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TRANSACTION NETWORK, TELEPHONES, AND TERMINALS

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Transaction Network, Telephones, and Terminals:

Overview

By J. W. FITZWILLIAM and R. L. WAGNER

(Manuscript received June 6, 1978)

Short inquiry and response messages, called transactions, are becoming increasingly important in the conduct of business affairs. These messages are moved electronically through data communications networks. To meet the need, a family of Transaction telephones, terminals, and associated networks, adjuncts, and arrangements has been developed.

I. INTRODUCTION

Data communications began to gain momentum around 1962 with data transmission channels provided over the voice network using both switched and private line facilities. Many uses for data channels were developed, including widespread use of switched network channels for very short data messages.

Such short messages are termed "transactions" in this issue of the B.S.T.J. A transaction consists of an *inquiry* message followed by a *re-*

sponse message, each of which is typically less than 100 characters long (less than two lines of a typed page). Such transactions may be used in a variety of applications—for example, in verifying the credit of a customer in the course of a purchase or in actually moving funds from the buyer's bank to the seller's bank. This second example is from the world of electronic funds transfer, which has been generating much interest among members of government, the banking industry, and their customers.

II. CURRENT SYSTEMS

Transactions typically involve computerized data bases (customer service centers), which may have the credit standing and current balances for all holders of a particular credit card in a given region, or they may be the computerized record of all checking accounts in a bank. There are many such possibilities. An individual making a credit card purchase, as an example, frequently experiences a salesperson making a telephone call and giving the card number and the amount of purchase. The purchaser never hears what comes back, but if the purchase is then completed, which is the usual situation, she or he may assume that it was an approval. The purchaser is frequently aware of a considerable wait, perhaps several minutes, while this transaction is under way.

Figure 1 shows what usually happens during this time interval. The salesperson has called a clerk seated at a cathode ray terminal (CRT). The information, received verbally, is entered into the CRT by means of a keyboard. From there it proceeds to the service center's computer, which contains the credit records. After a short time (usually a very few seconds), the computer has processed this particular inquiry and re-

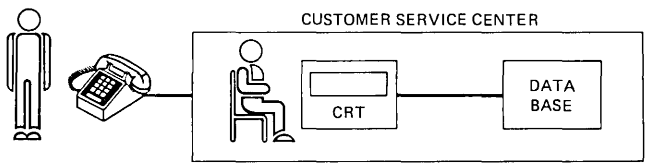

Fig. 1—Existing public switched network service.

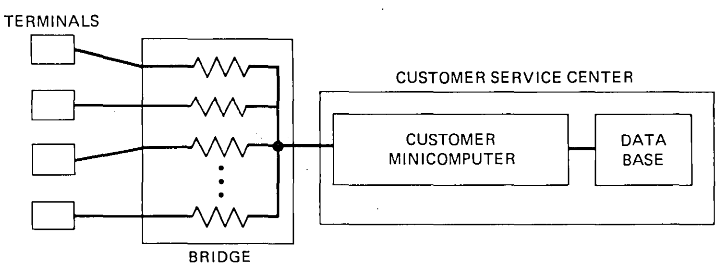

Fig. 2—Existing private line service.

sponds to the CRT, which displays the information. The clerk reads the computer's response to the salesperson waiting on the far end of the telephone connection. The clerk, one of many handling inquiries to the computer, then terminates the call and is ready to receive another. If there is a problem, the salesperson may be referred to another individual for its resolution.

Figure 2 shows an alternative way of reaching the service center's data base. In this situation, the salesperson has a special terminal connected directly to the computer via multipoint (bridged) access lines. Sometimes the terminal has a means for automatically reading the characters on the customer's plastic card. The dollar amount of the transaction is entered manually on a small keyboard (sometimes called a "pad" when only numerals are involved). The terminal also has means for displaying the response, including some cryptic explanation if it is a denial. Private line systems as depicted in Fig. 2 are particularly attractive to entrepreneurs who provide service involving high-volume sales positions. Such systems can be economical and have superior response time, since they eliminate setting up a public switched network call and verbal exchanges between the salesperson and the clerk at the CRT. A disadvantage is the need to handle referrals by a completely separate telephone call.

III. PROBLEMS WITH CURRENT SYSTEMS

Neither of the two systems depicted in Figs. 1 and 2 is entirely satisfactory. The reasons are different, however, The dial-in system of Fig. 1 may be slow, with call setup time approaching the duration of the message. Also, the presence of the intermediate person at the terminal represents unnecessary cost. Finally, concentration of a high volume of short holding-time calls at the customer service center may necessitate special engineering of the switching facilities serving that location so as to avoid traffic congestion problems adversely affecting other users.

The private line systems depicted in Fig. 2 solve the response-time problems and eliminate the need for the individual at the computer terminal. They suffer mainly from the infirmities of conference circuits (multipoint connections), which bridge many subscribers on a common channel going to the computer. Such circuits are effective in moderation, but as more terminals (and drops) are added to the network to make its operation economical, the reliability and difficulty of tracing problems become very troublesome.

IV. THE RESPONSE

The papers in this issue of the B.S.T.J. describe a multidimensional response to the problems and the opportunities outlined above. A family of products and serving arrangements has resulted, giving customers a choice.

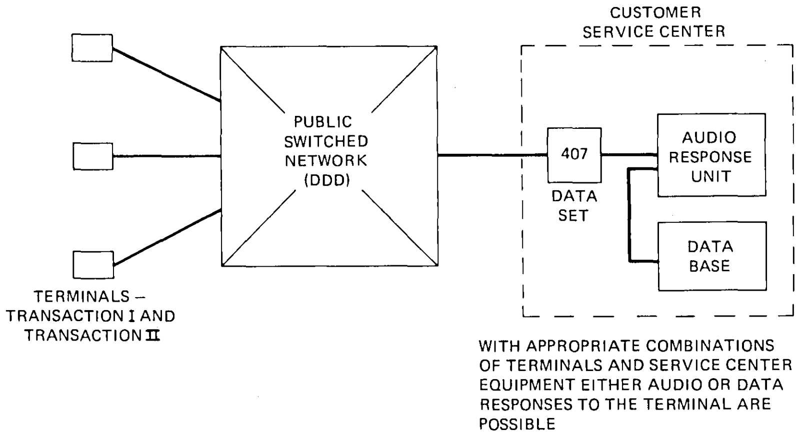

Fig. 3—One type of serving arrangement for transaction traffic.

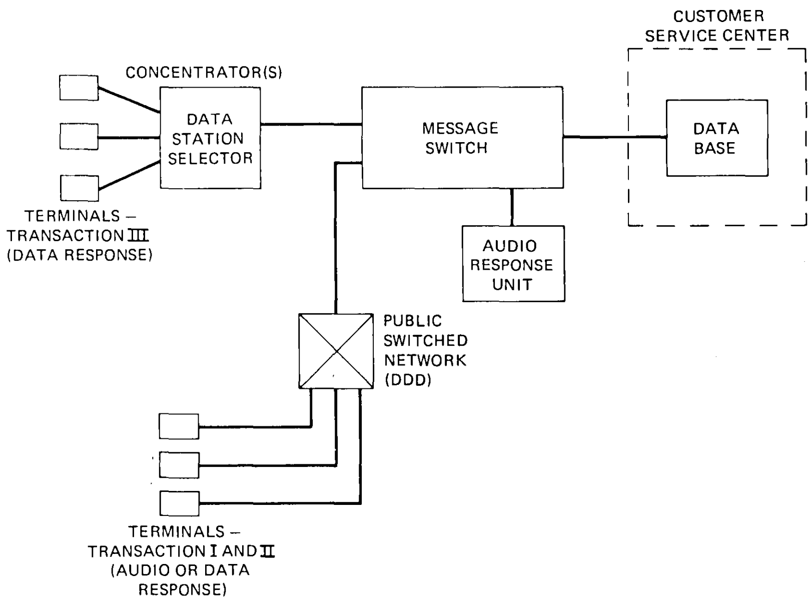

Fig. 4—Transaction network—another serving arrangement for transaction traffic.

One type of serving arrangement depends entirely on the public switched network. It is supported by Transaction telephones and data sets (type 407) tailored to this special use. A second type of serving arrangement, called the Transaction Network, introduces a message switching network to achieve better response time, reliability, sharing, and functionality tailored to transaction-oriented applications. These two arrangements are shown in simplified schematic form in Figs. 3 and 4, respectively.

Transaction telephones and terminals serve both of these networks and have wide applicability for other innovative uses. They provide simple, convenient data entry and data reception capabilities that are well matched to short data transactions. These telephones and terminals can all read the magnetically encoded stripe on the standard credit card. Transaction I and II telephones both operate on the switched network and double as ordinary telephones. The Transaction I telephone is the simpler, lower-cost terminal that receives audible response; the Transaction II telephone provides the additional capability of data output on a numeric (LED) display. The Transaction III terminal has no voice capability and was designed expressly for the Transaction Network, where it provides higher-speed performance. Transaction II and Transaction III are compatible with the Transaction printer for issuing receipts, verifying checks, or providing other hard copy as an alternative output of the Transaction terminals.

For the serving arrangements of Figs. 3 and 4, the connection is between the salesperson at the Transaction terminal and the computer, where either data or voice responses are composed. In both cases, recorded or synthetic speech is used when responding to the salesperson in the "voice response" mode. However, in Fig. 3 the customer service center provides the response from a dedicated unit, whereas in Fig. 4 voice responses are prepared with a shared-use unit at the message switch.

This brief explanation is intended to develop the context for the papers that follow. There are important subsystems, adjuncts, and arrangements that have not been mentioned here.

V. THE CHALLENGE

There is an evolving use of computers and associated communications systems to improve the quality of life. The technical advances described in this issue of the B.S.T.J. are a part of this larger view. Although each advance brings with it new problems and frustrations, the prevailing view of the futurists is that there is more change ahead involving computers, communications, and "us." What appears radical today in terms of dependence on computers, we are told, will be commonplace and comfortable tomorrow.

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Transaction Network, Telephones, and Terminals:

Transaction Network Service

By W. G. HEFFRON, Jr. and N. E. SNOW

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Transaction Network Service is provided by a message-switched communication system especially designed for short formatted data messages. The Transaction Network system carries messages between Customer Service Centers (customer-owned data processing centers) and polled terminals or dial-in Transaction telephones, as well as between Customer Service Centers. It does this quickly and economically, with high reliability and maintainability of service. This paper discusses first the need for Transaction Network Service and the system design goals set for it. Then the elements of the system are discussed, including how they work together in providing service.

