to dialing their own calling card or credit card numbers, customers could obtain operator assistance. Operator assistance was also given on calls from nontrial stations, during heavy calling periods, or when customers dialed zero instead of the card number.

3.2.1.2 Frequency of customer dialing success. Eighty-five percent of first dialing attempts succeeded. An additional 5 percent succeeded on the second attempt; and 1.5 percent succeeded on the third attempt. However, as Fig. 5 shows, these averages do not give a complete picture of successful dialing.

First of all, protocols were changed frequently during the course of the trial. Some produced higher than average success rates, others,
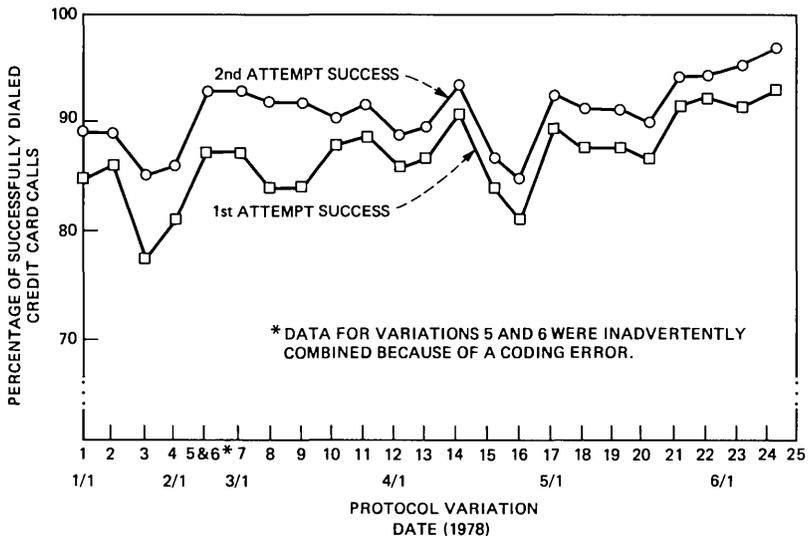

Fig. 5—Customer dialing success rate.
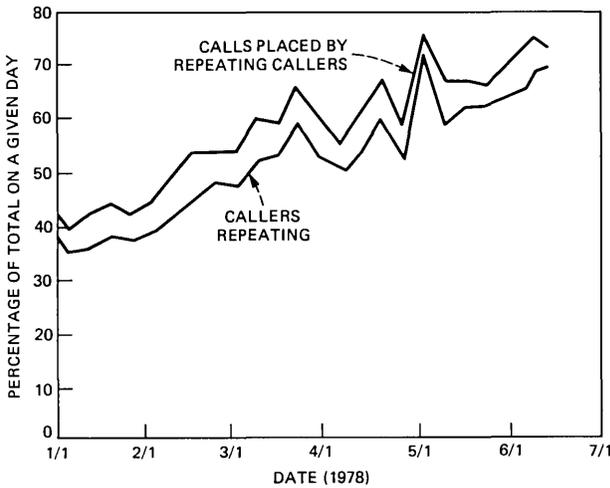
Fig. 6—Customer and call repeat rate.

lower than average. Second, protocols used late in the trial were generally better, because of continuing analyses and protocol refinements. However, the trend toward greater success is undoubtedly due in part to increased proficiency of repeating users. Separating these effects is difficult because callers could not be identified on calls where errors were not corrected. On balance, the best protocols might be expected, with time, to produce success rates in excess of 90 percent.

When customers erred on the first attempt, 45 percent attempted to dial again and 55 percent abandoned. Of those who made a second attempt, 65 percent succeeded. Of the customers who erred, 70 percent did so because they dialed too few digits before the call timed out.*

3.2.1.3 Frequency of repeated use. The percentage of callers on a given day who had placed calls previously during the trial is shown in Fig. 6. On the average, 46 percent of the customers on any day had used the service previously. Fifty-seven percent of the calls, on the average, were placed by these repeating customers. This indicates that many customers continued to use the service. Overall, more than 10,000 regular credit card customers successfully dialed over 28,000 credit card calls; about 6,000 made only one call from a trial station. One hundred twenty-two Calling Card customers dialed nearly 4,000 calls bringing the total to more than 30,000 customer-dialed calls.

3.2.2 Customer acceptance of Calling Card Service

As mentioned earlier, customers who successfully dialed calling card calls liked the service. On a four-point rating scale, they rated the

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* "Time out" is when allocated time elapses and the error sequence is triggered.

quality of their last call as slightly better than good. Customers who dialed unsuccessfully rated the same item lower, as shown in Fig. 7.

As shown in Fig. 8, customers liked dialing Calling Card Service calls. Customers who dialed their numbers generally indicated a strong preference for dialing, rather than having the call assisted by an operator, as we stated earlier. When asked why they preferred dialing to operator assistance, 48 percent indicated it was because of ease, convenience, or speed of dialing. Sixteen percent indicated that dialing eliminated repeating their billing number to the operator, 7 percent thought there would be fewer errors if the card number were dialed, and 6.5 percent mentioned that dialing avoided being overheard and, thereby, ensured greater billing number security.

Some customers said they still preferred operator handling—28 percent stated this was because they liked talking to the operator, and 25 percent stated that dialing the card number was no faster than having an operator handle the call.

Those customers who rated overall quality of service as either poor or fair indicated that it was difficult to locate trial telephones (31
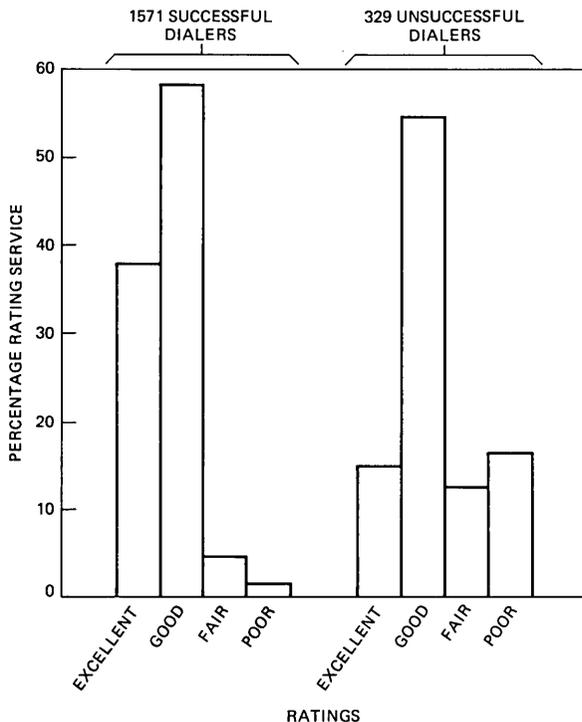
Fig. 7—Dialed credit card call "overall quality" ratings.
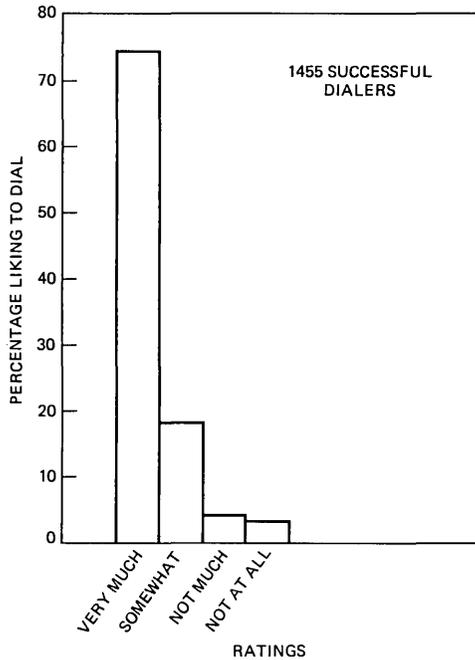
Fig. 8—"Liking to dial" ratings.

percent), and that Calling Card Service did not work correctly (29 percent). Other related reasons for downgrading service were that "the operator kept coming on the line" (10 percent) and that "the operators did not know enough about Calling Card Service" (8 percent).

3.3 Effects of Calling Card Service protocols on other callers

3.3.1 Abandonment

Quality service must also be maintained for callers not making calling card calls. Any caller following the normal TSPS 0+ dialing procedure at a trial phone was given the Calling Card Service protocol. Those who did not dial a billing number were routed to an operator. Some hung up (abandoned) before ringing started or before a busy signal was heard, or even before an operator was connected. The frequency of abandonments was closely related to the amount of time required to complete a service protocol variant. For example, both a tone-and-announcement protocol and a tone-only protocol, which required 23 seconds to complete, produced 24 percent abandonment rates. Abandonments declined with practice and shorter protocols. In the best tone-and-announcement protocol tried, abandonments were 7 percent for an 11-second protocol.

3.3.2 Service ratings by third-number and collect callers

Ratings of overall call quality and speed made by third-number and collect callers, who received the Calling Card Service protocol and were then assisted by the operator, averaged better than good, despite the presence of extraneous (delaying) information and protocols (see Fig. 9). Protocols which included a spoken dialing instruction were rated less confusing than those which presented only a tone. The dialing instruction also shortened the perceived operator answer delay.

3.3.3 Operator assistance

Several protocol variations were tested to determine how best to give callers access to operators, while encouraging the highest possible rate of caller dialing. At various points in the trial, callers could reach operators in one or more of three increasingly difficult ways—by waiting several seconds to time out, by dialing zero (after the tone), or by hanging up and dialing zero. Results indicated that removal of the time-out-to-operator option did not increase caller dialing but greatly increased abandonments. Therefore, we concluded that time-out (i.e., easy) operator access should be available.

In addition, noncalling card callers increased their tendency to dial zero (rather than wait) for operator assistance from about 2 to 25 percent after receiving an appropriate spoken instruction to dial zero. Thus, they demonstrated willingness to dial zero for quicker access to operator assistance.
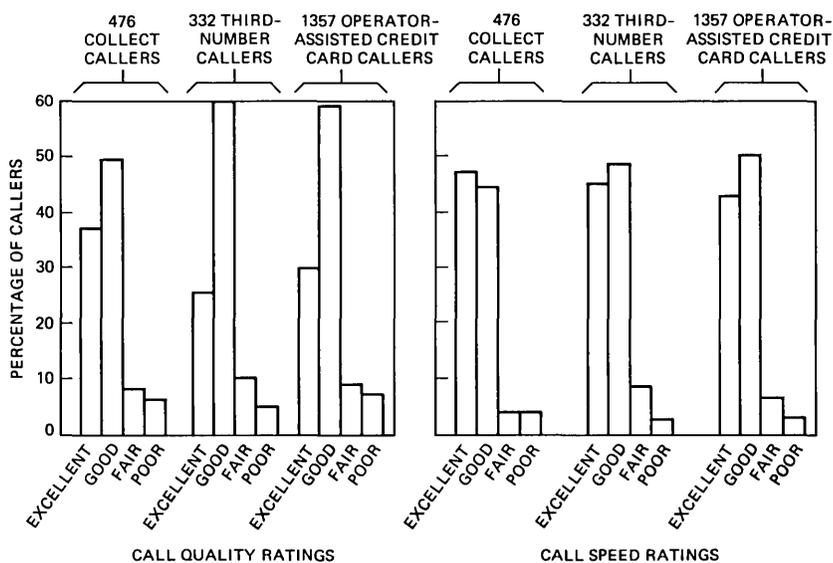

Fig. 9—Overall call quality and speed ratings for operator-assisted calls in the presence of Calling Card Service protocol.

In summary, the evidence suggests that noncalling card callers were not unduly disturbed by Calling Card Service protocols and that a substantial number dialed zero to avoid the additional delay inserted by instructions and time out. More avoided the delay when instructed to do so by the message: "··· or dial zero for an operator now." This instruction also improved service for calling card callers by increasing dialing and reducing confusion.

3.3.4 Service at unequipped stations

Service ratings were lowest when callers dialed and failed to obtain service. In one series of tests, rotary phone callers were verbally instructed to dial, even though the digits could not be received. (This condition simulated what would happen without the ability to selectively offer the service at *Touch-Tone* dialing stations only.) However, callers who failed when instructed to dial at rotary (unequipped) stations rated service no worse than those who failed for other reasons.

To selectively offer the service at *Touch-Tone* dialing stations, a special verbal instruction to discourage customers from dialing at rotary stations was tested:

"From pushbutton telephones only, please dial your card number or zero for an operator. (pause) From other telephones, please wait for an operator."

This instruction eliminated 95 percent of rotary station dialing of the calling card number, but it also suppressed dialing of the card number at *Touch-Tone* dialing stations by more than 10 percent. Customers reported being confused by this instruction at roughly the same rate as with other instructions tested. Ratings of overall quality and speed of this simulated Calling Card Service were slightly better than good.

However, the 10-percent suppression of dialing at *Touch-Tone* dialing phones is considered sufficient justification to make certain that prompts are made only at phones that provide the service.

3.4 Service manipulations

3.4.1 Dialing prompt effectiveness

As discussed in Section 2.3.1, laboratory tests indicated that a tone was necessary to signal users when to begin dialing their calling card number. In the field trial, prompting announcements were also systematically varied to study their overall effectiveness, as well as to select detailed wordings.

Several sources of trial data indicate that inexperienced callers are much more likely to dial their calling card number after a prompting

announcement is received rather than when it is not. The data also indicate that experienced callers dial reliably with only a tone signal to proceed.

Calling card and credit card number digits dialed before the tone were ignored. When the delay before the tone was decreased by 1 second, there was a significant decrease in the percentage of customers dialing before the tone. Therefore, it was concluded that the tone should be provided as soon as possible to minimize premature dialing.

At coin telephones with instructional placards, 15 to 20 percent more credit card callers dialed after a prompting announcement was received than when it was not received. This difference decreased slowly with caller experience. At coin phones without instructions, there was a 55-percent increase in credit card dialing because of the prompting announcement. These results suggest that prompting announcements are more effective than printed instructions alone for all but the most experienced callers.

Finally, customers were sensitive to wording of announcements. When the announcement "Dial your card number, please" was used, they appeared to have trouble understanding the directions. When "Please" was placed at the front of the announcement to help alert the customer, understanding increased. However, some customers still did not realize they were interacting with an automated service. Adding "or zero for an operator," after "Please dial your card number," lessened this kind of confusion. Adding "now" to the end of "Please dial your card number or zero for an operator" further reduced confusion between normal 0+ dialing and Calling Card Service dialing procedures. Systematic refinement of wording was found to be worthwhile. This observation was also made during the field trial of the Automated Coin Toll Service.[4]

3.4.2 "Thank-You" announcement effectiveness

A "thank-you" announcement was sometimes provided to callers who dialed correctly. However, when "thank-you" was not given during the trial, callers who had dialed a valid billing number waited in silence for ringing, busy, or other network sounds. As a result, those callers who had received prompting announcements abandoned more often. This may be because of abandonment by inexperienced callers who would not have dialed unless prompted to do so. To reduce these abandonments and provide more courteous service, a thank-you announcement was recommended.

3.4.3 Recovering from dialing errors

The 14-digit format of calling card numbers, combined with a file of valid numbers, virtually eliminates the possibility of billing errors

caused by errors in dialing. Consequently, when a caller misdials a calling card number, validation failure prevents the call from progressing until the error is corrected. In this situation, it is important for customer acceptance to provide an error-correction procedure that maintains billing security.

As shown in Fig. 5 and discussed in Section 3.2.1.2, callers succeeded on 85, 90, and 91.5 percent of attempts with 1, 2, and 3 tries, respectively. When an error was made, the caller received an announcement requesting another attempt. Several error-announcement wordings were tried. Again, wording was critical—some callers interpreted unrefined error announcements as failures to reach nonworking called numbers. This interpretation led to frequent abandonments.

However, when the error announcement immediately requested customers to dial again, e.g., "Please dial your card number again now," successful error recovery increased. A tone and prompting announcement, identical to that used at the start of the protocol, was also effective in stimulating error-recovery attempts. As at the start of the protocol, tones and prompt announcements were immediately truncated by dialing. Further, announcing incorrect digits back to the caller as part of the error announcement did not produce a significant increase in error recoveries.

Automatic operator access after repeated dialing failures was also tested. When operators were provided after repeated errors, no differences in dialing accuracy were detected. A customer who dialed and erred and required operator assistance could always obtain an operator by hanging up and dialing 0+ (or 0−).

3.4.4 Dialing time-out intervals

Calling Card Service dialing time-out intervals affect customer dialing success and acceptance of the service. During the trial, dialing time-outs were systematically adjusted, and the results were used to maximize overall dialing success and service acceptance without unduly increasing equipment holding times.

As mentioned, the calling card number is 14 digits long. It consists of either a 10-digit special billing number or a telephone number (NPA NXX XXXX), followed by a four-digit personal identification number (PIN). Thus, the 14 digits divide into four groups of 3, 3, 4, and 4 digits, respectively. As shown in Fig. 10, the interdigit dialing times depend on serial position. Trial data indicate that an interdigit time-out interval of 5 seconds and an interfield interval of 6 seconds will inappropriately time out less than 1 percent of the call attempts. The interval between fields 3 and 4 is an exception requiring 7 seconds to minimize false time-outs.

Experienced customers dialed faster. Figure 11 plots dialing time as
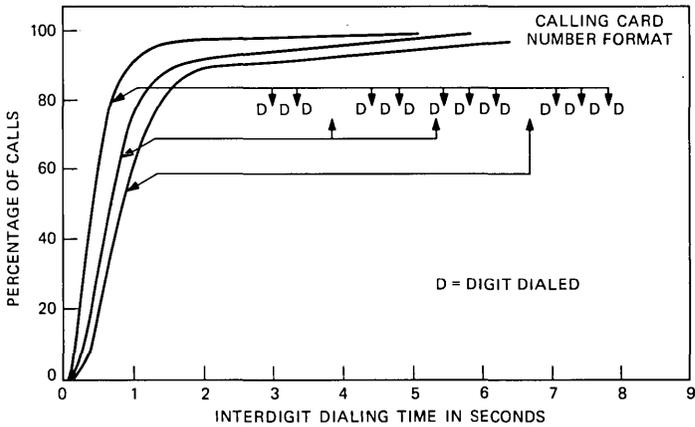
Fig. 10—Cumulative distributions of interdigit and interfield dialing times.
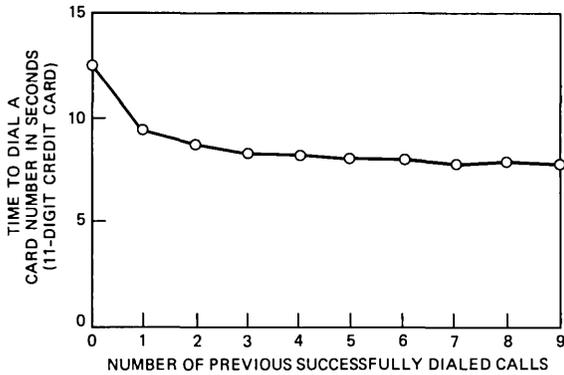
Fig. 11—Dialing time as a function of experience.

a function of experience. Customers reached asymptotic performance after about five successful calls.

3.4.5 Timing

The time between protocol events, such as prompts and operator access, has an important effect upon customer acceptance and performance. The trade-off is between rushing customers who would dial and being unresponsive to customers who require additional prompting or operator assistance. Generally speaking, trial data indicate that customers responded within 7 seconds of any prompt. Detailed timing data were used to make the final protocol recommendations.

3.4.6 Customer dialing instructions

Several types of dialing instructions were available during the trial. The instructional placards (bright orange) on trial coin phones were

CUSTOMER DIALS 0 +

(LOCAL OFFICE DELAY)

TSPS RECEIVES CALLING AND CALLED NUMBERS

EQUIPPED STATION ?

NO

YES

TONE

"PLEASE DIAL YOUR CARD NUMBER OR ZERO FOR AN OPERATOR NOW." *

DIALS NPA-NXX-XXXX-NXXX

DIALS 0

NO DIGITS DIALED

VALID?

YES

"THANK YOU"

PROCESS CALL

NO

A

A

"PLEASE DIAL YOUR CARD NUMBER AGAIN NOW. THE CARD NUMBER YOU HAVE DIALED IS NOT VALID."

TONE

"PLEASE DIAL YOUR CARD NUMBER."

DIALS NPA-NXX-XXXX-NXXX

NO DIGITS DIALED

VALID?

YES

"THANK YOU"

PROCESS CALL

NO

"PLEASE HANG UP AND DIAL 0 PLUS THE NUMBER YOU ARE CALLING. THE CARD NUMBER YOU HAVE DIALED IS NOT VALID."

"PLEASE HANG UP AND DIAL 0 PLUS THE NUMBER YOU ARE CALLING."

DROP CALL

SYSTEM ACTION

CALLER ACTION

DECISION

* ANNOUNCEMENT AT PUBLIC STATIONS ONLY

Fig. 12—Recommended Calling Card Service protocol.

surprisingly successful in persuading credit card customers to dial. The placard increased dialing 200 percent above the level at phones without placards. As discussed earlier, the prompting announcement was effective at phones with and without placards. Also, operator instructions produced a 4-percent increase above and beyond other instructional methods.

3.5 Sequenced calling

While sequenced calling was not offered in the field trial, data were gathered which indicated a need for this capability. Twenty percent of the credit card customers at coin stations made more than one call at a time. Some spontaneous comments from customers suggested the need for a sequenced calling capability. When asked, 67 percent of the trial Calling Card Service customers said such a capability would be useful. As indicated earlier, laboratory results were used to refine the sequenced calling protocol (see Section 2.3.2).

IV. RECOMMENDED CALLING CARD SERVICE PROTOCOL

Figure 12 illustrates the recommended protocol for public telephone Calling Card Service. Only public stations provide the prompting announcement. (A few trial customers complained about having the calling card announcement on their phones.) Placards are recommended for public phones initially. To use the Calling Card Service, callers can dial zero, plus the number they are calling. Then, after the prompt, they can dial their calling card number. The more experienced customers can dial immediately after the tone and, thereby, prevent the prompt announcement. Callers requiring operator assistance can dial zero or simply wait for the operator.

The recommended protocol was first implemented at Buffalo, New York, in July 1980. Service evaluation measurements developed for the field trial were installed. This was done to allow a detailed follow-up of the actual service. Preliminary results from follow-up studies have, to a remarkable degree, corresponded to results of the field trial.

V. ACKNOWLEDGMENTS

site evaluation interviewing. R. Michelsen, A. J. Sawyer, J. C. Dalby, and R. Welch each played an important role in the design of the field-trial facilities, and J. P. Delatore, E. M. Prell, C. B. Rubinstein, D. W. Heckman, and S. M. Bauman supported the field study. Finally, we especially thank Wisconsin Telephone Company personnel, including J. J. Wyssling for contributions to the success of the Calling Card Service field trial.

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Stored Program Controlled Network:

800 Service Using SPC Network Capability

By D. SHEINBEIN and R. P. WEBER

On April 25, 1982 the Federal Communications Commission approved the Bell System tariff for Expanded 800 Service. In the approval the FCC noted that the new features would "provide subscribers with operational and call routing flexibility previously unavailable." This service marks the first use, on a ubiquitous nationwide basis, of powerful call control capabilities provided by the stored program controlled network. This paper reviews the application of these capabilities to our 800 Service.

I. BACKGROUND

The 800 Service, which at one time was called Inward Wide Area Telecommunications Service (INWATS), allows a customer to establish an area of the country from which he or she can receive calls without charge to the calling parties. In the United States, the service is currently available for both intrastate and interstate calls. Tariff rates for the interstate 800 Service, for example, are currently based on the number of customer lines, the band of rate state or service area selected, the monthly hours of usage, and time of day. Over the last decade, the volume of 800 Service calls has increased to the extent that its traffic has become a substantial percentage of all toll calls served by existing telephone switching systems. The service has proven to be especially useful for business customers providing travel and hotel reservations, purchase orders, and credit verification, and in direct marketing applications. About one-third of the customers have unlisted 800 numbers, while many other numbers are heavily advertised on television and in newspapers and magazines.

Despite the commercial success of 800 Service, the ever-expanding

customer demands for the service and the manner in which that service is provided in the Public Switched Network have presented a number of problems for the telephone industry and its customers. Prevalent among the problems are the following:

(i) The requirement for a multiplicity of 800 numbers

(ii) Routing and numbering inefficiencies because of the service band screening operation

(iii) Ineffective attempts because of all-customer-lines-busy conditions

(iv) Network overloads because of mass calling to 800 numbers advertised on television

(v) The rigid geographical service band structure

(vi) The absence of traffic statistics for customers on the points of origin of their calls.

II. SERVICE TODAY

A customer purchases the service on an intrastate and/or interstate basis and is supplied with one or more 800 numbers. Such an arrangement is necessary because of current state and federal tariffs which require separate usage measurements and lines for intrastate and interstate calls. Interstate 800 Service is currently offered in six geographical bands relative to the state (more specifically the rate state) of the customer. Band 1 generally involves all states bordering the customer's home state; band 2 includes all of band 1 and additional states bordering band 1. This continues through band 5, which covers the continental United States and includes Puerto Rico and the Virgin Islands, and band 6 adds Hawaii and Alaska. In some cases, multiple bands of intrastate are also offered. Billing is done by clocking the call at the terminating local central office. A recent tariff change has been filed which provides for a usage-sensitive tapered schedule.

2.1 Previous method of routing calls

Figure 1 illustrates how 800 Service calls used to be routed through the network. The calls were routed by means of ten-digit numbers, the first 6 digits of which consist of two special three-digit codes. The first three digits were always 800. The second three digits consisted of an NXX code (N = 2 to 9; X = 0 to 9), corresponding to the terminating area code. One or more NXX codes were assigned to a particular area code. The first nine digits of the 800 number were associated with a particular band. This association was known only at the Terminating Screening Office (TSO) serving the particular NXX. NX2 codes were used for intrastate 800 Service.

When a customer dialed an 800 number, the call was routed to an Originating Screening Office (OSO), which was a toll switching office
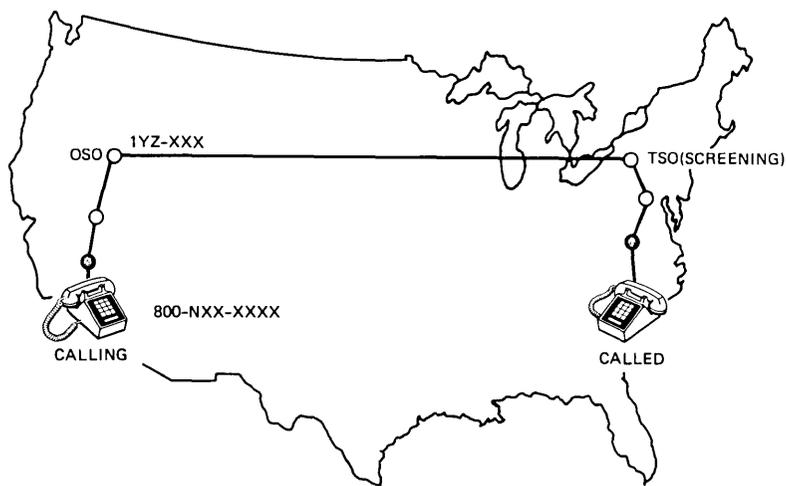
Fig. 1—Previous routing method.

capable of 6-digit translation. If an OSO served multiple rate states, adjacent rate states converted the 800 to 00X before sending the call to the OSO. In either case, by examining the first six digits of the call, the OSO determined the TSO to which the call was to be routed. The OSO then deleted the first six digits, substituted a 1YZ code (or code-converted the 800 to 08Z, if the call was to be routed through an intermediate office), the Y being an abbreviation for the NXX, with respect to the TSO which serviced up to five different NXX codes, and the Z indicating the rate band from which the call originated. The call was then routed to the TSO. By translating the first six digits it received, the TSO determined whether the call was permissible and, if so, the location of and routing to the local central office. The TSO then deleted the 1YZ code, prefixed an 0XX code or a directing digit for the local central office, and set up the call.

The problem with the above method of operation, developed over a decade ago in the era of electromechanical switching, was that it was inflexible. However, considering the technology available at the time and the desire to implement the service utilizing existing network capabilities, it was a most clever design and illustrates the robustness of the Public Switched Network. The system was based on communication using the ten-digit routing plan and six-digit translation capabilities. This resulted in routing restrictions, utilization of special codes, and constrained network management.

III. STORED PROGRAM CONTROLLED NETWORK

The Stored Program Controlled (SPC) Network, a network of proc-
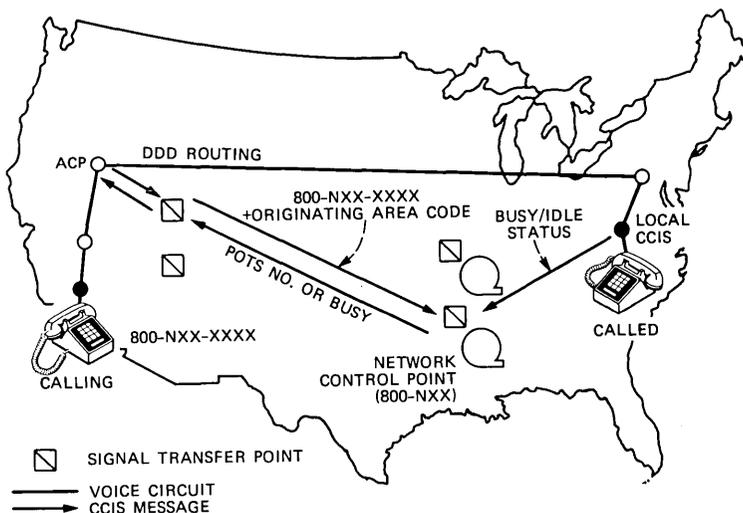
Fig. 2—Improved 800 Service.

essor-controlled offices interconnected with a packet signaling system (Common-Channel Interoffice Signaling—CCIS), removed many of the restrictions that existed. All nodes in the SPC network are able to communicate with one another. The SPC network is being augmented with CCIS-accessible processor-controlled data bases. These new network elements are called Network Control Points (NCPS). Such a configuration allows switching offices called Action Points (ACPS) to send inquiries to specific NCPS to find out how to proceed with the establishment of a call.

The 800 Service is one of the first call types to make use of this new technique. All 800 Service calls are routed to CCIS-equipped switching offices. Initially, this capability is in No. 4 ESS, No. 4A-ETS, and No. 1/ 1A ESS CCIS offices. Such offices send a CCIS message to the NCP to do the band screening operation. If the screening passes, a special unlisted telephone number is returned to the CCIS office which then sets up the call as any other DDD call. Billing is still being done at the terminating local office. Figure 2 illustrates how 800 Service calls are being routed through the network using the SPC network.

Under this approach, local offices equipped with CCIS would inform the data base of the busy/idle status of their 800 Service line groups. This would enable the network to stop ineffective attempts to busy 800 Service lines at the CCIS OSO office, where the busy signal would be returned to the caller. It is anticipated that in the future, calls may be routed to an alternate location when the data base recognizes a busy condition at the terminating location.

3.1 Data base configuration

The processor-controlled data bases, called network control points, which are to support this operation, are centrally administered by the AT&T Long Lines Department. They load information pertaining to each 800 Service customer into the data base. A more detailed discussion of the administration network is provided in the paper entitled "800 Service Using SPC Network Capability—Network Implementation and Administrative Functions," appearing in this issue of *The Bell System Technical Journal*. The NCPs are located at several of the CCIS Signal Transfer Point (STP) sites. The STPs are totally redundant and are engineered for mate-failure situations. The NCP on mate STPs are likewise redundant and engineered for mate NCP failure. NCPs in different switching regions contain different data. Each NCP pair is identified by a set of 800-NXX codes. It is the responsibility of the STPs to translate the 800-NXX code and route the message to the correct NCP. The STPs will be made aware of the NCP failures so that they could route the messages to the mate NCP.

IV. 800 SERVICE CALL PROCESSING

4.1 Action Point

The ACP is any CCIS-equipped switching office, toll or local, with the appropriate generic program. It is the job of the ACP to identify the incoming call as 800 Service, identify the area code from which the call originated (by incoming trunk classification or by examining an 00X code that a previous office substituted for the 800 code), format and send a CCIS inquiry message to either one of the STPs it homes on, and wait for a response. The CCIS message sent to the data base includes the dialed number (800-NXX-XXXX), the call's originating area code, the CCIS return address of the ACP, and a call identifier so that the response can be associated with the proper call.

The data base response contains either a special unlisted telephone number, a busy or closed indicator, an out-of-band indicator, or a vacant-line indicator. The call is then either set up as a normal DDD-routed call or given an appropriate announcement tone. A second message could be received with respect to an inquiry—a network management message. Such a message indicates that the data base has determined that a mass calling event is occurring to that particular 800 number and that a control action is requested at the ACP. The message would contain a gap interval of from a few seconds to 5 minutes. For the next 5 minutes the ACP will only allow calls to the affected number, spaced the specified interval apart, to be completed. This control would protect the voice network, the CCIS network, and the data bases from the overload effects of mass calling to particular

800 numbers. The process of detecting mass-calling events and determining appropriate gap intervals will be discussed later.

4.2 Network Control Point

The job of the NCP is to screen the call and translate the received 800 number into a nondialable yet routable "plain old telephone service" (POTS) number. This translation could depend upon the originating area code, the busy/idle status of a customer's line group, the time of day, or the day of the week. The NCP retrieves the file associated with the 800 number and checks the originating area code against a list of allowed area codes (band purchased). If this operation passes, an area code to POTS number translation is made. The 800 numbers may be associated with one or more such POTS numbers. Associated with each POTS number could be a schedule of the customer's opening and closing times for the week, an alternate POTS number, and a busy/idle bit. The process of updating this bit will be discussed later. An alternate POTS number may be assigned under the busy condition. If a call is allowed to transfer from one POTS number to the next, looping conditions are cared for.

V. NETWORK ADVANTAGES

5.1 Network management

The data base is in a unique position to detect, control, and monitor mass-calling situations. Mass calling to 800 numbers occurs frequently and is usually caused by these numbers shown on television. All calls to a particular 800 number go to the same data base for screening and translation. The data base monitors the number of attempts in each 5-minute interval against every 800 number. If a threshold, determined by the number of lines a customer has purchased, is exceeded, then a control action is taken. The thresholds have been picked so that even customers with relatively short holding times could maintain extremely high occupancies without setting off the control. The initial control tells the ACPs, when they send inquiries to the affected number, to space future calls at some initial gap interval for the next 5 minutes. The data base then monitors the effect of the control and either increases or decreases the gap interval in an effort to keep the attempt volumes equal to the threshold. These automatic control capabilities are backed up by manual control actions.

5.2 Busy/idle status indicator

The availability of CCIS at local offices will allow the removal of ineffective 800 Service attempts that are caused by an all-lines-busy condition. Local offices so equipped will send an all-lines-busy message to the NCP when the last line of an 800 Service line group goes busy.