I. A NEED FOR TRANSACTION NETWORK

Short data messages of the inquiry/response type have in the past been carried by two types of available telecommunications service offerings. One is the Public Switched Telecommunications network using either simple voice conversations, data and automatic voice response units, or full two-way data exchange. The other is the use of multipoint private line networks between terminals and computers in full two-way data exchange. Issues of cost, response time, reliability, engineering, and administration all arise and become more serious as greater volumes of transactions occur and as more locations are served.

Inward Wide Area Telecommunications Service—INWATS—is the common way of using the dial network. It puts no toll charges on the calling party, and is cost-effective for low volume/high value messages. Translation of the 800-type number cannot economically be provided in every service central office. An INWATS call must therefore be routed first to a toll office capable of the translation, and routed from there to the destination. Call setup times of some 12 seconds are common. Thus it is slow, and even though toll charges are relatively low, the net result is that it is most effective for high value transactions.

The multipoint private line network is appropriate for high volumes and fast response times. These two factors and the number of stations to be served determine the specific configurations. Restrictions occur because of technical considerations. As more stations are bridged together, the potential for electrical noise and echoes increases. The solution for echoes is to use separate channels for transmit and receive, causing increased cost. Noise limitations may govern the number of stations per multipoint circuit because the noise received at the host computer is effectively the sum of the noise in all the elements of the bridged multipoint circuit. When noise becomes excessive, the performance of the circuit degrades. Diagnosis and repair may be disruptive and tedious since the entire circuit must be removed from service and its components tested until the offending source is isolated and then repaired.

A further complication in multipoint circuits is in disciplining the flow of information. For example, only one terminal should send a message to the host computer at any one time. Not only is this discipline, called a protocol for information interchange, a nontrivial task, but different types of terminals commonly use different protocols. Thus, independent circuits and access arrangements to the host computer and independent "protocol software" in the computer are all required when differing types of terminals are needed and deployed.

The Transaction Network system addresses these issues positively. It includes a superior alternative to the multipoint bridged channel. It performs protocol management to permit a host computer to communicate with several types of terminals through one protocol, one software package, and one type of access arrangement. It uses the dial network for access when appropriate: by offering an Automatic Voice Answerback service, it makes the use of the dial network effective for residences as well as places of business.

As a brief characterization, Transaction Network Service is effective because it is a total system designed to meet the needs of the inquiry/response market. The following section discusses this in more detail.

II. SYSTEM GOALS

Figure 1 is a conceptual view of the design goals for the Transaction Network system. "Common user" is a goal from several perspectives. One is that a terminal or telephone may require connectivity to several Customer Service Centers to conduct the desired variety of transactions. Some terminals may not need such varied connectivity, but can benefit from the economies gained by sharing use of the network with others. TNS meets both needs, the former by having a switching capability and

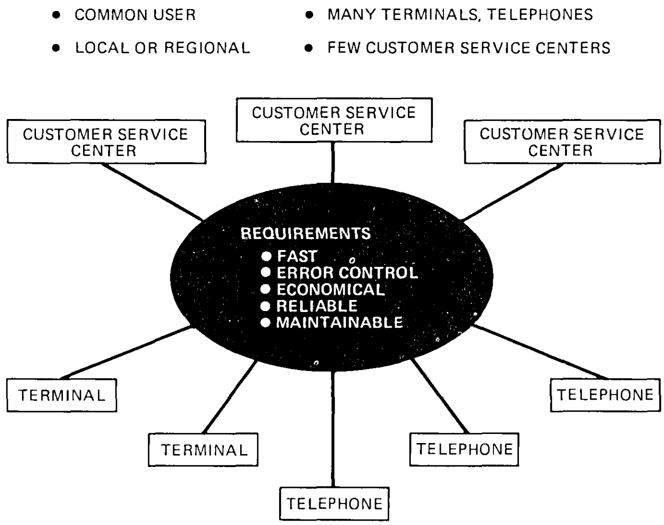

Fig. 1—Transaction Network design goals.

the latter by incorporating restricted routing options between terminals and Customer Service Centers and between affiliations of Customer Service Centers. The use of a single integrated system permits several users to share in the necessary costs of administration, engineering, and maintenance to their mutual benefit in cost and quality of service.

"Local or regional," in Fig. 1, relates to cost optimization and is listed because analysis shows a major component of cost in typical customer-designed networks to be in the local distribution network. This is one area where new economies are needed, and where they are provided.

Many terminals and telephones of several different types and few Customer Service Centers constitute the typical nature of the inquiry/response short data message market. In particular, Customer Service Centers served by Transaction Network Service will show major economies and simplification in hardware and software because of the protocol management capability of TNS. One type of connection and software in the customer's computer will reach the several types of terminals, but any terminal meeting the appropriate specifications will be supported. Transaction Network Service does not include the front-end hardware and software required at the customer's computer to interface with the network. The customer must provide these, as well as the computer itself.

Requirements and specifications for the interfaces to Customer Service Centers and to polled and dial-in terminals are available in the form of Bell System Technical Reference publications.[1–4]

The most important attributes of the Transaction Network are in the center of Fig. 1. Messages are carried with minimal delay. There is no store-and-forward or multiple address (broadcast) aspect to the

Transaction Network: messages that cannot be delivered are returned to the sender, with the type of irregularity encountered indicated in the returned message. Positive error control, on each link in the network, is also of major importance. The synthesis of these two aspects is that the customers can use the network confidently; the messages will be carried exactly as entered into the network—if they cannot, the user will know it promptly and unequivocally. In particular, the design of the Transaction Network makes it possible almost to eliminate uncertain transactions, at least insofar as network performance may contribute.

Reliability and maintainability must be and are high, promoting service availability at the levels needed by users. How this is achieved is best discussed after describing how the Transaction Network operates.

The following sections of this paper present an overview of the services provided and the functional operation of the system, serving as an introduction to the accompanying in-depth articles. As with most systems of the complexity of Transaction Network, numerous acronyms have developed. The appendix contains a listing of those used in this and the accompanying papers.

III. POLLED TERMINAL SERVICE

Figure 2 shows at the left polled terminals and at the right Customer Service Centers. Between them lie the polled access network, the message switch, and the synchronous links to the data processing centers.

Consider first the message switch. Typically, there is one of these in a metropolitan area, although, in large areas and as traffic grows, more than one may be needed. This message switching unit not only controls and routes the flow of messages, but also tests itself and the communication network it controls. It also does billing, traffic, and administrative tasks. Its use is shared by all subscribers.

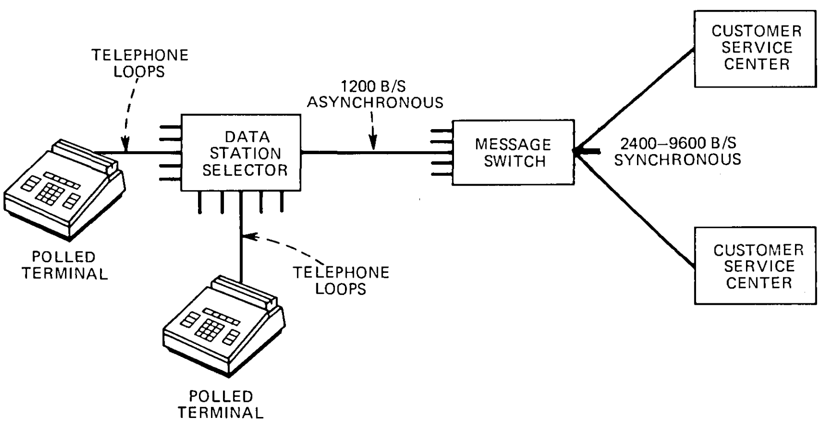

Fig. 2—Transaction Network (polled access).

The Data Station Selector is a newly developed, solid-state line concentration device leading to economies in local distribution costs. It is installed in the wire centers nearest the terminals, and can also be installed on customer premises. Its use is shared by up to 61 terminals. Each terminal is served by a two-wire loop which terminates in a Channel Service Unit. The loops are ordinary voice-grade quality with no special engineering required in the vast majority of the cases. The Channel Service Unit, which is an integral part of the network, is for maintenance purposes and for adjusting loop loss to meet the fixed level transmission plan. The chosen data speed, 1200 b/s, facilitates meeting the objectives of "no special engineering" of loops, the undetected error rate goal, and the speed of service goal.

Once the terminal is armed to transmit a message, carriage of the message begins with polling the terminal by the message switch. The Data Station Selector is commanded by the message switch to connect a specified terminal to the backbone trunk between the Data Station Selector and the message switch. Then the message switch sends an alerting signal to the terminal. This alerting signal is the same for all terminals: it is not a unique identification number for the specific terminal.

If the terminal has no message to send, it remains silent and, after a brief interval, the message switch moves on to poll other terminals.

The grade-of-service objective is 1.25 seconds on the average for access delay. That is, the average delay between arming a terminal to send a message and the start of its transmission towards the message switch is 1.25 seconds. The number of terminals supported by each Data Station Selector is engineered to meet this objective, the criteria including the amount of traffic generated by the terminals.

If a message is ready, it will be sent, and it must be of the form shown in Fig. 3. The major parts of this message are the heading, the text, and the Longitudinal Redundancy Check character. The BAL (Blind Alert) character leads all messages: it distinguishes a message from a command to the Data Station Selector. The heading is required because the Transaction Network is a switched service, requiring the routing infor-

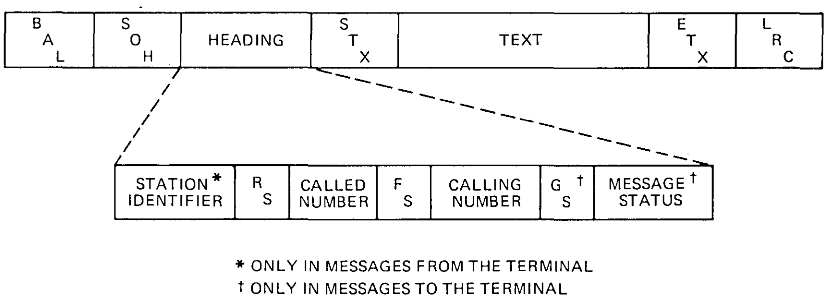

Fig. 3—Polled terminal message format.

mation contained in the heading. In the heading the Station Identifier field tells what kind of terminal is transmitting, to distinguish the user features of one terminal from another—information of particular interest to the data processing center in composing a response message to use these features most appropriately.

The called number in an inquiry message is that of the Customer Service Center. A new seven-digit number plan, totally independent of the usual telephone number directory plan, has been created. All seven digits in the calling and called number plan are not always needed.

In particular, polled terminal users can option "restricted access," and then the polled terminal can call or be called only by designated Customer Service Centers. In such a case, one number, and even no number (that is, implied addressing), is enough for the called number. Obviously, both the polled terminal and the Customer Service Center subscribers must agree to such an arrangement.

The calling number applies to the terminal and also is assigned by the telephone company. It is checked by the message switch to ensure that the Data Station Selector accessed the proper terminal; having it in the message is also a convenience to the Customer Service Center, since it is the directory number of the terminal. It could also be used as an identification of the calling party.

The message status field is not sent by a polled terminal. In case of irregularities, it occurs in messages to the terminal and identifies the irregularity.

Text is strictly under user control and is not rearranged or altered by the Transaction Network. All characters throughout are ASCII; text must be 128 characters or less, and not include control characters.

When the message arrives at the message switch, the following checks are among those made: the calling number is correct; parity in every character is correct; the Longitudinal Redundancy Check character, an overall parity test on the whole message, is also correct.

If all tests are passed, the message switch sends ACK (Acknowledgment) and the terminal then sends EOT (End of Transmission). Then the message forwarding begins. If any test fails, NAK (Negative Acknowledgment) is sent, and polling is resumed. On the next polling cycle, transmission is attempted again.

Figure 4 illustrates some of the possible modes of operation of this protocol. On the top two lines is seen a normal inquiry message transfer. Then the effects of three types of transmission errors are illustrated. The last two illustrate that no EOT (End of Transmission) from the terminal within an allotted time is cause for the message switch to send ACK again but that a garbled EOT is cause for an ENQ ("what was sent?") from the message switch and a subsequent retransmission of EOT by the terminal. Only the message switch can send ENQ. This protocol should yield an undetected error rate of 1 in 10^7 messages, or better.

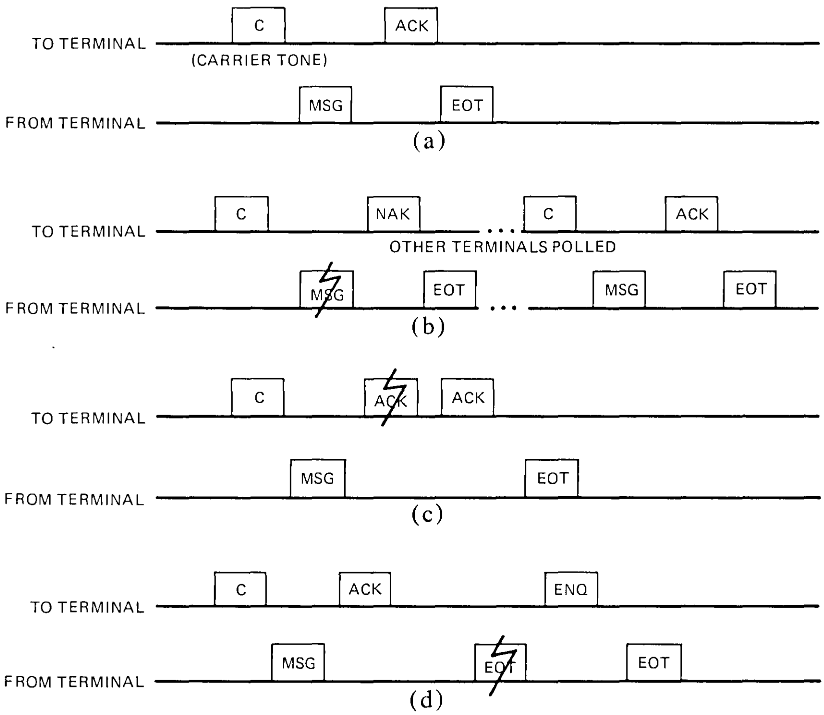

Fig. 4—Polled terminal protocol, inquiries. (a) Inquiry message, normal dialog. (b) Inquiry message, garbled. (c) Inquiry message, control garbled. (d) Inquiry message, termination garbled.

After additional checks, the message enters the buffer to the designated Customer Service Center. Among these tests is the class-of-service test. For example, if the Customer Service Center has elected not to accept messages from unrestricted polled terminals or from dial-in telephones, then the check will result in such messages being turned back, with appropriate message status codes.

When the Customer Service Center has processed the inquiry and sent a response message back to the message switch, the response enters the buffer for the Data Station Selector serving the proper polled terminal. Polling is interrupted and the message sent to the terminal. Errors are checked, and when ACK and EOT have occurred, the terminal can present the response to the user. The tests include correct called number, i.e., the message has reached the correct terminal. They may also include a test on the Customer Service Center to which the inquiry was sent, but this is strictly optional. The Transaction Network does not pair inquiries and responses. A terminal may send several inquiries one after the other and may receive several responses one after the other. The only restriction is that only one message may be sent per poll cycle.

IV. CUSTOMER SERVICE CENTER SERVICE

The synchronous link connecting the message switch to the Customer Service Center operates under an ANSI standard Binary Synchronous Control protocol. Although four-wire synchronous channels are used, the protocol is basically half-duplex. The message switch and the Customer Service Center take turns originating message flows, the other end checking for errors and acknowledging or negative acknowledging as appropriate, with retransmission the error recovery technique.

Figure 5 shows some details of the message composition for all messages to and from the Customer Service Center. On the top line, the SYN character is standard for achieving character synchronization. The prefix may be specified by the Customer Service Center to make its work easier—in all, there are some 24 options possible, all made available to make the Transaction Network easier to accommodate with existing Customer Service Center software. Text is the original, unaltered text. The suffix is again a Center option, and the LRC is the Longitudinal Redundancy Check character for the message. The goal of 1 in 10^7, or better, undetected error rate for messages applies to this link also.

The second line shows the components of the heading. The Heading Item Indicator tells what fields are in the heading. The Station Identification, called and calling numbers are as in the terminal's message but now the calling and called numbers are the full seven digits, and the sequence number counts the messages to help control flow over the link.

The third line on the figure is perhaps the most important. The Transaction Network can operate with one message per block, but it also can transmit and receive multiple messages in a block, as well as transmit several blocks before relinquishing the line to the Customer Service

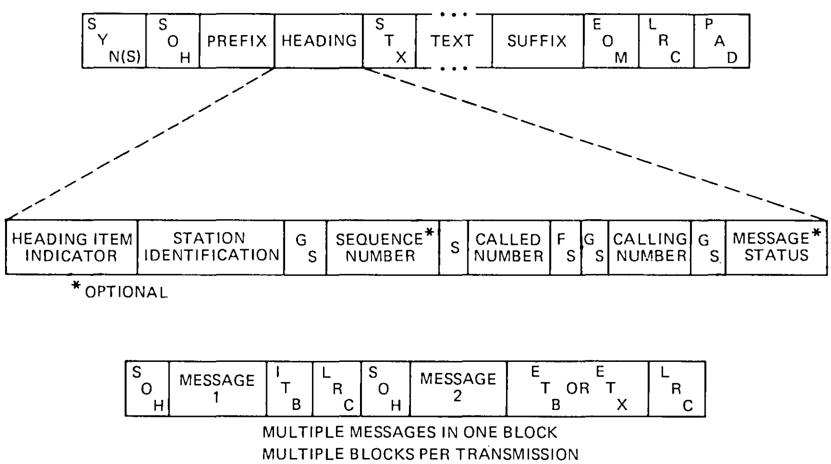

Fig. 5—Customer Service Center message formats.

Center. This should be the method of operation when efficiency is important. The Customer Service Center should be able to operate in the same way. The benefit is a faster transaction time (inquiry to response) and a more efficient, and thus lower cost, synchronous channel and associated hardware system.

Not shown is the list of Service Messages that can pass between the Customer Service Center and the message switch. They are appropriate to the application but include the ability to invoke a particularly valuable feature—alternate delivery. If, for example, the center needs to go out of service for maintenance, it can instruct the message switch to deliver messages to another center, until the command is cancelled. Obviously, prior arrangements must be made with both the telephone company and the other center. And, naturally, this feature will also be invoked if there is an unscheduled loss of either the synchronous channels or Customer Service Center—the feature provides both an automatic and a controllable backup.

After composing the response, the Customer Service Center sends it to the message switch using the same message format as in Fig. 5. The checks on errors are made, as are class-of-service tests. In particular, centers can form "affiliations" and message flows between centers will then be screened accordingly and turned back if inappropriate. Each center may belong to more than one affiliation.

V. DIAL-IN TELEPHONE SERVICE

Figure 6 shows dial-in service arrangements also, and is intended to suggest that three types of dial-in protocols are offered. One is for an ordinary *TOUCH-TONE®* service telephone with 12 keys, i.e., the * and # keys must be present. It transmits *TOUCH-TONE* signals, and receives responses through the Audio Response Unit (called Automatic Voice Answerback service). The protocol that supports this telephone is called the Voice Response protocol. A second is represented by the Bell System Transaction I telephone: it transmits all 16 of the possible *TOUCH-TONE* signals,* and the messages include two characters for error detection. Responses to it can be of three forms: an audio message; a keyed answer tone of 1.5 seconds to light a light, for example; or a keyed answer tone of 3.0 seconds to light a different light, after which an audio message is given. This protocol is called the Voice/Keyed Answer Tone (KAT) protocol.

The third telephone is exemplified by the Transaction II telephone and uses a different telephone number to access the ports on the message switch. This terminal uses all 16 *TOUCH-TONE* signals to transmit, but receives data responses, frequency-shift-keyed at 150 b/s, and can retransmit to overcome detected errors. Its protocol is called the Data

* The unusual four *TOUCH-TONE* signals are here called *a, b, c,* and *d*.