An idle message will be sent when any line of the group goes idle. A 5-second interval between busy and idle messages is required to add stability and to ensure that the messages do not get transported because of CCIS retransmissions. As stated earlier, the data base under an all-lines-busy condition will tell the ACP to give the busy tone rather than set up the call. If the busy bit has been set for an 800 Service line group for approximately 5 minutes, the data base will send an audit message to the local office to verify the busy condition. This will ensure that a customer cannot mistakenly get locked into the busy state.

Simulations have shown that approximately the same amount of signaling resources are saved by eliminating the setting up of the ineffective attempts as are used to transmit the busy/idle messages. Thus, it appears that the Busy/Idle Status Indicator (BISI) feature would yield, with no signaling costs, significant switching and trunking savings.

5.3 Other network advantages

The new method of establishing 800 Service calls has many network advantages associated with it. The terminating screening office function was eliminated. This resulted in more efficient routing and network management control of 800 Service calls. Numbering inefficiencies were eliminated, mass calling can be detected and controlled, busy attempts will be eliminated from the network, special routing codes were freed, and the directory assistance and intercept processes were simplified.

VI. POTENTIAL SERVICES

One of the major advantages to the new method of routing 800 Service calls is that a great deal of flexibility is inherent in the architecture. As described above, the data base makes the translation from 800 number to POTS number be dependent on many parameters. This allows the network to act as a customized automatic call distributor. Hence, new customer services become possible from the new architecture. Of course, any new services would be subject to the filing and approval of appropriate tariffs. Some examples of potential new services follow:

- *Single Number*—Allows for a combination of inter- and intrastate services, under a single 800 number, so that customers will no longer be required to advertise multiple 800 numbers.
- *Permanent Number*—Allows a customer to move to a different part of the country without changing his or her 800 number.
- *Customized Number*—Enables a customer to have easily remem-

bered numeric combinations for their 800 number, where available.

• *Variable and Customized Call Handling*—Allows customers to distribute calls based upon the originator's area code, the time of day, and/or day of the week.

• *Call Detail Information*—Provides a customer with a listing of all or a sample of call attempts itemized by call-originating area code.

As a case study, consider a customer that operates five regional reservation centers. Under today's 800 Service they would advertise five interstate and five intrastate 800 numbers. Furthermore, they can either staff all five centers 24 hours a day, use private lines between centers for after-hour coverage, or simply lose after-hour calls. With the new system, subject to tariff considerations, they will have just one 800 number to advertise, with the call being routed to the closest open-reservation center.

VII. COORDINATION

An extreme amount of coordination and cooperation was needed to provide, on a universal basis, features like the ones described in this paper. Timing for introduction of the improved 800 Service was important. Since, for universal service, all 800 Service calls had to be routed to CCIS-equipped offices, large trunking penalties could have resulted from a rapid implementation before sufficient CCIS availability. However, a delay in the implementation could have resulted in losing the early network advantages and marketing potential of these features. Transition and implementation plans were developed which allowed us to convert the past method of operation into the SPC network method. This required the development and loading of new generic software at No. 4 ESS, 4XB/CCIS, and No. 1/1A ESS (additional generic software is required to support local CCIS and the BISI feature), and a new STP generic to handle signaling to NCPs, NCP hardware and software, and a new centralized administration system.

The capabilities described in this paper are good examples of the potential of the SPC network and what we believe will be its ability to yield cost savings, as well as features to meet future customer needs.

Stored Program Controlled Network:

800 Service Using SPC Network Capability— Network Implementation and Administrative Functions

By C. W. HAAS, D. C. SALERNO, and D. SHEINBEIN

(Manuscript received September 15, 1981)

This paper describes the network elements and administrative functions affected by the implementation of the new method of operation for 800 Service. The new method of operation affected all existing network elements and required significant coordination of the implementation of the necessary modifications to meet the service dates. In addition, a new element being introduced into the network, called a Network Control Point (NCP), required the creation of a complete administrative plan.

I. INTRODUCTION

The 800 Service, which allows a customer to receive calls without charge to the calling party, has specific network and administrative methods of operation. In the previous paper on the 800 Service by Sheinbein and Weber, appearing in this issue of *The Bell System Technical Journal*, the change in the method of operation to use the Stored Program Controlled (SPC) Network and the use of centralized data bases called Network Control Points (NCPs) were discussed. With this new method of operation, the previous network and administrative methods were reviewed, adjusted, or totally changed. The network implementation involved changes in the type and characteristics of the Originating Screening Offices (OSOs), Signal Transfer Points (STPs), NCPs, trunking, routing, and overall coordination. The administrative changes primarily affected service provisioning, but they also had a significant impact on service maintenance, network maintenance, net-

1745

work administration, and network management. Sections II and III of this paper describe these changes.

II. NETWORK IMPLEMENTATION

To structure the network for transition from conventional 800 Service routing to the new common-channel interoffice signaling (CCIS) routing technique utilizing centralized data base translations, a plan with specific guidelines was established. A system letter was issued by AT&T to the Bell Operating Companies (BOCs) describing the CCIS 800 Service operation, equipment requirements for network nodes, network trunking needs, and plans for POTS routing. Specific dates were established for implementation activities and the BOCs were advised to establish project teams to provide overall coordination. The primary members of these teams were the CCIS coordinators for network implementation concerns and the 800 Service product managers for marketing and tariff activities.

2.1 Originating Screening Offices

Earlier sections of this issue of *The Bell System Technical Journal* discussed the SPC network and described the function of an Action Point (ACP). To review, an ACP is a switching office that has the capability to communicate with an NCP. The OSO will perform the ACP functions for 800 Service. Under the previous 800 Service routing arrangement, any switching office equipped with proper translation tables could function as an OSO. However, in the SPC network, CCIS OSOs (800 Service ACPs) are required to have CCIS capability to allow for initiating inquiry messages to a centralized data base for screening and translation. Initially, the only switching systems capable of providing the CCIS 800 function are No. 4 ESS (equipped with Generic 4E4) and No. 4A ETS (equipped with Generic 4XC2). No. 1 ESS and 1A ESS offices will be capable of CCIS OSO operation with Generics 1E7 and 1AE7 planned for 1982 and 1983, respectively.

In addition to updating software with the new generic, the 4A ETS offices required hardware modifications. Upon receiving dialed 800 Service calls, a sender must be able to function as a sender/outpulser. This means that the sender must be able to release and outpulse the terminating customer's DDD-routable number,* which was received from the NCP. This modification was required for all senders at a 4A ETS/CCIS office functioning as an OSO.

Upon establishing the number of CCIS-OSOs, all operating telephone companies planned to establish the trunks that would route dialed 800

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* The number returned from the NCP is a network-routable but not a customer-dialable number.

Service traffic to these new OSOs. The prerequisite for a CCIS OSO was established requiring that it must function as a conventional OSO prior to CCIS activation. This requirement forced a reduction from the over 200 available OSOs to approximately 124 that would be equipped for CCIS and CCIS-OSO operation.

2.2 Signal Transfer Point direct-signaling generics

To perform the function of sending inquiry messages via CCIS from ACPs to NCPs, a new feature—direct signaling—was required in the signaling network. This feature necessitated a new generic in all Signal Transfer Points (STPs). The new generic (4XS2 for those STPs that also served as switching systems and 1STP2 for stand-alone STPs) was first available in September 1979. Conversions to the new generic began in September 1979 and completed with all STPs converted in April 1980.

Direct signaling provides the capability for the STP to route messages based on the first six digits of the dialed number. Thus, for 800 Service, inquiry messages will be routed to the appropriate NCP via the CCIS network, based also on the first three digits which are 800 followed by the NXX.

2.3 Network Control Point

Network Control Points (NCPs) are centralized data bases that contain call-handling information to perform the band-screening functions (the determination of whether the call originated from an area subscribed to by the purchaser of the service) and translate the dialed 800 number to a standard ten-digit DDD-routable number of the customer's destination. New features that will be introduced with this new method of operation are based on the ability of further expansion of the translation at the NCP. This expansion will allow different DDD numbers to be returned for routing based on customer's requested routing. The NCP is a 3B2OD processor-based system described in more detail in other sections of this issue. The NCPs are individually duplexed systems that are deployed in 800 Service in mated-pair arrangements. For 800 Service, each pair will contain the data base for a subset of 800-NXX codes. Each member of the pair, a duplexed processor, will perform translations for half of the data as its primary responsibility and will perform translations of the other half of the data only in case of failure of the mate. The mate contains a copy of the same data base information but performs its primary and secondary functions in exactly the mirror images of the mate, i.e., what is primary data in one processor is secondary in the other. Each processor is traffic-engineered to 50 percent of its capacity during normal operation, which allows for carrying the total traffic (it and its mate) in the event of a mate failure.

The NCPs are connected to the CCIS network via dedicated inter-

processor (I) links to an STP. The NCPs are colocated with STPs. For initial service to accommodate all 800 Service data base requirements, seven pairs of NCPs were deployed: two pairs each at the St. Louis, Missouri, Dallas, Texas, and Denver, Colorado regional STPs, and one pair at a new pair of STPs within the Denver region. All NCPs were installed, operated, and maintained by AT&T Long Lines.

Installation of the initial NCPs began during the fourth quarter of 1980 and completed in September 1981. Cutover to service commenced on September 1, 1981 with the first two pairs in the St. Louis region, and completed with the seventh pair in the Denver region on November 1, 1981.

2.4 Trunking plans and POTS routing

One of the major network benefits of CCIS 800 Service is the ability to use DDD-routable translations and routing. As discussed in the Sheinbein and Weber paper, the use of a centralized data base for band screening and translation to a DDD-routable number allows the elimination of the Terminating Screening Office (TSO) function in the network. Since TSOs were located high in the network hierarchy, 800 Service traffic was routed over trunk groups to class 1 or 2 switching offices and, in many cases, utilized final trunk groups. This routing is inefficient since the call must eventually terminate at the class 4 office. Eliminating the TSO function allows traffic to be routed from the OSO over high-usage trunk groups as directly as possible to the serving office, consistent with standard traffic engineering rules.

To effect a transition from conventional to CCIS routing of 800 Service traffic, AT&T Long Lines had to plan additional trunking in the high-usage groups. These were engineered and provided in the 1981 construction program. The removal of TSO trunking is planned for in the 1982 construction program.

Another factor in converting to DDD-routable numbers is the number assignment in the serving office where the customer's 800 Service terminates. In many offices, the line number used in conventional 800 Service routing was assigned from the available numbers in the office NXX code. In these cases, this number is a ten-digit code, routable from anywhere in the network. However, in other locations where line numbers suitable for 800 Service were not available in the central office code, pseudo codes were established and the routing information for this code is only known at the TSO, the serving office, and in some cases the intermediate office. As a result, completion to these numbers is only possible by routing through the TSO. Therefore, the BOCs and independent operating companies (IOCs) had to assign a ten-digit DDD-routable number for these lines. This is now possible since the tens

block restriction on line assignments of the 800 Service conventional routing plan is eliminated with the new CCIS/NCP technique.

Conversion to DDD-routable numbers is under the control of the BOCs and IOCs for their respective territories. To effect this DDD routing, the BOC and IOC needed to load the ten-digit number into the data base for translation from the dialed 800 number. For those locations where DDD-routable codes are used in conventional 800 Service routing, this step occurred as soon as the NCPs were activated. At locations where pseudo codes were used, local translation changes and, in some cases, wiring changes were required before the POTS record could be activated at the data base. Therefore, a time period was allocated for BOCs and IOCs to complete conversion to DDD-routable numbers. The beginning of this period was determined by the activation date of the NCP that contained the specific 800 NXX assignments (September 1 to November 1, 1981) and was completed by February 1, 1982. This completion date was set since the 1982 trunking plan assumed that DDD routing was in effect and TSO trunking eliminated.

2.5 Cutover strategy

Since 800 Service is national in scope, cutover to the new CCIS operation without service impairment would be difficult. A plan was needed to allow the orderly activation of 124 OSOs and 14 NCPs. The plan was centered on the ability of an STP, whose NCP is not yet installed, to turn around inquiries, destined to the NCP, back to the CCIS-OSO. The format of the response looks to the CCIS-OSO as if it came from the NCP, except that a DDD-routable number is not yet available. The St. Louis, Dallas, and Denver STPs were initially equipped with the turnaround translation to return the dialed 800 number to the OSO.

As discussed previously, after February 1982, the NCP will contain only DDD-routable numbers. However, during the transition, the NCP or the STP may return an 800 number, and special arrangements to handle such responses were devised. Upon receiving an 800 number as a response to a data base inquiry, the OSOs will revert to conventional 800 Service operation and route the call to the appropriate TSO for completion. Activation of the CCIS-OSO function at OSOs began in May 1980 and continued each weekend until August 1981. All STP locations were equipped with 800-XXX routing information to direct inquiries to the proper STP and, thus, the NCP location. This step was completed in the second quarter of 1980.

The final step in cutover to CCIS 800 Service occurred during the September-November 1981 period with activation of the NCPs. Prior to this time, the normal installation procedures and acceptance testing took place and the operational responsibility of the processor was

officially turned over from Bell Laboratories to AT&T Long Lines. Loading to the data base occurred during the two weeks immediately preceding cutover. Service activation of the NCP occurred by activating the I-links to the STP and removing the 800 turnaround feature. All inquiries were then routed to the NCP for data base translation.

2.6 Coordination of implementation activities

The implementation of CCIS 800 Service required the close coordination of activities of a large number of organizations. In addition to the normal first application support activities performed by Bell Laboratories and Western Electric, coordination between AT&T, Long Lines, and the BOCs was vital to an orderly implementation. To provide this coordination, an 800 Service Network Implementation Committee was formed in October 1980. The committee, under the chairmanship of a representative of AT&T Network Design, consisted of representatives from various AT&T Network departments, Long Lines, Bell Laboratories, and Western Electric. This committee, which met monthly, was charged with monitoring the implementation progress of all network activities for CCIS 800 Service. This included identifying critical issues and taking corrective actions, coordinating all network activities, monitoring NCP installation progress, and providing central project control.

III. ADMINISTRATIVE FUNCTIONS

Development of a new 800 Service capability within the network necessitated careful study and definition of the needs of a Bell System operational environment. The operational plan must adequately support both the services that would utilize the capability and the network entities that would provide the capability. The administrative plan for the 800 Service capability encompassed five primary operational functions:

* Service Provision—The process that includes the tasks performed from the time a customer orders service to the time the service has been installed in the network and made available for the customer's use.
* Service Maintenance—The process invoked by a report of impaired service, initiated either by a telephone company (BOC, IOC, AT&T Long Lines) procedure or by a customer report, that covers the tasks of verifying, sectionalizing, and repairing the reported troubles.
* Network Maintenance—The process, peculiar to specific elements in the network, that guides the analysis of a problem, localization of trouble, and repair of that specific element. This process is

either keyed by a self-diagnostic alarm condition of the element or is triggered by service maintenance procedures.

- Network Administration—The set of tasks associated with monitoring the performance of elements in the network to ensure optimizing the load-handling capability of each element.
- Network Management—The process that monitors indications of abnormal network operation and supports the implementation of controls that will minimize total network harm.

Since 800 Service was an existing Bell System offering, there was already in place an operational set of methods, procedures, and tools that covered all of the above functions. The challenge of developing an administrative plan for 800 Service capability was not to create a total set of processes from the ground up but, rather, to identify the unique functional requirements in a manner that would blend with the existing operational environment. With this as an objective, a functional analysis of the total set of administrative needs was conducted. The results of that analysis indicated that the aspects of network maintenance, administration, and management that were related to the ACPs and the STPs could readily be applicable to the work centers and operations systems that were already responsible for those network elements. Since the NCP was being initially introduced into the network, a complete administrative plan covering network maintenance, administration, and management had to be created for this new element.

The functional analysis also indicated that major augmentation of the provision and maintenance processes for 800 Service would be required to accommodate the new methods of call routing that were being introduced by the CCIS-800 Service capability. The remainder of this paper will focus on the administrative plan developed for the NCP and on the new aspects of service provision and maintenance that will apply to the range of services that utilize the CCIS-800 Service capability.

3.1 Service provision process

As described in other papers in this issue of The Bell System Technical Journal, the major change in the network architecture was the introduction of the NCP and its related translation data base. The data base contains, for each 800 number, the following specific parameters required to successfully complete a call initiated to the 800 number:

(i) Valid originating area codes based on purchased area
(ii) POTS number translations for interstate and intrastate calls
(iii) Desired translations based on particular time of day or day of week

(*iv*) Alternative translations based on busy condition of primary line.

Obviously, the source of this information is the 800 Service customer. The primary new task in the service provision process is to capture that information and condition and place it in an NCP data base (and its mate data base). Procedures existed in each BOC and IOC to generate service orders, institute billing procedures, and ensure that the physical installation of the service took place. A key work group in those procedures was the Dialing Service Administration Center (DSAC), formerly called INWATS coordinators. The role of the DSAC was expanded to include the responsibility of deriving from a service order the information that would have to be provided to the NCP data base for 800 Service. To assure the integrity of that information, transform it to a form usable by the NCP, and deliver it to the proper NCP, a centralized Bell System Operations System was designed by AT&T Long Lines. The system, designated as the Network Support System-800 Service (NSS-800), provides on-line, dedicated access by each DSAC location. The DSAC interacts with the system to obtain and reserve unique 800 numbers. When a service order is issued, the DSAC again interacts with the system to enter required information about the service and a service date. These data are validated as they enter the system. Within NSS-800, a customer profile record is created. Twenty-four hours prior to the service date, NSS-800 will retrieve the customer profile record, format it for the NCP, determine the primary and mated NCPs that are to receive the record, and load the record into the appropriate NCPs. The NSS-800 is connected via dedicated 4800-baud private lines to every NCP in the network. The system will look for an acknowledgment from both NCPs (primary and mate) to ensure that the record was properly distributed. If both acknowledgments are not received, the system will alert the work center responsible for NCP data administration. That work center is the Operations Network Administration Center (ONAC), a Long Lines Network Services work group located in Kansas City, Missouri. The ONAC was created to coordinate the overall flow of service provisioning information from the DSAC organizations, through NSS-800, to the NCPs. The ONAC is responsible for managing that information flow and ensuring that any malfunctions in the flow are promptly repaired. In addition to this role in the service provision process, ONAC provides an important ingredient to the service maintenance process.