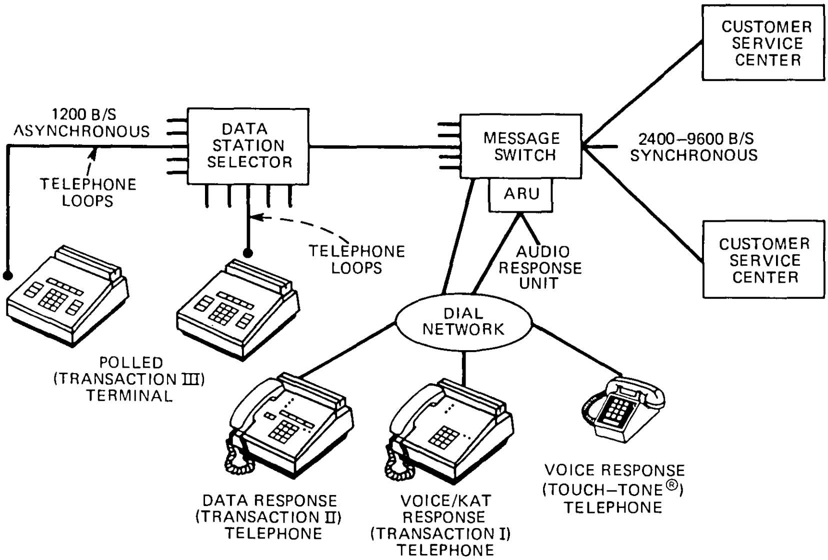

Fig. 6—Transaction Network.

Response protocol.

To illustrate dial-in service, consider now the second arrangement, using the Voice/KAT protocol. The first step in its use is to dial, as with an ordinary telephone, a number assigned to the ARU port hunting group for the message switch. When the connection is made, an answer tone will be sent from the port to the telephone for 1.5 seconds. After this, the telephone may transmit a message such as is indicated in Fig. 7.

First comes the heading. In it, the *b* signal is used to differentiate this telephone from a *TOUCH-TONE* telephone, and *b*20 together constitute both the Start of Heading (SOH) and the station identifier field (as seen earlier for the polled terminal). Then *b*8 is a field separator, and 5550076 is the Transaction Network identification for a specific Customer Service Center.

The calling number does not appear in this heading because Transaction Network service does not include Automatic Number Identification. That is, the message switch cannot automatically discover the "white pages" directory number of the calling telephone. In the message to the Customer Service Center, however, there is a calling number: it is the designation of the dial-in port at the message switch, which the data processing center must use in the response message. As a further safeguard, an "activity number" is also in the heading, sequencing the uses of the specific port. A response message also must contain the "activity number" and it must match the current number, or else the response will be rejected instead of delivered.

The text is user-specified, but with control characters avoided. The

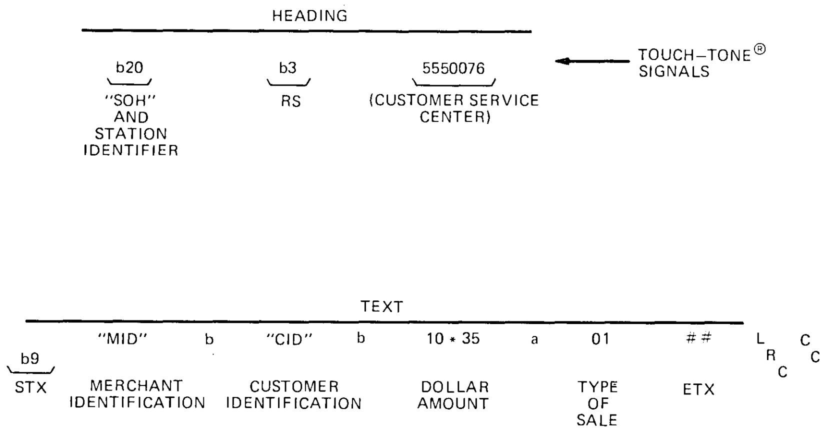

Fig. 7—Dial-in telephone message format.

example is for a credit card authorization as done with the Bell System Transaction I telephone.

Use of # # as ETX (End of Text) is a requirement, as are the LRC character (calculated using a four-bit representation of a *TOUCH-TONE* signal) and the character count (modulo 10) character. With these latter two characters, the 1 in 10^7 messages with undetected errors goal can be achieved on this link also.

Figure 8 shows some possible message transfers for this link. At the top is a simple inquiry and response. First is the answer tone from the message switch, then the message is sent. Not shown is the forwarding of it to the data processing center after the error, class-of-service, and other checks. The Customer Service Center, seeing from the Station Identifier field that an audio response is required, composes the response message in the following special way. In the station identifier field of the response message, it puts the code which instructs the message switch that the Audio Response Unit is to be used. In the text, the center uses triads of characters (maximum 128/3 = 42 triads). Each triad indicates a phrase chosen from the specified phrases for the Audio Response Unit. One phrase might be the utterance "ONE," another, "CHECKING TO SAVINGS TRANSFER." The phrases are then uttered in the sequence given.

In the simple transaction shown at the top of the figure, the attendant then hangs up. The telephone should send a "disconnect" sequence to the message switch, causing it also to hang up promptly and minimizing the connect time on the port, which is seized for the duration of the entire transaction. If the disconnect signal is not sent, up to 15 seconds additional connect time may occur before the message switch times out and hangs up.

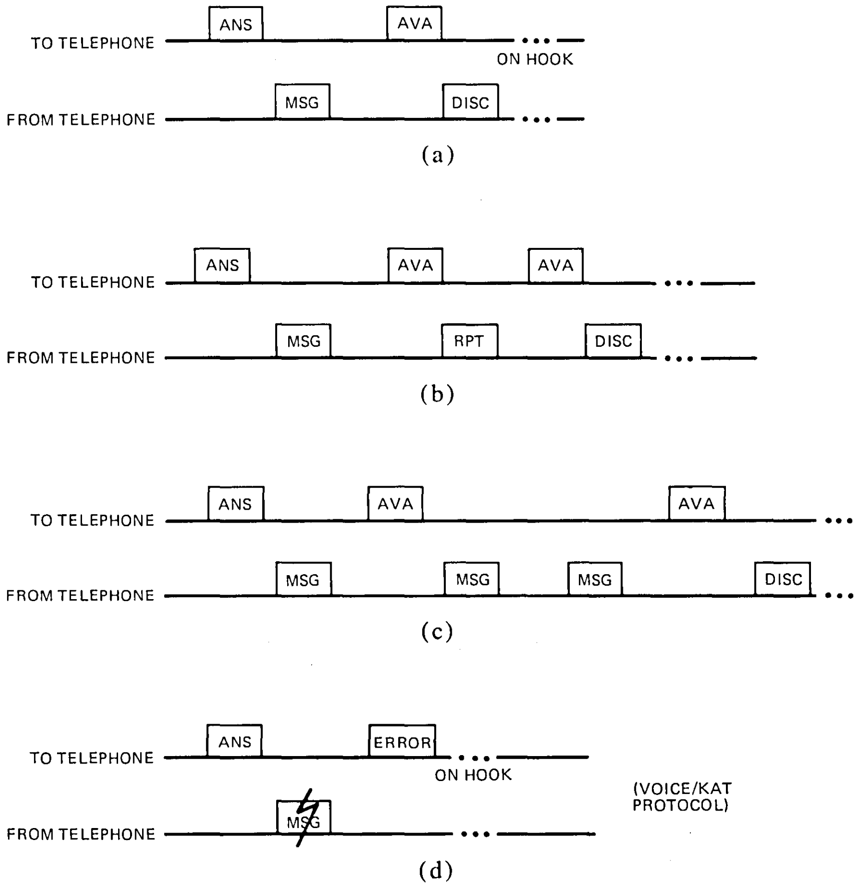

Fig. 8—Dial-in message transfer. (a) Normal dial-in transmission. (b) With AVA repeat. (c) Multiple messages. (d) Garbled transmission.

The second transaction in the figure shows the capability to request a single repeat of the audio message.

The third transaction shows the multiple inquiry capability of the Transaction Network. After the first inquiry, no heading may be input; the message switch will use the first heading for every message originated during the dial connection. Thus, all messages go to the same data processing center.

The last transaction illustrates that the Voice/KAT protocol has error detection capability, but no error correction through retransmission—a capability left to the more sophisticated "data-response" dial-in protocol and telephone. Having detected an error under the Voice/KAT protocol, the message switch announces a phrase such as "TERMINAL OR NETWORK TROUBLE. PLEASE HANG UP AND TRY AGAIN. GOODBYE" and disconnects.

VI. RELIABILITY AND MAINTAINABILITY

Reliability of service is achieved in the Transaction Network by using equipment redundancy, reliable components, fast and accurate diagnostic methods, and by prompt replacement of failed components.

The system consists of a dualized message switch which supports polled terminals on dualized dedicated transmission links by way of small dualized line concentration units (Data Station Selectors). Multiple dial-in ports are provided in central office line hunting groups for terminals which access the message switch by way of the dial network. Every part of the communication network, with the exception of the final serving loop, is protected from single failures.

The message switch is based on an enhanced version of a processor originally developed for a telephone Electronic Switching System. It operates on a working and hot spare basis and has a service reliability goal of 2 hours or less downtime in 40 years. The Data Station Selector is doubly fed by independent ports at the message switch and is itself redundant. If either of the backbone feeds or either of the two control portions of the Data Station Selector fails, then all the terminals are polled by the working sides. The message switch can command a status message from the Data Station Selector on its status and on the status of the loops to the terminals. Further, the message switch keeps track of the quality of transmission—the errors detected by parity and LRC checks—and issues trouble reports as appropriate.

Numerous loopback capabilities exist throughout the network for testing and trouble location: they are invoked periodically, or when trouble is detected, or under control of maintenance personnel.

Two "loopbacks" are of particular interest. To confirm proper installation of a polled terminal, it can send a message to itself through the message switch, thus testing the whole connection. The other is the same sort of capability for a Customer Service Center: this also is useful for testing before the Center begins service to terminals.

In the synchronous links, the message switch includes spare data sets, or, if the Digital Data System is used, spare Data Service Units, sparing being on a 1:n basis (where n represents the units in service). The spares can be inserted automatically. Customer Service Centers, of course, may wish to use more than one synchronous channel for reasons of reliability (additional to that made possible through alternate delivery) as well as for message traffic capacity.

Reliability of dial-in Automatic Voice Answerback service is achieved by having two on-line Audio Response Units, each connected to half of the hunting group terminations. If one fails, then all calls are taken by the other. The separate hunting groups for the ARU and for the Data Response telephones are sources of reliability, since any unit in a group is equally useful in answering calls.

Again, loopbacks within the equipment isolate the source of trouble or simply verify continued correct service. The unit is busied out, of course, before such tests occur. As before, such tests are run routinely, when trouble occurs, or when maintenance personnel command them.

While routine diagnostics are functional in detecting and isolating equipment failures, and redundancy or recovery tactics are effective in maintaining service availability, the network ultimately requires repair. The Transaction Network makes use of the wide range of telephone plant facilities. In doing so, it crosses many lines of organization and of craftsperson jurisdiction. For these reasons, the system maintenance planning has been directed toward use of existing organization capabilities. For example, troubles detected in the message switching office are directed to the Switching Control Center by teletypewriter; line terminal problems are referred to Station Installation and Repair, etc. The objective always is to insure rapid dispatch of the appropriate repair forces and to localize the problem so the dispatch is most effective.

VII. ENVIRONMENT AND DESIGN

The Transaction Network Service message switching office utilizes the same electronic switching system technology for all input-output peripherals as the processor itself. Manufacturing techniques are therefore common throughout. Groups of communication line adapters are arranged in equipment units for ease of engineering, ordering, and installing additional capacity without service interruptions. Combined with these units are data sets of standard designs used for customer services across the range of current Bell System data communication service offerings. Hence, the data craftsperson works with familiar equipment. Any telephone central office presently supporting or designed to support ESS telephone switching machines (over 1000 such offices are in operation at this time) is an ideal location for a TNS switch.

Data Station Selectors, normally being installed in the same central office that provides telephone service to the customer, or on the customer's premises, are subjected to a much wider range of environmental conditions. The design makes use of those technologies providing the highest degress of reliability under adverse power and noise conditions. As small, complete units, they are conveniently ordered and installed in telephone or private branch exchange office space or even customer-premises wiring closets. The modular design permits equipping of only the number of lines needed at the particular location.

VIII. CONCLUSIONS

Hallmarks of the Transaction Network are reliability, speed of message transfer, error control, and economy, factors especially vital to banking and financial communications and to many other areas of the short data message inquiry-response market. Reliability of service is achieved by extensive redundancy in equipment, the purposeful design of maintenance capabilities into the system, and the skill of Bell System personnel in establishing and maintaining the system. Speed of message transfer, with a high degree of error control, is achieved by careful system design, use of modern technology, and careful programming of software systems. Economy is based in part on modern technology and innovative system design and also on the shared use by customers of much of the system. The Transaction Network as outlined in this paper provides a new total communications system alternative to banking, the financial industry, and other industries requiring similar capabilities.

IX. ACKNOWLEDGMENTS

Numerous organizations and individuals participated in the realization of the Transaction Network system. Special recognition is due to L. R. Pamm, C. R. Moster, E. A. Irland, W. Ulrich, W. B. Cagle, T. M. Burford, and E. R. Kretzmer as directors of the organizations at Bell Laboratories in which the planning and development of the many hardware and software elements of the system were pursued.

APPENDIX

Listing of Acronyms Associated with Transaction Network and Transaction Network Service

ALA Asynchronous Line Adapter—interface to the message switch for 1200 b/s asynchronous communication.

ARU Audio Response Unit—output peripheral of the message switch for transmitting voice responses to telephone terminals.

ASCII American Standard Code for Information Interchange.

CLCI Common Language Circuit Identification—Bell System designation for a specific combination of circuit characteristics.

CSC Customer Service Center—a customer-owned data processing center which administers and maintains a data base information system.

CSU Channel Service Unit—a hardware device which terminates a channel on the customer's premises and provides the necessary maintenance, transmission power level adjustment, and protection features.

DBS Duplex Bus Selector—a hardware device giving either of duplexed message switches access to an I/O channel.

DLA Dial Line Adapter—interface to the message switch for dial network terminals.

DSS Data Station Selector—a line concentration device providing connection of up to 61 terminals to a common transmission facility on a polling basis.

FSK Frequency-Shift-Keyed—the type of frequency modulation used on 1200 b/s transmission channels.

KAT Keyed Answer Tone—pulse length modulation of a single frequency tone.

LAS Line Adapter Selector—an addressable concentrator for asynchronous or dial line adapters.

LHG Line Hunting Group—a group of telephone lines from which an idle line will be selected when a single telephone number is dialed.

MPCH Main Parallel Channel—a primary high speed I/O channel of the message switch.

MS Message Switch—the central control which routes messages, administers and performs maintenance diagnostics on the communication network, and performs billing functions.

PAC Polled Access Circuit—the asynchronous polled interface to the message switch, comprising duplexed line adapters, transmission facilities, and data station selectors.

PROMATS Programmable Magnetic Tape System—A magnetic tape system interfaced to the message switch for recording billing data.

SCAM Switch Control and Monitor—equipment which monitors the message switch I/O hardware, network status, power, and alarms and under message switch control performs equipment and channel protection switching.

SPCH Sub-parallel channel—An addressable I/O channel which connects peripheral devices to the main I/O channel of the message switch.

SLA Synchronous Line Adapter—Interface to the message switch for 2.4, 4.8, or 9.6 kb/s channels to Customer Service Centers.

TID Terminal Identity Code—a unique number assigned to each terminal served by TN.

TN Transaction Network–the entirety of message switch, I/O peripherals, communication channels, data station selectors, and local loops used in providing Transaction Network Service.

TNE Transaction Network Exchange—The area served by a Transaction Network message switch and described by a unique three-digit number in the seven-digit numbering plan.

TNS Transaction Network Service—the total end-to-end service and feature set provided by connection to TN.

TNCSB Transaction Network Customer Service Bureau—the Transaction Network administrative entity responsible for handling the addition, removal, changes, and problems related to individual customer services.

TRANSPLAN Transaction Network Service Planning model—a time-shared computer program package available to operating telephone companies in planning the introduction of TNS.

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Transaction Networks, Telephones, and Terminals:

Communication Network and Equipment

By C. A. BUZZARD, J. A. DRAGER, and B. R. SALTZBERG

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Implementation of the Transaction Network required development of new equipment and integration of existing equipment to create a message switch and a communication network that interfaces with the switch by means of polled, dial, and synchronous access. Particular emphasis was placed on the reliability and maintainability of the system.

I. MESSAGE SWITCH COMMON EQUIPMENT

The central element of the Transaction Network is the message switch. Besides providing termination for polled, dial, and synchronous communication facilities, the message switch controls and routes traffic, performs the billing and administration function, and controls maintenance of the network.[1,2]

The configuration of the common equipment is shown in Fig. 1. The arrangement was designed with particular emphasis on reliability and maintainability. Much of the equipment is also used in systems other than the Transaction Network.

1.1 Processor

The Auxiliary 3A Processor is an enhanced version of the same processor used in the No. 2B and No. 3 ESS systems.[3] The principal enhancements consist of the addition of parallel input-output channels, direct memory access capability, and microprogrammed instructions that are useful in applications other than line switching.

The processor is a duplicated unit, containing two 3A central controls and two semiconductor memories. In the initial Transaction Network installations, 256K words are required in each memory, each word consisting of 18 bits including two parity bits. At any time, one processor

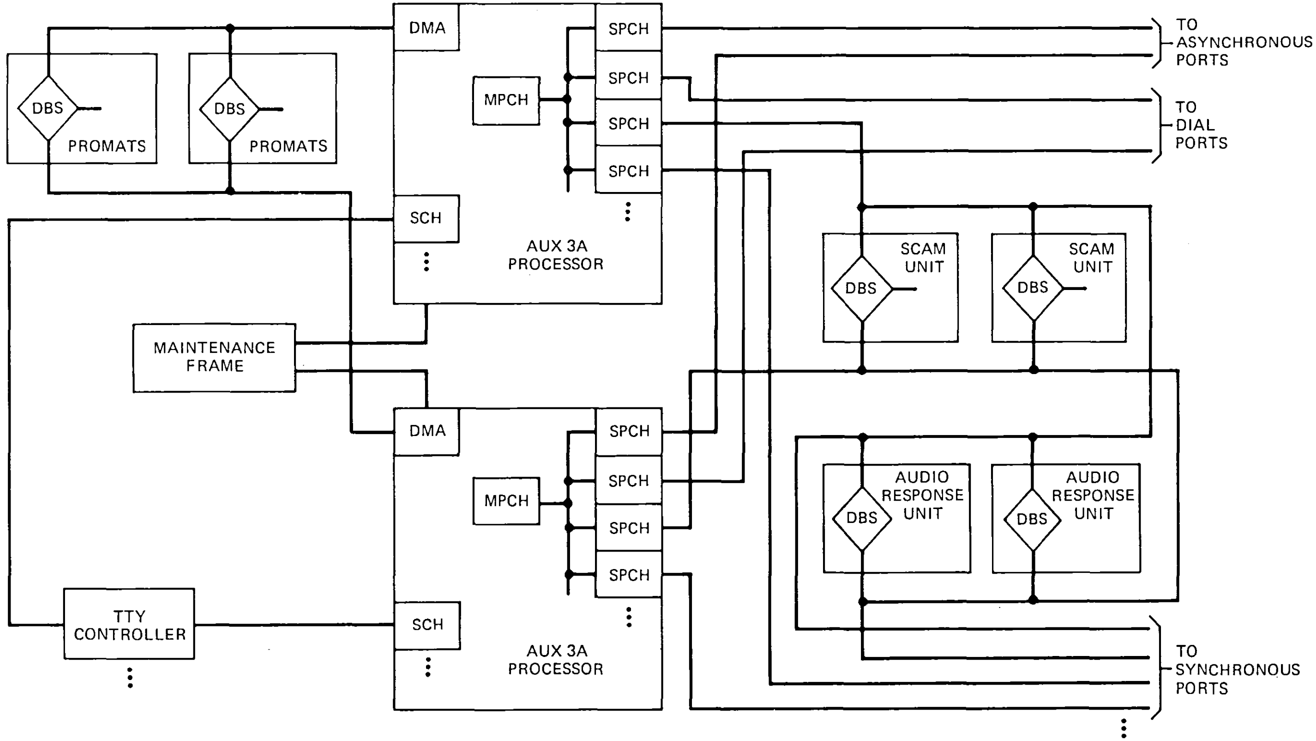


Fig. 1—Message switch common equipment.

and memory are active. The standby memory is continually updated so that the standby processor may be switched on line, with minimum disruption of service, in case of a fault in the active system, including an input-output port.