3.2 Service maintenance procedures

The placement of translation data bases throughout the network offers the potential for a customer-affecting trouble caused by a data record error. The previously existing maintenance plan for 800 Service

was expanded to include procedures that would effectively locate and clear possible data-related problems. Customer trouble-reporting procedures remained unchanged, being handled either by Special Service Centers (SSCs) or Repair Service Bureaus (RSBs). These centers will use existing procedures to verify, sectionalize, and clear physical plant problems. If it is ascertained that the customer reported problem could be data-related, the responsible work center (SSC or RSB) will contact their local DSAC and request their assistance. The DSAC has direct access on the NSS-800, and through on-line inquiry, it can audit customer record content, as well as determine which version of the record is contained in the NCP data base. If discrepancies are discovered, DSAC can transmit immediate corrections to NCPs through NSS-800. The ONAC has access to additional capabilities in NSS and, accordingly, the DSAC may contact ONAC and request their assistance on more difficult troubles.

In addition to serving as the tool that DSAC and ONAC can utilize to respond to trouble reports, NSS-800 is programmed to periodically audit the contents of the NCP data base. The NSS-800 retrieves each record in the primary data base and mate data base and compares them with the current active record entered by DSAC. Any discrepancy discovered in this comparison is reported to ONAC for reconciliation.

3.3 Network management

As mentioned above, NSS-800 is directly linked to each NCP to allow real-time data interactions between the NCPs and ONAC and the DSACs. The NSS-800 also serves to link the NCPs to the Network Operations Center (NOC) in Bedminister, New Jersey, so that the network management aspects of the CCIS-800 Service capability can be monitored and, if necessary, controlled in the case of mass calling to any 800 number. The NCP data base has been designed with automatic control capabilities that monitor attempts to each 800 number, compare those attempts against a threshold value and, when necessary, instruct OSOs to limit the volume of calls directed to that 800 number. When this control is initiated by an NCP, a message is sent to the NOC via the NSS-800. Thus, the NOC is alerted to the calling conditions occurring on the network. The NOC personnel can assess overall network performance and, based on their analysis, can elect to override the controls initiated by the NCP.

As described above, the NSS-800 and the ONAC provide the primary augmentation to the service provision and service maintenance processes to support the CCIS-800 Service capability. In addition, NSS-800 supplies the NOC interface to the NCPs to support the network management process. While the system was developed primarily to satisfy these functions, its role in several adjunct functions was identified.

Since the system became the collector of all 800 Service customer records, it was the logical source of information for the 800 Service Directory Assistance (DA) process. A mechanized interface was developed between NSS-800 and the 800 DA processor in Kansas City, Missouri. Each night, record changes that have been entered into NSS-800 by the DSACs are transmitted to the DA processor where they are conditioned and forwarded to the 800 Service DA centers.

The NSS-800 also provides a mechanized interface to the Centralized Message Distribution System (CMDS) in Kansas City. The information provided is the correlation between an 800 number and the translation that will exist in the network. This correlation is necessary for CMDS to correctly provide source data for the traffic engineering processes that it supports.

3.4 Network Control Point maintenance

The introduction of the NCP as a new network element required the development of a maintenance and administration plan for that entity. The basic design of the NCP, similar to other SPC-based elements, included self-diagnostic and self-repair capabilities. Primary interfaces for local craft personnel and for the No. 2 Switching Control Center System (2-SCCS) were provided. Because of the close relationship between the NCP and the CCIS network, it was desirable to provide NCP performance information to the work centers responsible for CCIS network performance. These centers are the CCIS Electronic Switching System Assistance Center (CESAC) located in Columbus, Ohio, and the zonal CESACs located in San Francisco, California; Denver, Colorado; Chicago, Illinois; and White Plains, New York. The centers are provided access to the data they need via a centralized Bell System Operations System, designed by AT&T Long Lines, called the Network Control Point Administration System (NCPAS). The NCPAS is directly linked to every NCP in the network and collects processor performance data from each NCP. These data are stored and formatted into reports that can be retrieved by CESAC and zonal CESACs. The reports are also received by the local craft personnel at each NCP location. The local craft personnel can be connected to NCPAS through the NCP itself. This arrangement removes the burden of formatting and storing report data from the NCP and provides the users with the flexibility to redefine report structure and content without incurring NCP development cost.

3.5 Network Control Point administration

Administration of the NCP processors encompasses two discrete functional processes. The first of these is definition of the software of each NCP: What service will the NCP be expected to handle (800 Service, Automated Calling Card Service, etc.) and what customer records

(800-NXX, NPA-NXX) will it contain? This software definition is contained in the NCPs "specification file." These decisions are made in an engineering process and provided to a national Long Lines work center, the Engineering Network Administration Center (ENAC). The ENAC uses the NCPAS to structure the specification files for each NCP, format them, and distribute them to the NCPs involved. Once the service specification has been distributed in this manner, there is a second function, the complementary administrative function, to be performed. Since the distribution of services and records among the NCPs is based on a forecast, it is necessary to monitor the actual call attempts that each NCP is handling to ensure that the engineering distribution is correct. The NCPAS is the vehicle used by ENAC to perform the monitoring function. When redistribution is appropriate, ENAC will use NCPAS as described above.

3.6 Traffic measurement collection

Embedded in the design of the NCP software is the capability to measure various attributes of the call attempts handled by each NCP. These data are valuable to the engineering or network provisioning and marketing processes that evaluate various aspects of a service offering. There is also a requirement to capture network usage statistics that will be used in the separations process. Although the NCP collects these types of data, it cannot analyze them. Accordingly, AT&T Long Lines developed a national Bell System Operations Support System called the Network Control Point Data Collection System (NCPDS). This system is linked to each NCP and collects the traffic measurement data generated by the NCPs. Sampling rates for the particular data to be captured by each NCP are set by ONAC and ENAC using NSS-800 and NCPAS, respectively. The NCPDS serves as a centralized data store that can provide the information needed by engineering and marketing processes.

3.7 800 Service record

At the time of implementation of the 800 Service capability using the SPC network, there were almost 200,000 customer lines for 800 Service. Records pertaining to each of these lines had to be verified, expanded to include valid POTS translations, and then loaded into the appropriate NCP data base. The source data for these records was resident in the BOCs and IOCs and existed in various forms and states of accuracy. The transformation of these data to a validated and consistent form that could be loaded into the NCPs represented a substantial task for the Bell System. To effect the necessary controls on the conversion process and to minimize the manual work effort, AT&T Long Lines developed a mechanized process that utilized two

existing 800 Service data records, Wide Area Telecommunications Services (WATS) Information System, and 800 Directory Assistance, plus a mechanized record of 800 numbers from those BOCs and IOCs that had one available. These records were compared and used to develop an initial load of the NSS-800 data base. Various reports indicating discrepancies resulting from the comparisons were furnished to each involved BOC and IOC. The NSS-800 was made available in December 1980 to all the BOCs and IOCs to allow them to complete and purify their records. All on-going service-order activity was entered into NSS-800 to build as complete and accurate a data base as possible before actually loading the NCP data base.

3.8 Network Support System-800 characteristics

The NSS-800 is implemented on a large-scale IBM main frame (3032) computer located in Rochelle Park, New Jersey. The machine is dedicated to the NSS-800 application. In addition, a second processor (IBM 3168) is available to sustain the system functions required to interface with the NCPs if there is a failure of the primary processor. In the unlikely event of a catastrophic processor failure at Rochelle Park, full-scale remote site restoral capability is provided in White Plains. The system uses the Information Management System (IMS) data base management/teleprocessing software package from IBM. Each line between NSS-800 and an NCP has a dedicated backup. These lines are all terminated on a COMTEN 3650 front-end National Cash Register processor that has been designed to support the BX.25 level 1, 2, and 3 protocol.

3.9 Network Control Point Data Collection System characteristics

This application has been implemented on the NSS-800 backup processor described above. Data related to 800 Service and its customers is fed indirectly to NCPDS from the NCPS via an IMS EXIT routine in the NSS-800. Processor traffic measurement data are fed from the NCPs directly to NCPDS. The COMTENs terminate simplex lines from NCP. This arrangement efficiently uses the processing power that has been provided at the Rochelle Park site.

3.10 Network Control Point Administration System characteristics

The NCPAS is implemented on two DEC 11/70 processors located in Freehold, New Jersey. Both processors utilize the *UNIX** operating system. One processor acts as a front-end, handling the communications interface to the NCPs (duplex lines) and supporting the BX.25

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* Trademark of Bell Laboratories, Inc.

level 1, 2, and 3 protocols. The second processor handles the network administration applications. The ENAC, located in Cincinnati, Ohio, is connected to NCPAS, and the zonal CESACS are provided with dial-up capability.

3.11 Center and system impact

While the introduction of the NCP and its translation data base has a dramatic effect upon the capabilities of the network, the impact on the operational environment required to support those capabilities was minimized. Two new national work centers (ONAC and ENAC) were identified, the role of DSAC was expanded, and three centralized operations systems were developed. The functions of both the centers and systems are intended to be consistent with the network capabilities. While the initial implementations are geared to 800 Service, the design of both the centers and systems is hoped to easily accommodate any new customer services that employ the SPC network capability.

IV. SUMMARY

The technical implementation of the CCIS 800 Service required modifications in all existing call-processing elements, as well as the addition of the new network element, the NCP. The administrative implementation affected service provision, maintenance, network administration, and network management. Clearly, such a new capability impacts how we provide service today and required the coordination of all elements of the Bell System-Bell Laboratories, AT&T, AT&T Long Lines, Western Electric and, most critically, the BOCS, as well as the IOCS. Without their cooperation, such a network capability could not have been implemented.

Stored Program Controlled Network:

Data Base Administration System—Overall Description and Operational Characteristics

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Large amounts of data about every customer line number and billing number in the country must be available for the Stored Program Controlled (SPC) Network features to operate. A method of obtaining, organizing, and cleansing the data or administering the necessary network data bases was needed. While much of the data could be obtained through each telephone company's service order system, these systems vary substantially in capabilities from one company to another and even from one region to another of the same company. To obtain the data, a new support system called the No. 2 Data Base Administration System (DBAS) was designed and new operational procedures for the telephone companies were developed. The DBAS interacts with all types of service order systems to obtain the data; provides initial load, as well as immediate and routine updates for the network data bases; and handles customer queries, statistics, special studies and other administrative functions off-line for the data bases. This minicomputer-based system bridges the gap between the telephone company paper flow and the SPC network. The DBAS provides reliable data in a timely fashion to the network to ensure the viability of the initial features. It provides a general capability for administration of additional customer data which may be required for future SPC network features.

I. INTRODUCTION

As discussed in companion articles of this issue of *The Bell System Technical Journal*, large amounts of data on every customer billing

number (a line number or special billing number) in the country must be available to various nodes in the SPC network for the network features to function properly. (See Ref. 1 for a discussion of the on-line data bases.) A method of obtaining, organizing, and cleansing the data, that is, administering the network data bases or Billing Validation Applications (BVAs), is needed. While the data can be obtained through each telephone company's (Bell or independent operating company) Service Order System (SOS), these systems vary significantly in capabilities and design from one telephone company to another and even from one region to another of the same company. Further, no existing telephone company administration system had all of the SOS data currently used or envisioned for SPC network features.

To obtain the data and provide the administrative functions, a new support system called the No. 2 Data Base Administration System (DBAS) was designed. [The No. 1 DBAS administered data bases in Automatic Intercept System (AIS) switching machines.] The operations of the Data Base Administration Center (DBAC), the telephone company center which operates the DBAS, were revised to reflect its new capabilities.

By defining a specific interface, DBAS interacts with all types of SOSs to obtain the necessary data. The DBAS will accept data link, magnetic tape, and manual clerk input, thus functioning in all of the modes of telephone company data entry for SOS information.

The DBAS is connected by one dedicated data link to each BVA containing billing number records administered by that DBAS. It is expected that, in most cases, there will be only one or two BVAs attached to a single DBAS, although the DBAS is designed to handle up to four BVAs. Backup links are also provided for use when dedicated link failures occur. A backup terminal, connected to each BVA by a dedicated link, is located at the DBAC for use in accessing the BVA.

The DBAS provides the means for initially loading, as well as updating, the BVA. It is also capable of auditing the BVA for inconsistencies and of restoring some or all of the BVA, if a catastrophic failure (both active disks and both backup disks are lost) occurs at the BVA. From the telephone company's viewpoint, the DBAS is the primary repository for the information that comprises the BVA, and for the information that is needed to administer the various features. That is, the DBAS contains a superset of the BVA information. (The BVA contains only those items needed by the requesting nodes for the on-line processing and billing of calls.) This superset of BVA information is stored in a data base at the DBAS. The DBAS also handles customer inquiries, statistics, and other administrative functions associated with the SPC network features. Thus, these functions are performed off-line from the switching network.

This minicomputer-based system bridges the gap between the telephone company paper flow and the SPC network. The DBAS provides reliable data in a timely fashion to the network to ensure the viability of the initial features. It provides a general capability for administration of additional customer data which may be required for future SPC network features.

II. SERVICE ORDER DATA

All customer Billing Number Record (BNR) activity originates in either a Public Service Marketing Center, Residence Service Center, or Business Service Center. The AT&T recommendation is for the record of this activity to be transmitted by service order. Standard Universal Service Order Codes (USOCs) and Field Identifiers (FIDs) have been developed to accommodate all data required to support Calling Card Service features. However, some companies may also transmit selected data by miscellaneous form or memo. All data are obtained from completed service orders with the exception of public, semipublic, and coinless Originating Station Treatment (OST) data, which are obtained from precompleted service orders.

Both the DBAS and BVA data bases are designed so that the data forwarded by the SOS are stored by utilizing the 10-digit telephone number (NPA-NXX-XXXX) or special billing number (RAO* 0/1 XX-XXXX) as the address. Furthermore, the data themselves are logically grouped into four categories corresponding to the features offered by Calling Card Service. These categories are as follows:

(i) Originating station treatment—The service order contains USOC information for each line, indicating whether that line has Touch-Tone† or rotary dial capability. It may also contain, at the customer's request, FID information if special OST is desired. These data are used to determine the protocol returned to the calling station (Tone, Tone and Announcement, or Operator Assistance) on 0+ calls.

These data are translated by the SOS and transmitted in the appropriate format to the DBAS.

(ii) Public telephone check (PTC)—The service order also contains a USOC which identifies the class of service for each line, i.e., residence, business, public, semipublic, or coinless. These data are used to determine if special operator handling is required on collect or bill-to-third-number calls.

(iii) Billed number screening (BNS)—The service order contains an FID providing toll billing exception for those customers that request

(a) no collect or bill-to-third-number calls

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* Revenue Accounting Office.
† Registered service mark of AT&T.

(*b*) no bill-to-third-number calls

(*c*) no collect calls.

(*iv*) Calling Card Validation—Finally, the service order contains a USOC which indicates the assignment of Calling Card service. This information is transmitted from the SOS to the Customer Record Information System (CRIS). The CRIS, upon receipt of these data, uses an algorithm to generate a four-digit personal identification number (PIN) which is associated with the billing number. On a daily basis, the CRIS system forwards the billing number + PIN information to the DBAS.

A block diagram indicating the source and flow of data is shown in Fig. 1.

In summary, BNR information is recorded on service orders. This information is then transmitted by locally developed SOSs directly to DBAS and CRIS. The CRIS generates Calling Card Service information and transmits these data to the DBAS.

III. SYSTEM ARCHITECTURE

The detailed system architecture of DBAS is the subject of a companion paper appearing in this issue. However, a high-level description of the architecture will be provided here as an aid to the reader in understanding the remainder of this paper.

Figure 2 is a simplified block diagram showing the functional relationship of the No. 2 DBAS programs associated with processing updates to the DBAS and BVA data bases.*

As noted previously, updates are entered into the DBAS from paper records, magnetic tape, or via high-speed data link. The DBAS programs associated with these three types of data entry are CLERKIN, READTAPE, and LINKIN, respectively. These programs check the data input for syntax, completeness, and self-consistency, and they output a logical grouping of 1 to 256 updates called a session file. Each completed session file is linked both to the Journal Program (JURNL) and order processors. The journal program copies the sessions to magnetic tape so that they may easily be reinput if a system malfunction should occur before they are completely processed.

Operating independently from JURNL, the order processor programs also begin their work. For a given update, the associated BNR information is retrieved from the data base and, using this additional information, further consistency checks are performed on the input record. If the record passes the checks, the DBAS data base is modified and an update for the BVA is generated. When an entire session is

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* Programs associated with processing AIS and TSPS updates are not shown.
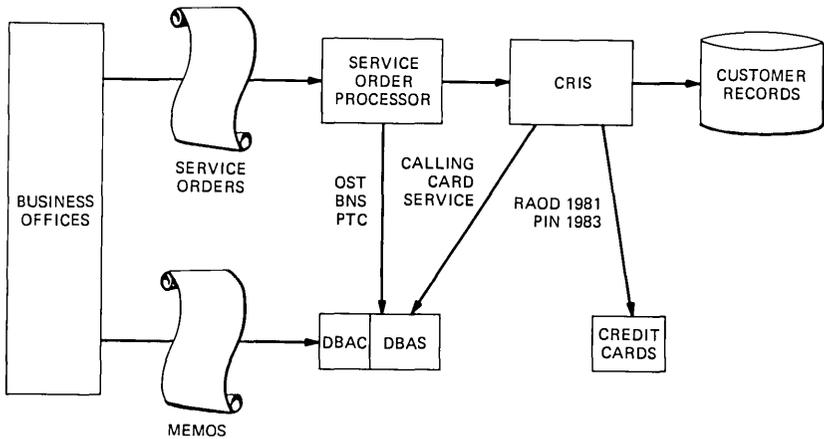
Fig. 1—Service order process.
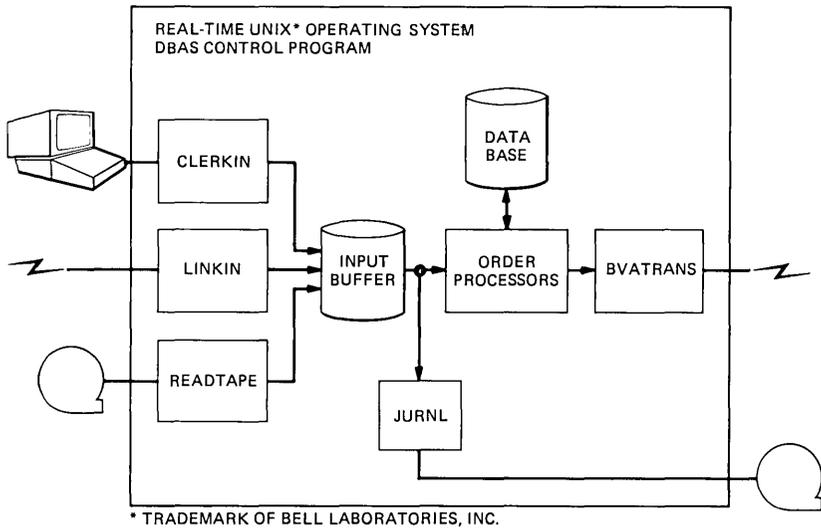
* TRADEMARK OF BELL LABORATORIES, INC.

Fig. 2—Data Base Administration System 2DB3 system architecture. (AIS and TSPS programs and interfaces not shown.)

processed, the associated group of updates (also called a session) is passed to the BVA transmission program (BVATRANS).

If a session passed to BVATRANS is designated high priority, BVATRANS will immediately transmit the associated updates to the BVA. All other sessions will wait until a designated time, usually during the middle of the night (the lowest traffic period for the BVA), to be processed. At that time, BVATRANS will sort the updates in order of

BNR (to save BVA real time) and transmit the sorted updates to the BVA.

The CLERKIN, READTAPE, LINKIN, JURNL, order processor, data base, and BVATRANS programs are discussed in more detail in the following sections.

IV. CLERK INPUT—CLERKIN

The clerk input process (CLERKIN) serves as the vehicle for manual entry of data into the DBAS system. Data are entered by clerks from as many as 24 terminals. The Universal Service Order (USO) is assumed to be the input source for these data. However, the CLERKIN package provides a flexible approach so that telephone companies not adhering to standard service order types can use other sources such as business office memos and verbal contacts.

The CLERKIN program has two modes of operation: a command mode and an update mode.

4.1 Update mode

The update mode is used to enter information into the DBAS. Thus, the major portion of the clerk's interface with CLERKIN occurs in this mode. It is assumed that a CRT is the standard terminal used to enter service order data. However, since hard copy terminals are also supported, CLERKIN determines the type of terminal (as defined by the system administrator) and behaves accordingly. Actions not applicable to a hard copy terminal (cursor positioning, screen erasing, etc.) are eliminated.

Thirty-two questions (prompts) totally define all input fields needed by DBAS to administer AIS, PTC, OST, BNS, and Calling Card Service data. This count includes spares for future expansion. Clerks are prompted for relevant information needed to complete an update. It is the clerk's responsibility to respond to the prompt, locate the data on the service order, and enter it via the terminal. Generally, clerks need not analyze the service order to determine the appropriate data to enter—this function is performed by CLERKIN itself.

To facilitate the location and entry of data, question prompts and valid responses generally match corresponding fields on the actual service order. Question texts are similar to the USO FIDs, and responses match the USOCs that follow them.

The CLERKIN program takes all reasonable steps to ensure a correct update. All syntax errors and consistency errors in the update are detected and reported as soon as possible. Also, potential data base errors are prevented by applying checks on the billing number as soon as it is entered by the clerk. The CRT screen is controlled by CLERKIN in the update mode. This control provides a clear and concise format

Table I—Clerk command summary

Commands	Action
Session Commands	
cancel	cancel the current session
list	list session file names
print	print session file(s)
remove	remove session file(s)
send	end the current session
update	enter updates into the current session
Retrieve Command	
getbr	get billing number record
Miscellaneous Control Commands	
clrbng	clear the billing number group
exit	exit the clerk input process
help	print helper dialogue
setbng	set up a billing number group
poadmin	perform pending order administration

for the clerk. Update data does not scroll off the screen, and is thus always available for inspection.

4.2 Command mode

The command mode allows clerks to perform various high-level tasks outside of their normal entry of updates. Unlike the update mode, clerks direct CLERKIN by specifying the particular command they want it to execute.

Commands can be logically grouped into the following three categories: (*i*) session commands, which allow the clerk to enter the update mode, terminate the current session, and recall sessions; (*ii*) retrieve command, which allows the clerk to retrieve billing number records from the DBAS data base; and (*iii*) miscellaneous control commands.

Command lines are entered in response to an asterisk. The asterisk means that CLERKIN is in the command mode and is ready to accept commands from the clerk. The command line format is as follows:

$$\text{Command(options)(arguments)}\langle CR \rangle.$$

The command name must immediately follow the asterisk prompt and uniquely identify the command that the clerk wants to execute. The remainder of the line may contain options and arguments that are passed to the named command.

A summary of commands available to the clerk is given in Table I.

V. MAGNETIC TAPE INPUT—READTAPE

The tape input process (READTAPE) is an interactive program used to input data from a magnetic tape in a specified format. It performs two functions: It reads externally generated input tapes and it reads journal tapes for restoral of the DBAS data base and/or AISS. The READTAPE program performs syntax and consistency checks on the

input data. Errors found are printed on the DBAC line printer for subsequent investigation.

The magnetic tapes read are industry standard, nine-track, and employ recording methods and densities which meet the American National Standards Institute (ANSI) specifications. Both 1600-cpi, Phase Encoded (PE) and 800-cpi, non-return-to-zero, change-on-ones (NRZI) tapes can be utilized.

Input tapes must adhere to the following format. First, there is an 80-character block termed the "Volume Header Label," which identifies the physical reel of magnetic tape. This is followed by another block of 80 characters called the "File Header Label," which identifies the contents of the "file," that is, the data recorded on the tape.

The file is a collection of input records containing BNS, Calling Card Service, PTC, OST, and AIS data. The input records are grouped into sessions, where the input records in a session have all come from the same source (e.g., the same telephone company). Multiple sessions on a tape must be used to separate input records from different telephone company or different regional SOSS within a telephone company. The maximum number of input records per session is generally limited to 256. Each session is started by a session header which indicates the source of the data (the telephone company). An "End-Of-File Label" follows the file. This is an 80-character block which identifies the end of all input data records recorded on the tape. Also recorded on the tape are single-character blocks containing a Device Control (DC3) character. These are termed "tape marks." One tape mark precedes the file, one succeeds the file, and two follow the End-of-File Label.

VI. SERVICE ORDER DATA-LINK INPUT—LINKIN

The DBAS data-link input program, LINKIN, provides the capability to receive service order information on a real-time basis from a single telephone company SOS. This method of operation has advantages over magnetic tape input in that it allows immediate updates to be input without the manual intervention of DBAS clerks. Data-link input is otherwise functionally equivalent to tape input. That is, the format of sessions input to, and output from, the LINKIN program are essentially identical to those associated with the READTAPE program. In addition, the consistency and syntax checks performed by the two programs are also identical.

The communication protocol used for the data-link input is BX.25, which has been adopted as the Bell System standard for communication between Operations Support Systems, and between these systems and SPC switching systems. The physical data link consists of two four-wire private lines. Data are normally transmitted over only one of the lines, with the alternate line serving as a "hot" standby. In case of

excessive transmission errors, the data flow is automatically switched from the active line to the standby without loss or duplication of information. Communication over the link is full-duplex synchronous at a speed of 4800 baud.

VII. JOURNAL TAPE—JURNL

The JURNL program functions to produce a journal tape which is the image of the on-line data base additions and modifications from the CLERKIN and LINKIN processes since the beginning of the work day. The READTAPE input may also be journaled to consolidate magnetic tapes. In the case of a system failure, if the integrity of the on-line data base is in doubt, the system may be restored, using the journal tapes to efficiently reinput the day's updates.

Tapes produced by the JURNL process are compatible with the requirements of READTAPE. To assure compatibility, journal tapes are created in the same format described previously for the READTAPE process, PE and 800 or 1600 cpi.

The production of a journal tape involves the interchange of messages with the console operator. Messages to and from JURNL pass through a control program (CONTROL) and follow the formats specified therein. These messages are invaluable aids to procedures, such as tape mounting and dismounting, tape mount verification, system shutdown, and system restart. The messages also highlight operator or tape errors. For example, it is in the best interest of DBAS to have a journal tape mounted whenever input sessions are being processed. The following error message is printed regularly whenever input sessions are in the journal directory but when no tape is being written.

++(jurnl) SESSIONS ARE WAITING TO BE JOURNALED,
PLEASE MOUNT JOURNAL TAPE

The JURNL program is started by CONTROL when DBAS is started and runs continuously until the operator requests either a total system shutdown or a selective process shutdown. The JURNL program, however, will only write to tape after operator action. After a shutdown, JURNL ceases to exist. It will be automatically started the next time DBAS is started, or the operator may restart it manually.

VIII. ORDER PROCESSING

As was described above, in general, the order processing programs accept sessions from the input programs, update the DBAS data base and/or generate updates for the BVA transmission program. Also, since the order processing programs have access to the data base records, they can perform certain additional consistency checks which the

Table II—Order processor functions

Order Processor	Accepts Input From	Reads Data Base (BNRS)	Performs Consistency Checks	Writes Data Base (BNRS)	Generates BVA Updates
ILOP	Magnetic tape	No	Yes	Yes	Yes
UOP	Clerk, data link, magnetic tape	Yes	Yes	Yes	Yes
POP	Not applicable	Yes	No	Yes	Yes
MOP	Not applicable	Yes	No	No	Yes

input programs could not. Any inconsistencies are reported to the DBAC via exception reports written to the line printer.

In actuality, there are four different order processor programs. These are the Update Order Processor (UOP), the Initial Load Order Processor (ILOP), the Pending Order Processor (POP), and the Move Order Processor (MOP). Each of these is discussed briefly below. Table II summarizes the functions performed by each order processor.

8.1 Update order processor

There are four UOP programs which process daily updates from the CLERKIN, READTAPE, and LINKIN programs. Multiple UOPs are used to implement the requirements for handling various updates at different levels of priority.

One UOP processes only immediate, or high-priority updates. Immediate updates can be generated by CLERKIN or LINKIN (but not by READTAPE) to handle denials, restorals, or customer trouble reports. Since one UOP is dedicated to handling immediate updates and because the number of immediate updates required is relatively small, an immediate update is processed and ready for transmission to the BVA within 10 minutes. Naturally, if the immediate updates were handled by the same UOP as lower priority updates, processing time would be extended as a result of the intermingling of updates. Otherwise, a more complex program would be required to allocate resources appropriately.

For similar reasons, another UOP is dedicated to handling non-high-priority clerk updates. Thus, since the number of these clerk updates is generally small compared to the mechanized input, clerk updates get processed relatively quickly (within 1 hour) also.

Finally, the third and fourth UOPs are dedicated one each to READTAPE and non-high-priority LINKIN inputs. Since the quantity of mechanized updates is relatively large, and handled on a first-come, first-served basis, these updates are given resultantly lower priority handling by default.

8.2 Initial load order processor

The ILOP is the order processor used to perform an initial load or reload of the DBAS data base.

Since several million records may have to be loaded initially, input for the ILOP must be provided in a special restricted format to speed processing. The ILOP accepts only input from READTAPE. Furthermore, the initial load tape must be organized in sessions each of which consist of all the BNRs for a given Billing Number Group (BNG). After performing syntactical checks, the ILOP places the records in the session in an order required for the data base to store the entire session efficiently rather than store each record individually. In addition, the ILOP provides the session to BVATRANS for subsequent transmission to the BVA.

8.3 Pending order processor

A pending order is an update for Calling Card Service data which was input via one of the input programs with an effective date sometime in the future. That is, it is a Calling Card Service update which must take effect 24 hours or more later than the time on which it was entered. For instance, if a customer telephone number change is to take place seven days in the future, a pending order must be generated to delete the PIN from the old number on that effective date. The POP is the program which searches the DBAS data base for pending orders having a given effective date, updates the data base with the pending data, and generates the appropriate update to pass on to BVATRANS for transmission to the BVA. The POP is normally run manually once a day after regular updating is complete.

8.4 Move order processor

The MOP is actually not an order processor, but simply a program which can read BNRs from the DBAS data base and supply the records to BVATRANS for transmission to the BVA. Thus, it provides a means to restore the BVA data base directly from the DBAS data base should such a need arise.

IX. DATA BASE ADMINISTRATION SYSTEM—INTERNAL DATA BASE

The DBAS internal data base contains the data needed by the BVA and associated data for off-line activities, such as customer inquiries. There is a BNR for each billing number assigned to the DBAS. The data kept for each BNR is shown below, with the default values (that is, the meaning of the absence of data in a given field) in italics.

(*i*) OST indicator: Customer-requested, tone, tone and announcement, cut through to an operator, or *none*

(*ii*) Service indicator: *Touch-Tone* service, rotary dial service, or *unknown*

(*iii*) PTC data: Public coin, public-coinless, semipublic-coin, business, or residence, or *unknown*;

(*iv*) BNS code: Customer requested no bill-to-third number, no collect, no bill-to-third number or collect, or *no restrictions*

(*v*) Unrestricted PIN (*no PIN*)

(*vi*) Service denial bit for unrestricted PIN (*no service denial*)

(*vii*) Service start for unrestricted PIN date (*no date*)

(*viii*) Restricted PIN (*no PIN*)

(*ix*) Service denial bit for restricted PIN (*no service denial*)

(*x*) Service start date for restricted PIN (*no date*)

(*xi*) Date of most recent DBAS data base update activity and medium (clerk, tape, or data link) of the update for this record (*no date, no medium*) and priority of last update

(*xii*) Counter to indicate the number of pending orders for this BNR (*zero*).

When an update results in default values for all data items in a billing number record (except for item *xi*), the DBAS deletes this billing number record from its data base.

The data kept for a billing number group (i.e., BNG—the 10,000 numbers with common NPA-NXX or RAO 0/1XX) include:

(*i*) Status: *Vacant*, nonparticipating, no input allowed, local administration or active administration for BVA administration*

(*ii*) Date that each feature (Calling Card Services, BNS, and OST) was activated in the BVA. *No date* indicates that the feature is not enabled.

(*iii*) Current RAO† (*no RAO*): This RAO corresponds to the RAO stored in the BVA for the billing purpose.

(*iv*) Previous RAO (*no RAO*): This RAO should be the same as the current RAO code for the BNG. It corresponds to the RAO stored in the BVA for the RAO digit (RAOD) check.

(*v*) Ownership: Telephone company that owns this BNG (*no ID*)

(*vi*) BVA(s) identity: Where this BNG resides (*no BVAs*)

(*vii*) Activity counts: Number of inserts, deletes, or changes since last daily report (*zero for all*)

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* Vacant means that the BNG is vacant and no BNR input is allowed; nonparticipating means that the BNG is active, but no billing number records are associated with the BNG; local administration means that no BNR updates are being sent to the BVA(s); no input allowed means that the BNG is being moved or restored; active administration means that the BNR updates are being forwarded to a BVA.

† When changing the RAO code for the BNG, the new RAO should be entered as the current RAO and forwarded to the BVA. After the transition period of RAO change is over, the DBAC personnel should manually reset the previous RAO to be the same as the current one.

(*viii*) Date that the billing number records in this BNG were initially loaded in the DBAS data base. *No date* indicates that the data are not loaded.

The DBAS data base interfaces functionally in two ways with the rest of the system. It provides administrative data for reports and studies, and it supports order processing, which consists of insertion, deletion, and changes to records in the data base.

9.1 Administration of data base

There are two DBAS administration programs, GETBNG and GETBNR, which permit the DBAC administrator to access the data base information described above. First, before any BNR information can be entered into the data base, the GETBNG program must be used to initialize, for administration, the appropriate BNG records. This program has the capability of inserting, updating, deleting, or listing any information in the BNG record. Second, a listing of the BNR data (which was entered through the CLERKIN, LINKIN, or READTAPE programs) is provided by the GETBNR program. Thus, the DBAC administrator can easily determine the contents of any BNR record in the data base.

X. BILLING VALIDATION APPLICATION TRANSMITTER—BVATRANS

The BVA transmission program (BVATRANS) is responsible for controlling the flow of all updates from the DBAS to the BVA(s). To do this, BVATRANS operates on files of BVA updates produced by the seven order processor programs discussed above. These operations include sorting, formatting, and transmitting immediate and batch updates.

The sorting operation is required to group all updates for BNRs within a given BNG. Transmission of updates grouped in this way saves a considerable amount of BVA real time. In addition, the sorting operation helps BVATRANS to prevent the possible overwriting of an immediate update by an earlier batch update which is transmitted at a later time.