A maintenance frame associated with the duplicated processor includes a system status panel, two cartridge tape units used for loading programs, a teletypewriter, two teletypewriter control units which may serve several remote teletypewriters as well as the local one, and relays for activating office alarms. All these peripherals are connected to the processor via serial channels.

Parallel channels are used between the processor and the various communication ports to effect fast data transfer. Each processor contains a main parallel channel which couples to several subparallel channels. At each peripheral device, a duplex bus selector (DBS) is connected to a parallel channel from each processor. Under processor control, the DBS switches communication from the device to the active channel. The DBS insures that no single processor or channel failure will render the device inoperative, and also prevents any device failure from disabling the channel. Each pair of subparallel channels can support a chain of 16 DBSs and their associated devices.

1.2 Magnetic Tape System

The Transaction Network message switch contains two Programmable Magnetic Tape System (PROMATS) frames for recording of billing information. Information is recorded in 9-track, 1600 b/in. phase-encoded format.

Each PROMATS includes two programmable controller PROCON microprocessors for control and error detection. Direct memory access at the processor permits very fast bulk transfer of information. Each PROMATS frame is connected to each processor's direct memory access circuitry by means of a DBS.

1.3 Switch Control and Monitor

The Switch Control and Monitor (SCAM) provides a means for the processor to exercise control over the communication channels and to monitor the network configuration in real time. It also provides the processor with the capability of monitoring the condition of the communication hardware. In this function, it operates the switching relays which are used to busy-out dial ports, to connect dial ports to a test circuit, to switch in spare synchronous ports, to loop around synchronous ports, and to perform other miscellaneous control functions. A contact from each relay operated by the SCAM is also in turn monitored by the SCAM to check its own operation. Other monitor points are used to permit the processor to check all office power supplies and to scan numerous office alarm outputs.

The SCAM includes two control units, one of which is operative at any time. Each unit is connected to the duplicated processor by a DBS. Either unit may disable the other unit. It is also possible to disassociate switching relays from the SCAM units and leave them in a known condition, so that one control unit can perform diagnostic tests on the other without affecting operation on any communication port.

II. POLLED ACCESS

Polled terminals communicate with the message switch over dedicated facilities using 1200-b/s, serial, asynchronous, frequency-shift keying in each direction. Communication is half duplex. A remote switch, known as the Data Station Selector (DSS), permits one of many terminals to be connected to the message switch in response to a poll issued by the message switch. At the message switch, the Asynchronous Line Adapter (ALA) couples the transmission facility to the processor and implements the polling routine. A typical polled access arrangement is shown in Fig. 2.

The TN local distribution network is designed to be a cost-effective solution to problems inherent in bridged multipoint services that have been used to implement inquiry response communication systems in the past. Unlike bridged multipoint, the DSS provides isolation between loops. This facilitates maintenance and contributes to low transmission error rates. Costs are kept low by using two-wire facilities between each terminal and the DSS.

2.1 Asynchronous Line Adapter

Each ALA includes a frequency-shift modulator and demodulator coupled via a 4-wire transmission facility to a DSS. The ALA is capable of full duplex operation, although this capability is not used in initial Transaction Network Service.

The ALA may buffer up to 64 characters received from the processor, prior to transmission. During the conversion to serial format, start, stop, and parity bits are added to produce standard 10-bit asynchronous ASCII characters. Received characters from the demodulator are in the same format. After stripping of extraneous bits, checking, and conversion to parallel form, up to 64 characters may be stored in the ALA prior to being read into the processor.

When no information is being transmitted or received, the ALA autonomously implements the polling procedure without intervention from the processor. The list of station addresses is kept in the transmit buffer, which is configured as a recirculating register during polling. Each station is sequentially and repetitively polled until a station answers or the processor intervenes. After each poll is transmitted, the ALA remains silent for a period of time between 27 and 50 ms to wait for a possible

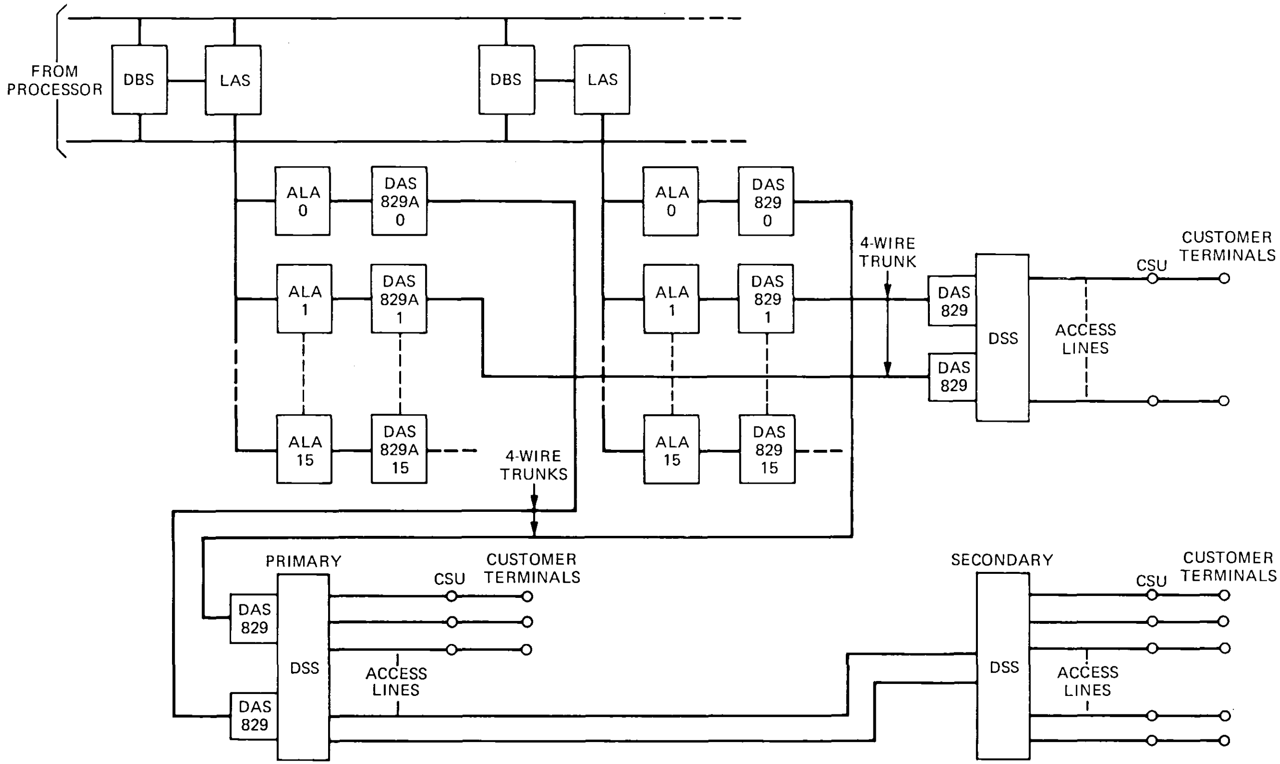


Fig. 2—Polled access configuration.

message before beginning the next poll. This period of time is set during installation by means of a group of switches. It allows for the maximum round-trip propagation delay through the DSS to the furthest station, in addition to other delays. When polling is interrupted by a message from a polled station or by a response message from the processor to a station, the polling list in the ALA is erased. The list must be reloaded by the processor before polling is resumed.

To keep costs low, a line adapter selector is used to perform some common functions for up to 16 ALAs and to interface this group of ALAs to a single duplex bus selector.

2.2 Data Station Selector

As shown in Fig. 2, the Data Station Selector (DSS) is interfaced to the message switch by means of a pair of trunks terminated in 829-type data auxiliary sets. Like the polled terminals which it serves, the Data Station Selector communicates with the message switch using 1200-b/s, serial asynchronous frequency-shift-keyed data signals. A modem contained within the DSS demodulates address (polling) signals from the message switch and passes these to the DSS control logic. As received at the DSS, addresses are the binary equivalent of the line numbers (0 through 62). The DSS control logic decodes the poll address and connects the corresponding terminal to the Asynchronous Line Adapter. The selected station is polled when it receives a burst of marking carrier (followed by a slow carrier turnoff) transmitted from the message switch. If the polled station replies to the poll with an inquiry, the DSS control logic is inhibited from decoding the response address. When a reply message is delivered from the message switch to a terminal through the DSS, the DSS is first instructed to make the proper connection and a BAL (Blind Alert) character (ASCII"?") is included in the reply message. The BAL character is interpreted by the DSS to mean that information which follows is intended as a reply to the terminal and is not to be interpreted as an address.

The DSS contains features which make possible one-person station installation and facility lineup. Direct current is normally present on the loop between the DSS and the customer terminal. Continuity is maintained through the 150A Channel Service Unit at the station location. When the craftsperson operates a screw switch in the Channel Service Unit, loop current is interrupted. This interruption is detected at the DSS, which then puts a 1000-Hz lineup tone onto the loop. The craftsperson may then adjust attenuator pads within the Channel Service Unit without any assistance at the DSS location.

The DSS is a duplicated unit. Each half is connected via a separate 4-wire facility to a separate ALA. These two ALAs are connected to different line adapter selectors, duplex bus selectors, and power supplies. In normal operation, half the stations associated with a DSS are assigned to each ALA. When an ALA or transmission facility must be taken out of service, its station list is added to that of the other ALA associated with that DSS. This permits continued operation to all terminals with somewhat slower service.

The line adapter selector generates and checks parity on all information transfers to and from the processor. The ALA includes other checking features. The processor may interrogate the status of these circuits to analyze trouble conditions.

Test characters may be generated by the processor and have them looped back at any one of several points, for transmission to the processor for trouble isolation. Loopback points exist at the input to the duplex bus selector, at the input to the line adapter selector, and at two points internal to the ALA. In addition, the modulator output may be connected to the demodulator input, with the transmission facility disconnected. All loopbacks are enabled under processor control.

When commanded by the processor, the line adapter selector can check the operation of the control and timing circuits in any one of its associated ALAs by measuring and reporting the time required for completion of a single poll.

The DSS has a test port which, when addressed in the same manner as a station, causes a test message to be returned to the message switch. This procedure provides an overall test of the ALA, the transmission facility, and most parts of the DSS. The DSS, as previously mentioned, maintains direct current on the loops to each Channel Service Unit. If the sealing current is interrupted for any reason, that fact is noted by the DSS and an indication of the faulty loop is provided to the message switch as part of the test message. The test message contains one bit for each of the 63 addressable ports. The DSS also contains circuitry which enables it to detect an abnormally high transmitted signal from a customer terminal. The line address of the loop carrying the overload signal is remembered by the DSS and returned to the message switch in the test message. The test message also contains information on the status of the DSS power supplies. To facilitate trouble isolation in the transmission path between the message switch and the DSS and between the two sections of the DSS, the two trunks may be interchanged. This is accomplished from the message switch by the transmission of a special command to the DSS.

The transmission facilities between the message switch and the DSS are terminated in 829-type data auxiliary sets at both ends. Besides providing access, these sets permit loopback testing of the transmission facility from a centralized transmission test location.

III. DIAL ACCESS

The message switch may be accessed over the normal dial network by Transaction telephones using ordinary *TOUCH-TONE®* dialing with 12 button pads. Communication from the message switch to the station may be in the form of audio response, keyed tones, 150-b/s, serial, asynchronous frequency-shift keying, or a combination of these.

The dial access configuration is shown in Fig. 3. Each incoming line at the message switch terminates at a standard 407A data set.[4] A Dial Line Adapter (DLA) interfaces each data set to the processor. The frequency-shift modulator is part of the DLA. Those ports which require audio response are coupled to the Audio Response Unit (ARU), which delivers spoken words under processor control. Ports with and without audio response capability are arranged in separate hunting groups in order to conserve ARU ports.

3.1 Dial Line Adapter

The DLA controls the answering, disconnect, and other control features of its associated data set based on commands received from the processor. *TOUCH-TONE* characters detected by the data set are passed on to the processor in 2-out-of-8 format. The DLA times the interval between these characters. If no character is received for a period of approximately 13 seconds, the processor is notified so that it may initiate a disconnect.

Characters to be transmitted are presented by the processor to the DLA, which constructs serial asynchronous FSK characters to be transmitted through the voice answerback input channel of the 407A data set. The format is the same 10-bit ASCII as in polled access. The DLA may also cause the data set to send keyed 2025-Hz tones by operating its tone answerback lead for the proper period of time. When required, the ARU is also coupled through the DLA to the voice answerback input of the data set.

The same *DESIGN LINE** adapter selector that is used for the ALA is used to connect up to 16 DLAs to a single duplex bus selector and to perform common functions for them.

3.2 Audio Response Unit

The TN Audio Response Unit (ARU) design is based on a semiconductor random access memory containing up to 6.8 Mb of digitized

* Trademark of American Telephone and Telegraph Company.

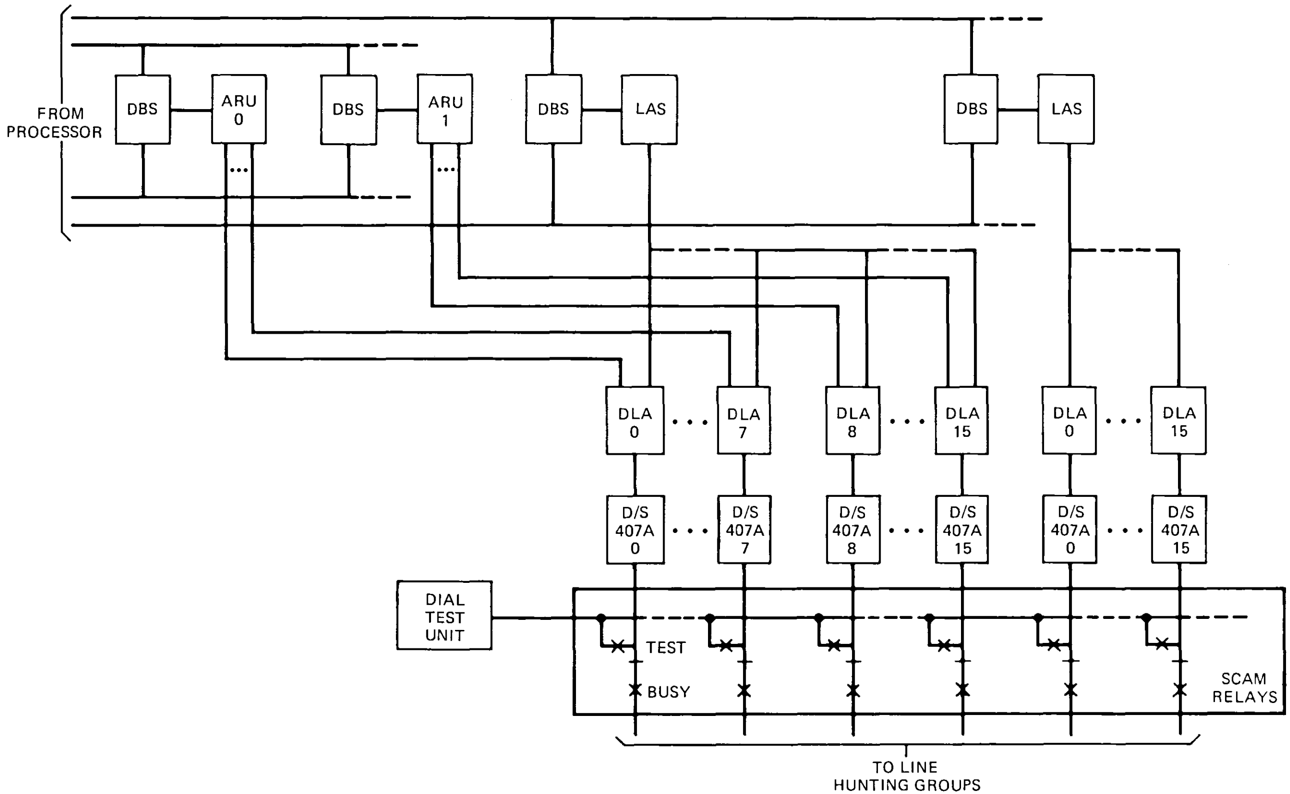


Fig. 3—Dial access configuration.

speech. The digitized speech is obtained from analog recordings of the words to be spoken which are converted to digital form at 24 kb/s using an adaptive delta modulation technique developed for subscriber loop carrier. Stored digitized speech segments are retrieved from the memory and pieced together to form phrases and sentences under control of the 3A Processor.

Each ARU speech memory can contain up to 560 spoken words and deliver as many as 76 simultaneous and independent audio responses. The ARU is an output peripheral for the auxiliary 3A Processor and is controlled by high-speed data signals sent to and from the processor on a subparallel channel. The ARU contains a duplex bus selector. Information is delivered across the DBS interface to cause the ARU to deliver an audio response to a telephone, to load the ARU speech memory with digitized speech stored on a 3A cartridge tape, or to return maintenance information from the ARU to the processor.

The ARU produces a voice response by piecing together speech segments which are approximately 170 ms long. The 3A Processor operates the ARU by delivering a list of those speech segments required to create the desired response. One 16-bit computer word must be delivered to the ARU each 170 ms for each equipped port. A buffer is provided that allows the processor to deliver these words at any time within the interval. If the processor fails to deliver the required data, the ARU will substitute silence.

The audio response delivered to a calling telephone is determined by the Customer Service Center computer. The customer has available a list of English phrases from which he can compose messages. Each phrase is specified by a triplet of ASCII characters sent to the message switch in the text portion of a response message. The 3A contains a translation table which permits it to generate the list of speech segments required to produce the desired audio output.

The vocabulary for a particular Transaction Network message switch is contained on a magnetic tape cartridge which can be read by the 3A Processor. As the tape is read, the digitized speech is delivered across the DBS interface and stored in the ARU speech memory. In the event of a power failure, the contents of the speech memory will be lost, and the ARU must be reloaded from the tape. Checks are made after a load is completed to ensure that it has been properly accomplished. Ten minutes are required to completely load an ARU. In TN applications, a pair of ARUs is provided. One ARU may be providing service while the other is being loaded.

The ARU construction is highly modular. Audio responses are produced through a port circuit pack, and each ARU must contain at least one such circuit pack which serves two ports. Port capacity may be expanded by adding additional circuit packs up to a maximum of 38; thus, each ARU can serve from 2 to 76 ports. Anywhere from 1 to 104 memory plane circuit packs may be ordered for the speech memory, providing vocabulary storage ranging from 2 to 560 spoken words.

The three major components of the ARU circuit are the digital speech memory, the array of port circuits, and the time division switch and bus arrangement that interconnects these two. In addition, control, timing, and maintenance functions are provided. These components are interconnected as shown in Fig. 4. Digitized speech is cyclically read from the speech memory and placed on a bus, where it is available to the port circuits. The port circuits select the proper bits from the bus as specified by information received from the processor through the buffer.

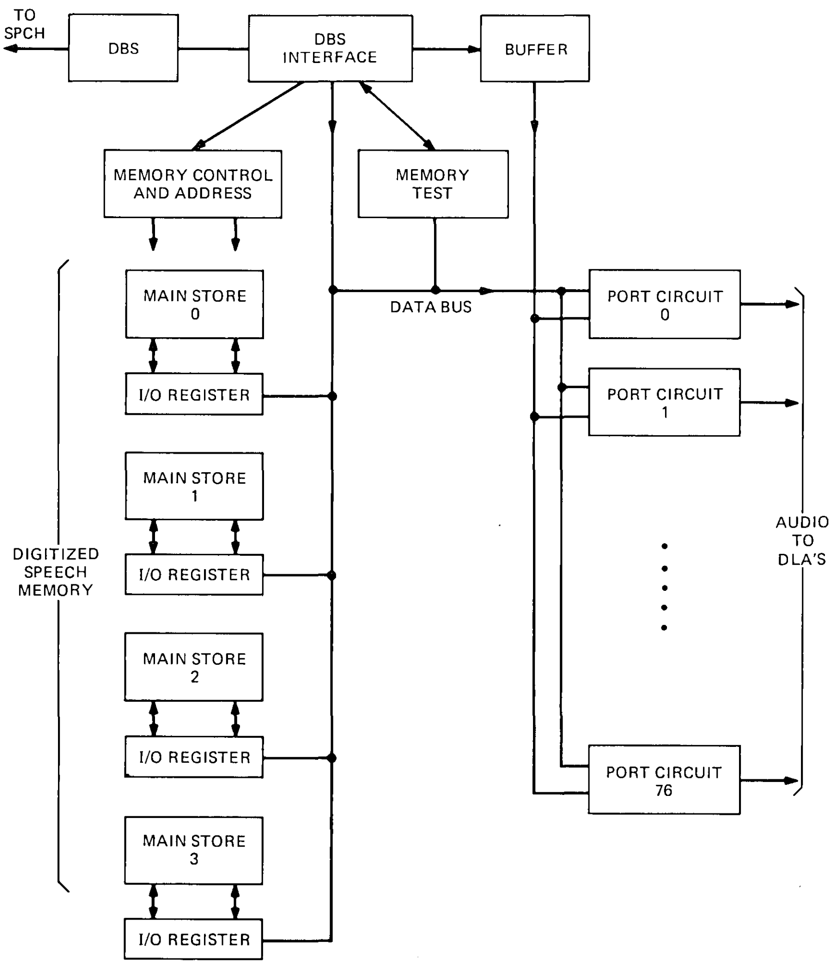


Fig. 4—Audio response unit.