XI. SYSTEM ADMINISTRATION

In addition to the programs associated directly with the data base updating functions, which were described above, the DBAS provides a set of system administration programs. These programs fall into two broad categories: (*i*) system parameter generation and (*ii*) report generating. The system parameter generation programs allow the system administrator to describe the hardware configuration of the particular DBAS and generate various system tables and files which are unique to that site's operations. The report-generating programs provide statis-

tics describing various aspects of the daily operations and the status of system processes and files.

The specific functions of these administrative programs are described in more detail below.

11.1 System parameter generation

There are four major administrative programs which are used to define data unique to a particular DBAS. These programs are SYSGEN, CLOSTRANT, ACCESSRST, and ORDERTYPE.

11.2 SYSGEN

SYSGEN is the administrative program used to define various parameters associated with the AIS, TSPS, and BVA interfaces and to define clerk login IDs. In addition, it is also used to define optional peripheral equipment including tape drives, disk drives, terminals, and data links. Because of this, the SYSGEN program must be run before updating and other system activities can begin.

Generally, the first time the SYSGEN program is run, the initialization function is performed to establish values for all of the required system parameters. When performing the initialization function, the SYSGEN program prompts the user with a question and the user responds with the appropriate value for that particular parameter. When all of the parameters have been initialized, the user "quits" the program, thus causing the parameter file just created to be stored on the system disk for subsequent use by all other programs.

After the first parameter initialization is completed, other functions which may be performed by SYSGEN include:
  (i) Update—change the current value of a specified parameter
  (ii) Print—print all or any data parameter
  (iii) Backup—save all parameters on magnetic tape
  (iv) Restore—transfer all parameters from magnetic tape to disk.

It was noted above that SYSGEN is an interactive program, that is, the program prompts the user for appropriate responses. However, as is the case for most all of the DBAS programs, SYSGEN can also operate in a command mode, whereby an experienced user can input on one line data normally input on several lines in response to several SYSGEN prompts.

11.3 CLOSTRANT

The system administrator uses the CLOSTRANT program to build a Class of Service Translation Table. This table is then used by the DBAS data input programs (CLERKIN, READTAPE, and LINKIN) to translate the class of service code on the service order to one of the six internal class of service codes used by the DBAS and BVA. A translation of this

type is required since a telephone company may need several hundred different class types to define all of the different categories of telephone service which are tariffed (and so appear on the service order), whereas, from the DBAS and BVA viewpoint, program efficiencies are gained by having to work internally only with the six classes which completely define the service for the line from the standpoint of the Calling Card Service, BNS, OST, and PTC features.

The actual CLOSTRANT table built by the administrator consists of up to 750 entries, each of which gives the internal DBAS class of service code which was assigned to the particular USOC. The CLOSTRANT program provides commands to edit and print the table, while magnetic tape backup and restore for the table are provided by the corresponding SYSGEN features.

11.4 ACCESSRST

The ACCESSRST program is used by the administrator to define which clerks and which telephone company will be allowed access to given sets of BNGs for updating purposes. For example, to provide access restrictions for data input via clerk terminal, a table is built for each clerk ID specifying which BNGs can be accessed under that ID. Likewise, to provide access restrictions for data input via magnetic tape or data link, a table is built for each telephone company ID specifying which BNGs can be accessed by that telephone company. These access restrictions help ensure that billing number record data are not modified from an unauthorized source.

The ACCESSRST program provides commands to initialize a new table, modify, delete, and print existing tables, or create a new table which is identical to an existing table. Tables are named C100 to C999 and T000 to T255 for the corresponding clerk and telephone company IDs, respectively.

11.5 ORDERTYPE

As was described above, the clerk input program is an interactive data entry system based upon a sequence of up to 32 questions which the clerk answers from information on the service order or a trouble report. To maximize the efficiency of the entry process, the sequence of questions asked is based upon the order-type code entered by the clerk. This order-type code is the second question asked and is preceded only by the entry of the billing number.

Using the ORDERTYPE program, the DBAS administrator creates and maintains a file which defines the question sets for up to 64 order-type codes. In addition to specifying the question sets, the administrator defines which questions the clerk may skip and which questions will

automatically receive specified fixed answers. Thus, the clerk input program may be tailored to the needs of the particular DBAC.

Specific capabilities provided by the ORDERTYPE program include the ability to print the order-type file, insert new order types, modify existing order types, and delete order types.

11.6 Report-generating programs

There are several programs which have been provided to allow the administrator to monitor the performance and status of the DBAC. All of these programs must be run manually by the administrator. Three of the programs provide daily operational statistics. These programs and their functions are as follows:

ACTSTAT Provides counts of the number of inserts, modifications, and deletes of BNRs on a per-BNG or per-telephone company basis during a given day.

CLERKSTAT Provides clerk performance statistics such as average work time per update, clerk sessions cancelled, total time logged in, etc. One to eight summary reports may be generated.

LINKSTAT Provides statistics regarding the health of all BX.25 data links.

Other report-generating programs are run on an as-needed basis to investigate possible system trouble conditions and to assist the system administrator or operator with system shutdowns and restarts and file management. These programs and their functions are as follows:

AUDPRINT Provides a summary of DBAS/BVA audit reports on a BNG basis.

BVAPRINT Provides a printout of the daily BVA transmission file on a BNG or BNR basis.

SYSTAT Provides a report of all processes active in the DBAS at the time SYSTAT is run.

FILES Provides a list of files accessible to various DBAS processes. The owner and size of the file, and date and time of last modification are given for each file.

XII. DATA BASE ADMINISTRATION CENTER

The DBAC is responsible for the administration of the intercept number data used by AIS and the Calling Card Service data stored in the DBAS and BVAS. The DBAS is in the Operator Services organization

and is typically managed by one second-level manager and one to three first-level supervisors.

The DBAC uses the DBAS as the principal means of administering the contents of BVAs. The DBAC also uses the direct terminal to the BVA as backup for DBAS outages and for certain administrative functions of an infrequent nature.

The DBAC activities can be separated into the following categories: (*i*) Administration, (*ii*) Updates, and (*iii*) Support.

12.1 Administration

The administrative responsibilities of the DBAC include the creation and maintenance of a data base environment in the DBAS and BVA which will allow for the storage of BNRs and their subsequent access and use by the CCIS network for call-processing purposes. The activities required to do this are as follows:

(*i*) Programming of the DBAS nongeneric parameters via SYSGEN.

(*ii*) Creation of the necessary tables, records, and files in the DBAS to allow updating. These are BNG records (created and maintained for each NPA-NXX and RAO-0/1XX assigned to the DBAS location), Class of Service Translation Table, Access Restriction Tables, and Ordertype File.

(*iii*) Coordination and negotiation with AT&T Long Lines to ensure CCIS and BVA availability. The DBAC must also coordinate the establishment of new BNGs and the migration of BNGs between BVAs or DBASS.

(*iv*) Administration of RAO validation and the check-digit algorithm. The DBAC inputs the check-digit algorithm as provided by AT&T and sets the transition indicators as required for RAO and algorithm changes.

(*v*) Schedule audits and perform necessary actions to resolve inconsistencies. The DBAC runs audits between the DBAS data base and the BVA. Regular audits are under program control, but the DBAC also initiates demand audits as required. The DBAC is responsible for resolution of audit inconsistencies to ensure accurate DBAS and BVA data.

(*vi*) Perform DBAS file backups at prescribed intervals and, if required, restore the DBAS and BVA files. Backup of the DBAS system disk is done each working day and backup of the DBAS data base is done once a week. Restoration of the DBAS and the BVA is done utilizing the backup disks and journal tapes retained for that purpose.

12.2 Updates

The DBAC is responsible for the entering of updates into the DBAS. Updates may be entered by data link, magnetic tape, or clerk work

station. The DBAC must initiate the appropriate DBAS programs to allow input from the above-mentioned sources. The DBAC must resolve any incomplete or erroneous update information received by the DBAS.

The DBAC must also run the pending order processor daily to update Calling Card Service information in a timely manner.

If the DBAS or the data link between the DBAS and BVA is not operational, the DBAC must update the BVA with the DBAC/BVA terminal to ensure accurate call processing.

12.3 Support

The DBAC is responsible for the analysis, resolution, and clearance of data base trouble reports. Trouble reports are typically received from Centralized Repair Service, Answering Bureaus, Repair Service Bureaus, Business Service Center, and Residence Service Centers. In addition to these centers, clearance of trouble reports may also involve interaction with comptrollers, public services, AT&T Long Lines, and TSPS Operator Services Facilities Administration.

The DBAC monitors the operational status of the DBAC equipment including the DBAS, data sets, and terminal equipment. This includes analyzing hardware/software problems and ensuring that corrective action is taken. The DBAC is also responsible for ensuring the proper storage, cleaning, and transportation for magnetic tapes and disk units.

The DBAC must ensure that BNG data maintained at the BVA are accurate by reviewing all enabled services by BNG and reviewing all query addresses assigned to the BVA(s). In addition, the DBAC coordinates with the AT&T Long Lines Engineering and Network Administration Center to ensure proper CCIS network and BVA operation, including matters concerning translations, migration, and data links.

The DBAC also initiates all special studies performed at the DBAS or BVA and reviews the BVA counters and reports and takes corrective action, if required.

XIII. SUMMARY

The DBAS was designed to bridge the gap between the business office and a new user of business office data, the SPC network. The DBAS interfaces with the various telephone company SOSS, which range from totally automated to totally manual, to obtain the information needed by the network to provide its services. The DBAS keeps a superset of the data needed by the BVAS in an internal data base so that many administrative functions, such as customer inquiries and special studies, can be processed by the DBAS; this relieves on-line network nodes from having to store extra data and process extra transactions which are not call related. After cleansing and ordering the service order data it receives, the DBAS provides initial load and daily update capability

to the BVAs it administers by way of data-link transmission. In case of a massive failure at a BVA, the administering DBAS can reload the BVA's data.

XIV. ACKNOWLEDGMENTS

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Stored Program Controlled Network:

Data Base Administration System— Architecture and Data Base Design

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The Data Base Administration System (DBAS) maintains a data base of up to 12 million entries, and supports an update rate on these entries of up to 7,000 per hour using magnetic tape, direct data link, or clerk terminal entry. The DBAS software architecture and data base design to support these requirements are described in this paper. The architecture was developed using real-time functional process modeling techniques. Software process concurrency and modular separation of the major software functions optimize throughput and permit quick clerk terminal response.

I. INTRODUCTION

The No. 2 Data Base Administration System (DBAS) administers data bases stored in Automatic Intercept Systems (AISs), Traffic Service Position Systems (TSPSS) and Billing Validation Applications (BVAs). This administration consists of providing an initial load of data, ongoing updates, audits, and various reports. In general, the No. 2 DBAS serves as the telephone company's (Bell operating and, possibly, independent telephone companies) interface to data stored in these aforementioned systems.

1.1 Transition from No. 1 DBAS to No. 2 DBAS

The No. 2 DBAS supersedes the No. 1 DBAS (previously known as the File Access Subsystem, FAS) and subsumes the responsibilities of the No. 1 DBAS for administering data in the AIS. This is accomplished by retaining the application software used on the No. 1 DBAS, and

running it on the No. 2 DBAS processor in timeshare with new software that was written to administer TSPS and BVA data bases.

Retaining the original software to perform the AIS administration was less costly than writing a totally new set of programs for this purpose, even though modifications to the existing software were required.

1.2 Basic software architecture

The software architecture for the No. 2 DBAS is shown in Fig. 1. For the purposes of this paper, software architecture will be defined as the division of the application software into processes, plus the design of the interprocess communication. A process, in the *UNIX** operating system sense, is a running instance of a program.[1] Several processes may share one program text, and are distinguishable only by the data on which they are working.

In Fig. 1, the software processes retained from the No. 1 DBAS are shown above the horizontal line. They will be referred to as the AIS Update System. The new software processes used for BVA and TSPS updating are shown below the line. They will be called the BVA Update System. The architecture is described in detail in Sections II and III.

1.3 The DBAS data base

When administering AIS data bases, the No. 1 DBAS was strictly a transaction-oriented system. Updates sent to the No. 1 DBAS by the telephone company's Service Order System (SOS) were passed directly to the AIS as soon as possible, after passing appropriate consistency checks. Although a copy of the total contents of the AIS data base was kept on tape at the File Administration Unit (FAU), which operated the No. 1 DBAS, no on-line accessible copy of the AIS data base was kept in DBAS. This meant that checking the exact current contents of the AIS data base required querying the AIS itself. Similarly, administrative reports based on the contents of the AIS data base were limited by the ability of the AIS to supply the required information.

For the large BVA data bases to be administered by the No. 2 DBAS, this type of administration would not be practical. Therefore, an on-line accessible data base was established on disk as part of the No. 2 DBAS. Further, this data base was designed to be the master copy of all data kept in the BVA. (No on-line copy of the AIS data base is maintained and the TSPS data base is an interim subset of the BVA data base.) Thus, all telephone company needs for information about

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* *UNIX* is a trademark of Bell Laboratories.

Fig. 1—DBAS software architecture.

data existing in the BVA data bases can be met by querying the DBAS. Therefore, the No. 2 DBAS was designed primarily as a data base system. Adequate throughput and integrity in data handling were required to be certain that the subset data bases kept in the BVAs were appropriate copies of the DBAS master data base.

The details of the DBAS data base are described in Section III.

II. THE DBAS SOFTWARE ARCHITECTURE

2.1 Throughput requirements

The DBAS is capable of handling the following throughput:

$$\tfrac{1}{2} DI + MI + \tfrac{1}{2} AU + BU > 7000/\text{hour},$$

where

        DI = number of data link inputs per hour
        MI = number of clerk CRT (manual) inputs per hour
        AU = number of AIS updates per hour
        BU = number of BVA updates per hour.

For clerk and data link, an "input" is counted each time a line number is presented to DBAS. One "input" can result in several changes to data kept on a line. However, an "input" is still counted even if no change to line data results. Change data applied in special format to a "block" of lines is considered one input per line in the block. Inputs from magnetic tape are not considered in the formula as it is assumed that magnetic tapes can be read in during off-hours.

An AIS update is counted for each message sent by DBAS to an AIS. Here, blocks of line numbers count as only one update. A BVA update is counted if any change is sent to a BVA, or if the DBAS data base is accessed, even if no change is sent to a BVA. Blocks of lines again count as multiple updates if the DBAS data base changes.

In normal operation, most DBAS inputs will be mechanized (either data link or magnetic tape). Further, most transmissions to the BVA will be made during hours of light traffic at the BVA. However, the actual transmission to the BVA uses a small fraction of the total central processing unit (CPU) and disk time required per update.

2.2 Additional requirements

In addition to throughput requirements, the DBAS must meet several other design constraints:

(*i*) The AIS update latency must be low. When an AIS input has been completely received by DBAS, it is desirable for the update to be ready for transmission to the appropriate AIS within 10 minutes.

(*ii*) BVA update latency must be low. When a BVA "immediate" (high-priority) input has been completely entered into the DBAS, it is desirable for the update to be ready for transmission to the appropriate BVA within 10 minutes.

(*iii*) Clerk terminal response must be good. When clerk terminals are being used to enter data, they must be given priority over other processing tasks. This is because clerk terminals will generally be used only to enter high-priority input or to perform troubleshooting.

2.3 BVA Update System software architecture

As shown in Fig. 1, DBAS input can be received via either clerk entry, magnetic tape, or data link. A software process is associated with each input medium. For clerk input, a software process is associated with each physical CRT. These clerk input processes are separated, but share program text to minimize their memory utilization.

The role of each input process is first to deal with the specifics of each input medium. For example, the magnetic tape input process checks tape headers and trailers; the clerk input process interprets keystrokes and interacts with the clerk. All processes then perform basic syntax and consistency checks on the input they receive. These checks are the same for any input medium.

For each input process, a group of inputs is collected to form a "session." A session may contain up to 256 separate inputs. When all input for a session is complete, the entire session is written into a disk file under the *UNIX* operating system file system. This disk file may be linked into several directories for access by the appropriate processes. Inputs within a session are thereafter processed as a group, improving processing efficiency.

For example, every session file containing any error-free input is linked to a directory where it can be accessed by an Update Order Processor (UOP) process. The UOP reads the session file, and for each line number, retrieves the existing data (if any) for that line from the DBAS data base. The existing data are compared with the proposed changes to be sure the changes are reasonable. If so, the changes are made to the DBAS data base. If subsequent changes also need to be made to a BVA data base, the UOP creates a session file in a different directory accessible by the BVA transmission process.

With this architecture, significant buffering can be utilized at several points to load-balance and improve the total throughput possible on a daily basis. For example, consider a case where a substantial amount of clerk input was required in a particular hour. Work by the UOPs and data base on routine updates could effectively be suspended, and most of the CPU and disk resources could be available to clerk input processes. In practice, this is done by giving processes with terminal I/O work a higher priority in accessing the CPU. In this example, good clerk response time would be maintained. Sessions would be buffered in the directories between the clerk input processes and UOPs. Later, when the clerk input load was lower, the UOPs and data base software would begin processing the buffered routine updates. In general, this processing of buffered change data could continue for several hours past the conclusion of clerk data entry, if a peak in update volume was seen on a given day. This processing of buffered data would be completed

before the scheduled time of data transmission to the BVAs, which occurs in the middle of the night.

2.4 Integrated input

Early in the design of the No. 2 DBAS, it was recognized that if changes affecting services provided by a BVA were requested on a line, changes would usually also be applied to an AIS. Therefore, an input to the BVA Update System would have to be duplicated as an input to the AIS Update System, if these two software systems were kept fully independent. This would be a very inefficient "double entry."

Therefore, a process called the Automatic Intercept Center (AIC) Converter was included in the software architecture. This process is shown crossing the center line on Fig. 1. If an input process in the BVA Update System finds input requiring an AIS update, it links the session file to a directory whose contents are scanned by the AIC Converter process. The AIC Converter reads the session file and extracts update information for the AISs. This information is converted from the data formats used in the BVA Update System to the format used in the AIS Update System. The update is then inserted into the AIS Update System's processing stream.

2.5 Performance-guided development

From the start of development of the No. 2 DBAS, it was recognized that the throughput requirements would use a substantial fraction of the available resources of a PDP 11/70 running the real-time *UNIX* operating system. Therefore, it was decided that the development of No. 2 DBAS would be guided by the need to meet the performance requirements. A first step in this direction was to develop a simulation of the No. 2 DBAS. This simulation was to prove whether or not the requirements could be met, and possibly suggest improvements in the software architecture.

Several different types of simulation were considered. These included analytic models, General-Purpose Simulation System (GPSS) simulations, etc. The method finally chosen was a functional process simulation, wherein some of the developers write model processes for all processes in the proposed architecture. These simulated processes then incorporate dummy processing loops, make disk reads and writes, and perform interprocess communication in an attempt to utilize system CPU and disk resources in the same way as the eventual software system.

A functional process simulation has several advantages. There is no need to simulate the hardware or operating system, as the "real thing" is being used. This eliminates considerable effort and removes substantial uncertainty from the simulation. The simulation can be

evolved into the final product, recovering some of the effort required to produce the simulation. Since the simulation is written by developers of the final system, it gives them substantial exposure to the language, operating system, and project software architecture. This exposure can be especially valuable if the average level of experience of the designers is low. Finally, estimates of the amount of code and effort required for the final product can be improved by observing the development of the simulation.

For No. 2 DBAS, a functional process simulation of the proposed DBAS architecture was developed. As compared with Fig. 1, the initial architecture had the equivalent of a single UOP, accepting sessions from one session file buffer. No simulation was provided for the data link input capability, and no attempt was made to interface with actual AIS or BVA hardware.

Initial results of the simulation are shown in Table I. The simulation indicated that the proposed architecture, running on a PDP 11/70 under the real-time *UNIX* operating system, could meet the DBAS throughput requirements. However, when measurements were taken of CPU and disk utilization for the case of magnetic tape input (line 1 of Table I), both were substantially less than 100 percent. This meant further improvement could still be obtained.

Analysis revealed that a single UOP interacting with the data base tended to serialize the utilization of CPU and disk. For example, the UOP and data base processes would simultaneously block waiting for disk I/O, and the CPU utilization would drop during this interval. Therefore, more concurrency was required. The simulation was modified to include the equivalent of three UOPs operating on the same input session directory, each handling approximately every third session file. The throughput now became as shown in line 5 of Table I. Using this as a guide, the No. 2 DBAS BVA Update System software architecture was modified to the final version shown in Figs. 1 and 2. This architecture will be discussed in more detail in Section III.

In addition, analysis of results of the simulation contributed to selection of the clerk terminal, and helped in the human factors design

Table I—Data Base Administration System performance simulation—typical results with continuous magnetic tape input

| Simulated Test Run	Clerk Inputs Per Hour	BVA Updates per Hour	AIC Updates per Hour	Total
1	(Tape only)	9391	1356	10,747
2	681	9388	1632	11,020
3	1406	8795	1535	10,330
4	2071	7020	1479	8499
5	(Tape only) improved architecture	13,299	1555	14,854
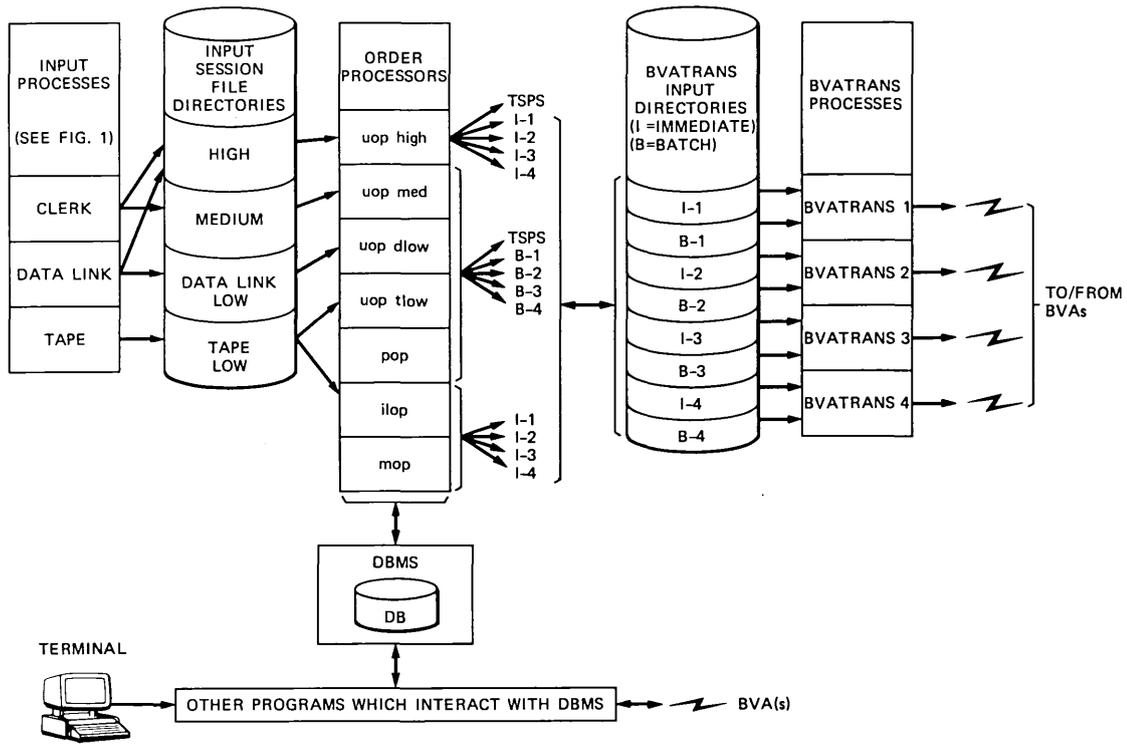
Fig. 2—Update processing architecture.

of the clerk interface. The original software written for the simulation proved to be of continuing value during development, in addition to being the basis for the final product. For example, during the design of the interprocess communication (see Section 2.6), a question arose as to the utilization of the real-time *UNIX* operating system message buffers. The simulation was run under heavy load with special message buffer instrumentation in the operating system, and was used to determine the utilization level.

As a result of this performance-guided development approach, the initial release of the No. 2 DBAS successfully met its performance objectives.

2.6 Process control and interprocess communication

When programs are run in the typical *UNIX* operating system time-share environment, they are usually associated with the CRT (or teletypewriter TTY) of a single user. Users and processes are very effectively prevented from interfering with each other, and each user and the user's programs see an entire "virtual" computer system.

However, for applications such as No. 2 DBAS, some degree of efficient process interaction is desirable, and it is also necessary to be able to control a group of processes as a software system. Both of these required additional development specific to DBAS.

In general, No. 2 DBAS processes are independent and modular. For example, it is possible to run a clerk input process from a *UNIX* operating system terminal like any other *UNIX* program. Session files can be created, and would be processed normally, if the rest of the DBAS software were subsequently run. However, there are important exceptions to this independence. For example, most administrative report programs can be run from *UNIX* terminals like the clerk input program. But, they cannot produce a report on the DBAS data base unless the data base processes have previously been properly started. These interdependencies between processes could be confusing to the DBAS user. To establish the complete BVA Update System, more than a dozen separate processes would have to be started. During operation, most of these processes produce brief reports on their progress, which would result in scrambled printouts if all were directed arbitrarily to a common terminal.

To solve this, a set of processes was designed, collectively called CONTROL. The DBAS user starts CONTROL from an arbitrarily designated control terminal, specifying one of several modes of operation. Based on this mode, CONTROL creates and runs all the processes that the user requires. For example, in the "update" mode, all programs needed for BVA updating are started. In the "data base" mode, only the data base processes are started. The user can then run

various administrative programs successfully, and can change critical per-site data with the knowledge that no updates (which might depend on the changing data) are in progress.

CONTROL also handles the orderly demise of processes it has started. If ordered by the user to perform a "graceful shutdown," CONTROL requests each process it has started to exit at the next convenient stopping point (e.g., completion of processing the current session file). If the user requests an "immediate shutdown," CONTROL requires each process it has started to quit immediately. This request is only made under rare circumstances.

All processes running under CONTROL have access (through CONTROL) to the terminal at which CONTROL is running. They can print messages to the user, or request user input. Therefore, this single (control) terminal can communicate with any desired process, and messages output by any process under CONTROL are printed in an orderly, meaningful manner, where the process requesting the printout is clearly identified. This communication capability is provided by a standard interprocess communication package based upon the real-time *UNIX* operating system "message" feature.

CONTROL can also start processes at a scheduled time of day. For example, if transmission of routine updates to a BVA has been scheduled for 11:00 p.m. daily, CONTROL will automatically start the appropriate processes at that time. Several such events can be scheduled by the DBAS users via administrative programs.

III. THE DBAS DATA BASE MANAGEMENT SYSTEM, ORDER PROCESSING, AND BVA TRANSMISSION PROGRAMS

The DBAS Data Base Management System (DBMS), Order Processing, and BVA transmission programs form a group of interrelated programs that were designed to provide three specific functions:

(*i*) The initial load of the DBAS and the BVA Data Bases.

(*ii*) The ongoing daily update capabilities of DBAS and BVAS.

(*iii*) Data base house cleaning, backup, and restoration functions. Each of these functions is described in detail below with an accompanying explanation of the contribution of their components.

3.1 Initial load function

An initial load starts with tape input of billing number data. The DBAS stores these data in its data base (DB) and then immediately sends a copy to its associated BVAS. If run continuously, the initial load of even the largest DBAS DB and its BVAS could be completed in about one week. However, the initial load might have to be interrupted to process normal updates for connected AISS or TSPSS. For example, the DBAS might be used for initial loading on the weekend, but during the

week, it would be used to process normal updates. In this case, subsequent weekends are necessary to initially load the DBAS and BVA data bases until both data bases contain all of the line numbers assigned to that DBAS.

The important point here is that initial loading is done at a different time and quite separately from regular daily updating. This method of operation arises from the need to process updates at considerably different speeds in each case.

The initial loading rate per update must be much faster than the daily update rate because the DBAS data base may contain from 1 to 12 million records (average approximately 4 million records) that have to be initially loaded, but only about 1 percent of the total records are modified per day. Thus, the normal update rate of DBAS can be much slower than the initial load rate. The normal update rate capability of DBAS is about 7,000 updates per hour as mentioned in Section 2.1. In contrast, an initial load rate of over 100,000 updates per hour was achieved. This required the following special developments:

(*i*) An initial load tape format was specified requiring all billing numbers in a billing number group (BNG) to be sequentially ordered on the input tape to DBAS. This avoids a sorting operation normally performed during routine updating.

(*ii*) An Initial Load Order Processor (ILOP) was developed which ensures the sequentiality and uniqueness of each set of updates in a billing number group. It also generates files for the DBAS data base and BVA transmission programs.

(*iii*) An Initial Load Data Base Management System (ILDBMS) was developed to store complete BNG files on contiguous strips of DBAS disks.

The ILOP and ILDBMS are shown in Fig. 3, along with the other programs involved in initial load processing. The READTAPE and BVA-TRANS programs are also used for normal daily updating. The common use of these programs was a design goal aimed at minimizing the number of different DBAS programs that had to be developed, tested, and maintained. As a result, the unique capabilities needed for initial loading were implemented entirely in the ILOP and the ILDBMS.

The ILOP and ILDBMS were designed to work very closely together. The set of all updates in each BNG is in order of line number. The resultant file is then passed to ILDBMS via a "store-all" command used only for initial load. The ILDBMS reads each update, assigns them to buckets (disk pages) and writes the subsequent complete set of buckets into contiguous disk blocks belonging to the DBMS. This marriage of functions and strip loading of DB disk space basically underlies DBAS's relatively fast initial load rate.

The BVA transmission program (BVATRANS) gets its input files from
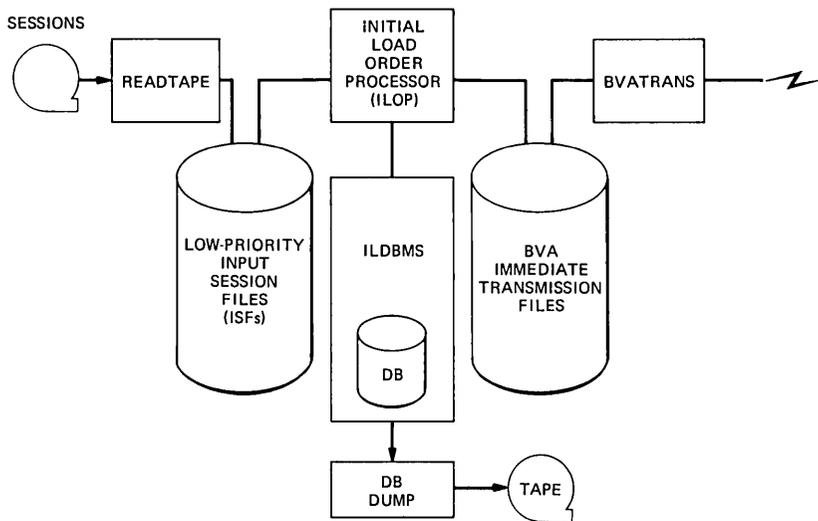
Fig. 3—Initial load architecture.

the ILOP and transmits the file immediately to the BVA. Since this file is sequentially ordered by line numbers (directly from the input) the data can be packed compactly into the packets that DBAS uses to communicate with its BVAs. The BX.25 protocol is used for this communication. Each packet contains billing number records for only one billing number group. Up to 126 billing number records may be sent in a packet. Since there are potentially several thousand billing number records in every billing number group in the initial load stage, the packets are usually filled to capacity and the resultant transmission between DBAS and the BVA is very efficient.

Procedures for accomplishing the initial load were distributed to the telephone companies. These specified how various initial load situations should be handled. In particular, the situations of concern were the conversion of early DBAS generics to 2DB3, which is the latest generic. For example, if a company was using a 2DB2 generic, its DBAS would contain a data base consisting of any data used to load certain TSPS data. It was necessary to develop the program called DBDUMP shown in Fig. 3 by which the 2DB2 data base was dumped on a tape in a format that was compatible with inputting to a 2DB3 system. Since the 2DB2 data bases are generally small (less than 100,000 records) the time to reinsert the 2DB2 records was not of concern.

It was necessary to retain the 2DB2 data during and sometime after the 2DB3 initial load because telephone companies may have to continue updating TSPS data bases until the BVA(s) are activated. Other potential generic conversion situations were explored and doc-

umented for the use of initial load coordinators in each telephone company.

3.2 Daily update processes

After the initial load for each BNG is completed, updates to these BNGs are entered using clerk, data link, and/or tape input medium. Each corresponding input program groups these updates into Input Session Files (ISFs). The input process then links the ISFs that are formed to one of three types of directories: high, medium, or low priority. Priority has the following significance:

(*i*) High-priority sessions contain updates that must be transmitted to the BVAs immediately (i.e., within 10 minutes). Any type of update can be input at high priority.

(*ii*) Medium and low priorities are intended for ISFs containing updates that do not have to be transmitted to BVAs until a specified time of day, usually in the evening. Most updates will be of this type. For example, only a few hundred high-priority updates per day would usually be entered as compared to about 30,000 medium- or low-priority updates.

As in the initial load architecture, order processors read ISFs, format and enter changes to the DBMS, and generate files for transmission to BVAs; the DBMS stores records; and BVATRANS sends the updates to the BVA. However, in contrast to the initial load situation, ISFs in the update mode are generated by three types of input media, and the update data will generally be randomly ordered (as opposed to sequentially ordered in the initial load mode). This required setting up a more complex order processor architecture as shown in Fig. 2. An Update Order Processor (UOP) is associated with each type of input directory. The input session files generated by each of the input processes are very similar, so that a single program was designed to process all the various types of ISFs as described below.

All UOPs are started by CONTROL and normally run all day. When created, each UOP is passed a parameter indicating its source of ISFs. This parameter also sets up each UOP to modify its operation as follows: The UOP which processes high-priority ISFs links its output to immediate BVATRANS input directories (e.g., to I-1, I-2, etc.); the UOPs processing lower priority ISFs link their output to the batch input directories of the BVATRANS processes (e.g., to B-1, B-2, etc.). Otherwise, all UOPs handle ISFs in the same manner—when first started, the UOP creates a BVA update file for each BVA in its own data directories. Then, whenever a UOP completes processing an ISF, it determines which BVA update files have been used and sends them to the appropriate BVATRANS. That is, it closes the file, links it to the BVATRANS data directory, and creates a new BVA update file so that it can

continue processing. Each UOP performs various checks on every update in the ISF to ensure that the new data are consistent with the data already in the DBAS DB prior to finally updating the DBAS data base, the BVAs, and the TSPSs. Checks that fail result in exception reports describing the reason for the report and the input and data base records in question. For example, an ISF update specifying a Personal Identification Number (PIN) for a public telephone record in the DB would be rejected with an appropriate message.

The Pending Order Processor (POP) does not run continuously like the UOPs. Instead, it runs briefly once a day to process the pending orders in the data base whose effective dates become current. A pending order is any update whose effective date is tomorrow or up to 6 months further in the future. The POP obtains a list of pending updates from the DB, modifies the DBAS DB, and then produces a single BVA update file for each BVA linking those files to the appropriate BVATRANS batch data directories.

The Move Order Processor (MOP) is started by the DBAS administrator when it is necessary to move the data stored for a set of BNGs from one BVA to another. This process obtains a file from the DBMS for an entire BNG which has been specified as a parameter in the DBAS move command, reformats the file, and links it to the target BVATRANS batch directory. If more than one BNG is required, the program repeats the above for each.

Figure 2 also shows that multiple instances of BVATRANS are used to communicate with a corresponding number of BVAs. A parameter is passed by CONTROL when it creates each BVATRANS process. This parameter tells each BVATRANS process which input directories to use for its corresponding BVA. It should be noted that several BVATRANS processes might be invoked in the same manner for initial loading several BVAs simultaneously.

3.2.1 Handling mixed priority and multiple updates

The DBAS is required to process and output multiple updates for billing numbers (BNs) in the same sequence as they were entered in any given day from a given source (tape, clerk, or data link). Furthermore, a high-priority update for a particular BN must override any previous lower priority update for that BN which may have been processed the same day. For example, a high-priority service denial update should block any lower priority change order which may have been on that day's tape and processed earlier. These requirements were implemented in the following manner.

When any medium- or low-priority UOP reads an update from its ISF, the corresponding DB record is also retrieved. The date when the DB record was last changed is compared to the current date (which it

gets from the ISF name). If the two are the same, and the DB record was last changed by a high-priority order, then the new update is rejected with an appropriate exception report. If the DB record was last changed by a low-priority order, the UOP time stamps each update passed to BVATRANS. The new update and the time stamp are passed along to the appropriate BVATRANS. In its batching mode, BVATRANS sorts updates by line number and then by time stamp to properly order multiple line number entries. A high-priority update for a BN that was preceded by a lower priority update that same day is "marked" by the UOP. This mark permits BVATRANS to block the latter updates by an in-core filter routine.

3.2.2 The DBAS data base management system (DBAS DBMS)

The major challenges in the DBAS DBMS design were its size and its high update volume: up to 12 million records with up to 100,000 updates per day. To meet these needs, the most interesting features are briefly described below.

(*i*) File structure and file access—The data base comprises a set of *UNIX* operating system special files accessed by raw I/O, each being a DEC RP06 disk pack (176 Mb). A two-stage extendible hashing algorithm is used to access the record of a given ten-digit billing number.[2] The number of records in the data base can grow and shrink dynamically. The record size (10 to 50 bytes) is variable. The average number of disk accesses per update is four to six.

(*ii*) Concurrency control—An Application Program (AP) is either an order processor or an administrative process outside the DBMS. Multiple APs can access the data base at the same time to make the system easier to use. Multiple copies of the lower level DB access modules can be run at the same time to achieve a high data rate between core memory and secondary storage devices. This is achieved through the implementation of a two-level hierarchical locking scheme. An AP can either lock the whole data base or a portion of the data base. Only exclusive locks are available for simplicity. Deadlock is avoided by the restriction that each AP can request and hold at most one lock at a time.

(*iii*) Data independence—Data base conceptual schema and views are provided at the lower access level, and the APs, for example the UOPs, have direct access to these lower access modules. User process security is enforced by the restriction that each AP sees only the data it needs through a predefined view.

(*iv*) Buffer management—A large number of buffers can reduce the number of data base disk accesses. The *UNIX* operating system on the PDP 11/70 restricts the size of a particular process's virtual address space to 128 kb. Compared with a 2-Mb physical core memory, this

small virtual address space presents a problem in buffer management design. The problem was solved by sharing a set of buffers between the virtual address space of the lower level access module and physical main memory. When a data base replacement request follows an earlier retrieval request, no additional disk accesses are required to reference the same data base record in core memory.

(v) Secondary storage management—Contiguous disk blocks are freed and allocated dynamically. The disk write module writes one or more contiguous disk blocks from contiguous buffer space in a single real-time *UNIX* operating system I/O request. When contiguous disk space is available, these features reduce the number of disk I/O calls.

(vi) Secondary key retrieval—A restricted form of secondary key retrieval is provided to handle the pending service order feature, which permits inputting service orders to be processed at a future date. A file of record keys (each representing a record with a pending order for a given date) is output by the lower level access modules using the date as the secondary key.

3.2.3 Internal operation of the Data Base Management System (DBMS)

A process view of the DBMS is shown in Fig. 4. This shows that the system comprises two main processes: the Data Base Manager (DBM) and the Access Task Process (ATP). Features described above in Section 3.2.2 are implemented in these two processes which operate as follows: Application Programs initially interact with the data base via "opendb" or "begin session" commands. The DBM assigns the ATP to the process, keeps track of views in use, and provides for recovery as described in the next section. Upon receiving an acknowledgment from the DBM to its initial command, the AP accesses the data base through another set of commands now directed to the ATP, such as "retrieve," "replace," "delete," or "store" data.

The set of all commands that are available for APs to access the data base is called the Data Manipulation Language (DML). The commands were incorporated as subroutine calls in each AP, and the subroutines actually interact with either the DBM or ATP. The subroutines also convert the data for the DBMS. For example, line numbers are converted to long integers. Hence, the DBAS DBMS is a special-purpose DBMS in that only special values of some data fields are allowed. In this manner, data are stored quite compactly in DBMS disk pages (over a hundred records per page).

3.3 The DBAS backup and recovery

The DBAS data base is backed up by periodic disk-to-disk copying of the data base disks. Following certain severe system failures it may

APPLICATION PROGRAMS
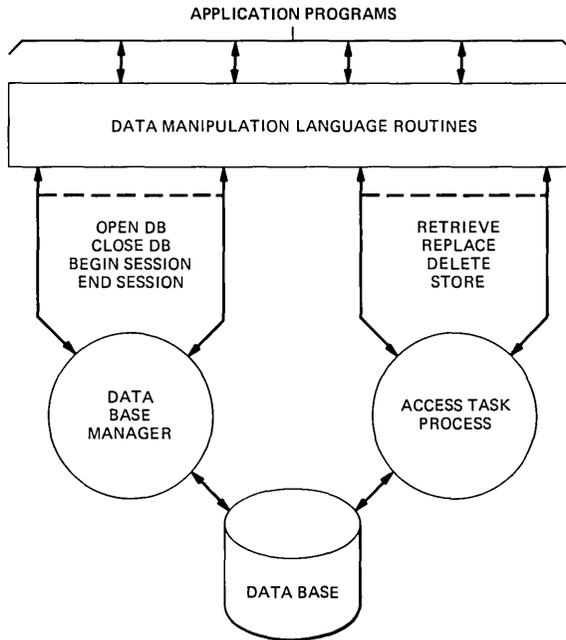
Fig. 4—Data Base Management System.

become necessary to recreate the DBAS data base, starting from these backup copies and integrating updates received between the date that the backup copies were made and the time that the failure occurred.

During normal updating operations, a special DBMS "checkpoint" mechanism is employed to protect the integrity and consistency of the DB in the event of system crashes or other system stoppages. The explanation of this vital feature is as follows: The data base disks are separated into read-only disks and writable disks. The primary data structure of the data base is a tree of disk blocks. The blocks of the first two levels, the root and its children blocks, reside in core memory to minimize the number of disk accesses per data base record access. Whenever a block on a read-only disk (a write-protected disk drive) is to be modified, writable disk blocks are allocated on a separate writable disk known as the "working volume." One or more of the newly allocated blocks are then written with the modified data, as well as with its ancestor blocks (except the first two levels) so that the contents of read-only blocks are not touched. Disk blocks on the writable disk belonging to the most recent consistent data base copy are temporarily assigned read-only status until a new consistent copy becomes available. At the end of each day, the writable disks and the read-only disks are merged to produce a new set of read-only disks for the next day.

For this purpose, a Merge DBMS was designed whose only functions are merging and some daily DB housecleaning. Also, at regular time intervals during the day, root blocks are written to save a consistent copy of the data base on disk. This is called the data base checkpoint. Before the checkpoint is taken, the system synchronizes itself, through blocking, so that no updates are in progress to ensure that data are consistent.

In case of accidental machine failure, only the work done since the previous checkpoint needs to be repeated, thus permitting easier and faster recovery. Following a successful merge, the old working volume is saved, along with the most recent backup copy of the data base disks. They may be reused at the same time as the associated data base backup disks, usually in two weeks. To facilitate system recovery, the DBMS maintains a session trace file for the sessions that UOPs have processed. For each session, all UOPs send Session-Begin (SB) and Session-End (SE) messages immediately before and after processing data in their session files. The DBM keeps the time of these messages and the session identification in the trace file. When a checkpoint is to be taken, the DBM stops replying to SB messages, thereby halting the UOPs when they reach an SB. Programs other than UOPs are allowed to finish their processing, but no new ones may start while the checkpoint is pending. When all writing has been stopped, the DBM does its checkpoint routines. It then resumes replies to SB messages so that all application programs can continue.

A necessary condition in restarting after a machine failure is for the APs and DBM to have a consistent view of the data base. Upon a crash or other ungraceful system stoppages, a special program is invoked to examine the session trace file so as to identify successfully completed sessions. Damaged or missing sessions need to be reinput from the original input medium or from the journal tape. As mentioned in a previous article, a journal tape is maintained by the DBAS journal program that can keep a record of all service order inputs. The DBAC (Data Base Administration Center) operator must notify those responsible for inputting data, if some sessions have to be repeated. It should be noted that specially tailored checkpoint capabilities are provided in both the Initial Load and Merge DBMSs. Hence, these systems can recover from certain common system stoppages without having to reprocess much data just like the regular DBMS.

IV. SUMMARY

A performance-guided analysis of required features and operating environment led to an early choice of the DBAS's architecture. The resultant design has the following capabilities: a wide range of administrative, control, order processing, data base, and BVA interaction

functions; initial load rates of 100,000 updates per hour; ongoing update rates of 7,000 updates per hour; a special-purpose, yet flexible, Data Base Management System; and an innovative backup and recovery scheme that permits the use of a simplex processor and simplex periphery.

V. ACKNOWLEDGMENTS

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ACRONYMS AND ABBREVIATIONS

ACP	action point
ACTS	automated coin toll service
ADC	acceptable digit count
ADC	address complete
ADI	address incomplete
AGC	automatic gain control
AIC	automatic intercept center
AMA	automatic message accounting
ANC	answer charge
ANI	automatic number identification
ANIF	automatic number identification failure
AP	application program
ATP	access task process
BCD	binary-coded decimal
BISI	busy/idle status indicator
BLK	blocking
BN	billing number
BNG	billing number group
BNR	billing number record
BNS	billed number screening
BOC	Bell Operating Company
BVA	billing validation application
BVATRANS	BVA transmission
CA	call cancel
CAMA	centralized automatic message accounting
CCIS	common-channel interoffice signaling
CCIS/DS	common-channel interoffice signaling/direct signaling
CCITT	Comite Consultatif International Telegraphique et Telephonique
CCR	control and ringback
CDA	coin detection and announcement
CDT	control, display, and test
CESAC	CCIS electronic switching system assistance center
CFD	call failure detected
CKF	continuity check failure

CLD	called
CLERKIN	clerk input process
CLF	clearforward
CLG	calling
CMDS	centralized message distribution system
COF	confusion
COT	continuity
CPD	central pulse distributor
CPU	central processing unit
CRC	cyclic redundancy check
CRIS	customer record information system
CRT	cathode-ray tube
CTO	continuity time-out
CTT	compare translation test
DA	directory assistance
DB	data base
DBAC	data base administration center
DBAS	data base administration system
DBM	data base manager
DBMS	data base management system
DCT	digital carrier trunk
DDD	direct distance dialing
DML	data manipulation language
DP	dial pulsing
DP-IS	dial pulsing, immediate seizure
DSAC	dialing service administration center
DSD	direct-service dialing
DSDC	direct-service dialing capability
DSTT	direct-signaling translation test
DTF	data terminal frame
DTMF	dual-tone multifrequency
DTT	data translation test
EIS	expanded inband signaling
EM	a type of signaling
ENAC	engineering network administration center
ESAC	electronic switching system assistance center
ESS	electronic switching system
ETS	electronic tandem switching
ETS	electronic translator system
FAS	file access subsystem
FAU	file administration unit
FID	field identifier
FIFO	first-in-first-out
FSM	finite-state machine

FWD	forward
GLR	glare
GPSS	general-purpose simulation system
HILO	four-wire switching network
IA	ineffective attempt
IAD	incomplete address detected
IAM	initial address message
ID	identification
IKF	integrity check failure
ILDBMS	initial load data base management system
ILOP	initial load order processor
IMA	ineffective machine attempt
IMS	information management system
INA	ineffective network attempt
INWATS	Inward Wide Area Telecommunications Service
I/O	input/output
IOC	Independent Operating Company
ISDN	integrated services digital network
ISF	input section file
ISU	initial signal unit
ITA	ineffective traffic attempt
JURNL	journal program
KP	key pulse
LINKIN	data link input program
MDA	multifrequency detection and announcement
MF	multifrequency
MMUM	miscellaneous multiunit message
MOP	move order processor
MRF	message refusal
MTTF	mean-time-to-failure
MTTR	mean-time-to-repair
NC	no circuit
NCP	network control point
NCPAS	network control point administration system
NCPDS	network control point data collection system
NOC	network operations center
NPA	numbering plan area
NSD	no-start dial
NSS	network support system
ONAC	operations network administration center
ONI	operator number identification
OSO	originating screening office
OST	originating station treatment
PBC	peripheral bus computer

PDT	partial dial time-out
PE	phase encoded
PER	pulsing error
PIN	personal identification number
POP	pending order processor
POTS	"plain old telephone service"
PROCON	programmable controller
PSC	processor signal congestion
PST	permanent signal time-out
PTC	public telephone check
PUC	peripheral unit controller
PUC-DL	peripheral unit controller-data link
R&R	rate and route
RAM	random-access memory
RAO	regional accounting office
RAOD	regional accounting office-digit
READTAPE	tape input process
RLG	release guard
RO	reorder
ROM	read-only memory
RSB	Repair Service Bureau
RSS	remote switching system
RST	reset trunk
RT	real time
RTT	reply to test message
SAC	service access code
SB	session begin
2-SCCS	No. 2 Switching Control Center System
SE	session end
SF	single frequency
SFG	simulated facilities group
SNF	signaling network failure
SOS	service order system
SPC	stored program control
SPL	special
SQD	supplemental query data
SSAS	station signaling and announcement subsystem
SSB	subscriber busy
SSC	special service center
SSU	subsequent signal unit
ST	start
STP	signal transfer point
T&C	time and charge
TCM	traveling class mark

TAC	terminal access circuit
TDA	tone detection and announcement
TDC	test and display circuit
TEO	terminating-end office
TLM	trouble locating manual
TSO	terminating screening office
TSPS	Traffic Service Position System
TTY	teletypewriter
UOP	update order processor
UQL	unequipped label
USO	universal service order
USOC	universal service order code
UXS	unexpected stop
VC	vacant code
VFL	voice frequency link
VNN	vacant national number
WATS	Wide Area Telecommunications Services
XST	expected stop time-out

CONTRIBUTORS TO THIS ISSUE

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Robert G. Barrere, University of Florida; Southern Bell, 1959–1978; AT&T, 1978—. Mr. Barrere works in the Operator Services Planning and Facilities Group at AT&T and is responsible for AIS and No. 5 ACD. He has been involved with the mechanized Calling Card Service project since 1978. He is chairman of the Calling Card Service Data Base Administration Committee and is responsible for overall Calling Card Service data base implementation and administration.

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for metropolitan areas. In 1972, under a plan to give selected Bell Laboratories staff experience in the Bell Operating Companies, he joined New Jersey Bell and was responsible for planning and administering the facilities of a Traffic Service Position System (TSPS). He returned to Bell Laboratories in 1974, and was engaged in engineering and planning studies of new features of TSPS. From 1976 to 1982, he supervised groups conducting planning studies and formulating requirements for operator number services systems, operator toll systems, and for operations systems that support new services that will use Direct Services Dialing capabilities. Currently, he is Supervisor of the Software Defined Network (SDN) Planning group formulating requirements for adding SDN capabilities to the Public Switched Network. Member, IEEE.

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Sidney F. Sampson, B.S.E.E, M.S.E.E, New York University; M.B.A., Roosevelt University; Bell Laboratories 1953—. Mr. Sampson has developed a wide variety of components, circuits, processor, and peripheral subsystems for several types of electronic switching systems, as well as equipment for electromechanical switching systems. This included the development of computerized test facilities for development and factory test purposes. He was the Bell Laboratories field representative at Illinois Bell, and during the DBAS development was the Supervisor of the DBAS Data Base Management Group. Member, Tau Beta Pi, Eta Kappa Nu.

John M. Sebeson, B.S. (Physics), 1969, Michigan State University; M.S.E.E., 1971, and M.S. (Materials Science), 1973, Northwestern University; Bell Laboratories, 1969—. Mr. Sebeson has worked on the development of optical memories, hybrid integrated circuits, and high-capacity magnetic bubble memories. From 1975 to 1979, he was engaged in the physical design of control processors for electronic switching applications. In 1979 he began work on the development of systems used in the CCIS network, including studies of network reliability and performance. He is presently Supervisor of the Data Switching Physical Design Group at Columbus.

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TO OUR READERS

Beginning with this issue of *The Bell System Technical Journal*, we will highlight our special issues with distinctively colored covers—tan covers to denote special-subject issues and gold for our forthcoming "Computing Science and Systems" section.

EDITOR

Bell System