3.3 Dial access maintenance features

The DLA and the line adapter selector include several checking circuits to detect troubles. They also contain status registers which may be interrogated by the processor to analyze abnormal conditions.

The processor can set up a loopback at the input to the duplex bus selector, to the line adapter selector, or to the DLA through which characters generated by the processor can be sent back to it. A dial test unit located in the SCAM provides an overall test of the dial port, including the 407A data set. Under processor control, the SCAM can connect the line side of any one data set to the dial test unit and simultaneously make the incoming line look busy. A ringing generator is used to check the answering functions of the data set. Frequency-shift-keyed characters transmitted by the port are converted to *TOUCH-TONE* signals and transmitted back to the 407A, providing another loopback point. In addition, the dial test unit checks the amplitude and duration of the keyed answertone and the disconnect feature of the data set.

The 407A may also be checked manually in the standard manner, either locally or with a remote data test center.

Any dial ports that have been determined to be faulty are placed out of service by making the incoming line appear busy. This out-of-service feature is provided in both the DLA and the SCAM. To minimize possible degradation of service, lines from each hunting group are distributed among ports using different line adapter selectors, duplex bus selectors, and power supplies.

Like the LAS and DLA, maintenance of the ARU is under control of the 3A Processor. Two signals are provided from each ARU power sequencer to the SCAM, and a considerable amount of maintenance information is routinely transferred from the ARU to the processor through the subparallel channel interface. The message switch software will bring in a minor alarm if more than a few errors are detected in the digital speech memory. Each quarter of the speech memory can be viewed as an array of 52 columns, each containing 32K bits. The first column contains a parity bit, and each row of the memory is checked for correct parity as it is read. The parity error alarm threshold is programmable. Each column of the memory should contain a known number of ones which are counted by the test circuitry on each memory cycle and the eight least significant bits of the resulting check sum are returned to the processor for verification. If the memory degradation is serious enough to be audible or if another problem is detected which requires the removal of an ARU from service, a major alarm occurs. If both ARUs are removed, a critical alarm is generated.

The ARU has been designed with a minimum of test access points and nearly all maintenance activities are carried out automatically. Two diagnostic software packages are available for the ARU. One diagnostic contains all those tests which may be conducted without disturbing the contents of the ARU speech memory. The second diagnostic assumes that it is necessary or desirable to reload the contents of the speech memory and contains additional tests based on special patterns specifically loaded into the speech memory for test purposes. In this case, the ARU is reloaded with digitized speech at the conclusion of these tests.

The ARU also contains a short FSK test sequence which may be delivered to any port under processor control. In conjunction with the SCAM and Dial Test Unit, the processor may cause this FSK sequence to be looped through the Dial Line Adapter and its correct interpretation verified by the processor.

IV. SYNCHRONOUS ACCESS

Communication between the message switch and data processing centers is implemented using either standard data sets and 4-wire private line analog facilities, or digital data system channels. Synchronous serial communication with full duplex capability at 2400, 4800, or 9600 bits per second is provided by the 201C, 208A, or 209A data set, respectively, or the appropriate 500A data service unit.

At the message switch, the Synchronous Line Adapter (SLA) acts as the interface between the processor and a data set. Figure 5 illustrates the architecture of the synchronous access arrangement at the message switch. Each SLA is coupled to the duplicated processor by a duplex bus selector.

4.1 Synchronous Line Adapter

To provide flexibility in communicating with different types of data processing centers, the SLA has been designed such that many of its operations can be changed according to instructions received from the message switch processor. This approach permits a single hardware design to meet several applications.

A principal function is conversion between the parallel format of the processor and the serial format at the data set. The processor programs the SLA to transmit and receive character lengths of 5, 6, 7, or 8 bits including even, odd, or no parity. The same format applies in both directions. First-in, first-out buffers of 64-character length are provided in the SLA in each direction to reduce the frequency at which the processor must deliver or accept strings of characters.

The processor programs the SLA to generate an interrupt after a given number of characters have been transmitted since the last interrupt. An interrupt is also generated when the transmit buffer becomes empty. These interrupts may be disabled under processor control. The fill character that is to be transmitted after the buffer is empty is also programmed into the SLA.

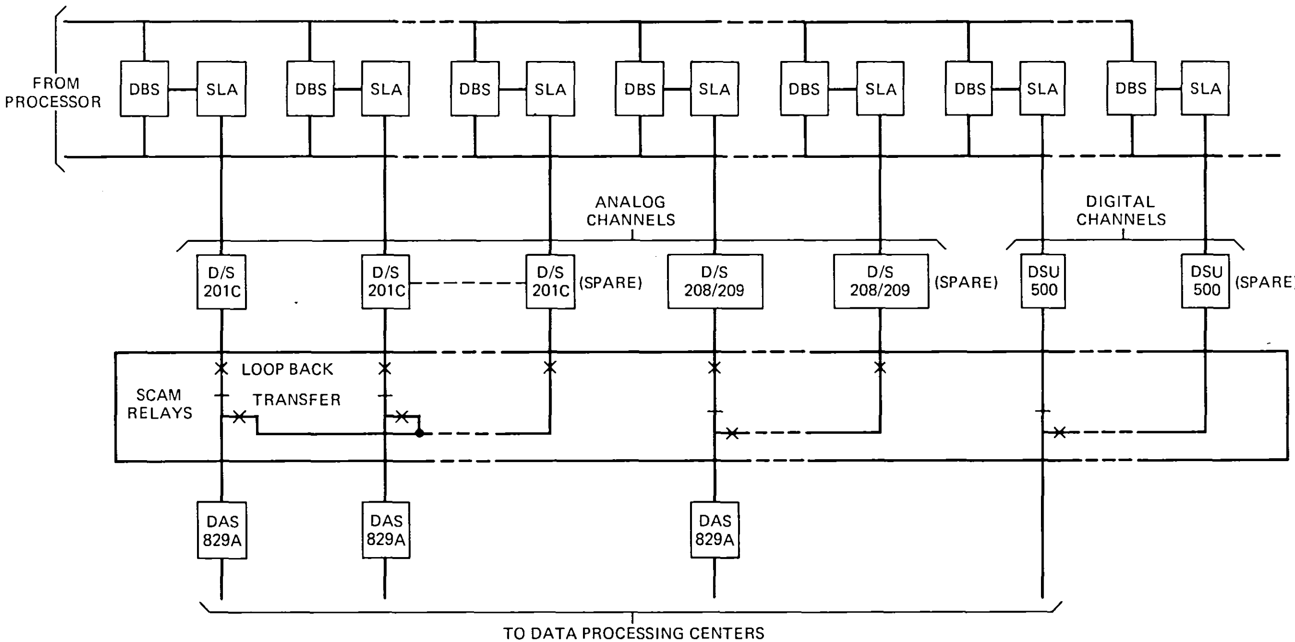


Fig. 5—Synchronous access configuration.

Similarly, the SLA is programmed to interrupt after a given number of characters has been received. An interrupt is also generated when the associated data set detects loss of carrier. In addition, up to 256 special characters may be programmed into the SLA such that an interrupt will be generated whenever any of those special characters is received. The receive interrupts may also be disabled.

Another instruction to the SLA determines the particular synchronization character that is to be recognized to establish received character synchronization. The SLA is also instructed on whether or not synchronization characters are to be passed on to the processor along with other received data.

The SLA derives all its internal clocking from the clock supplied by the data set. Its operation is therefore insensitive to data rate.

4.2 Maintenance features

All testing of synchronous access equipment at the message switch is performed under control of the processor. Tests may be manually initiated by means of teletypewriter input to the processor. Tests may also be automatically initiated by the processor periodically or whenever a trouble condition is indicated.

Malfunctions are localized by having test characters generated by the processor, looped back at a loopback point determined by the processor, and sent back to the processor. Loopback points exist at the input to the Duplex Bus Selector and at the input and output of the SLA. An additional loopback point for including the operation of analog data sets is available through operation of a SCAM relay. This loopback causes the transmitted output of a data set to be connected to the input of that data set through an attenuator.

The SLA includes parity checking and other circuits to detect troubles. The processor may interrogate the status of any of the SLA circuits to detect and analyze troubles.

For analog channels, data sets and associated transmission facilities may be tested manually from remote test centers. The 829 data auxiliary sets provide access jacks and tone-activated loopback.

One spare SLA and associated data set is provided for each type of data set used. The spare port may be substituted for any one of its associated ports by operation of a SCAM relay. All diagnostic features remain operable for the out-of-service synchronous port, as they do for the spare at all times.

V. PHYSICAL DESIGN

The functional units of the Transaction network are interconnected very simply. The physical design addresses the integration of two basically different types of hardware, ESS and data, into one system.

5.1 Message switch hardware

The basic physical design of the message switch hardware makes use of 1A technology, which was initially developed in No. 4 ESS. The 3A Processor and maintenance frames were in manufacture at the Western Electric Northern Illinois Works when design of the new hardware was started. Since this equipment employed 1A technology, its choice provided a uniform office configuration and allowed the entire system to be manufactured and tested at the North Illinois Works without new tooling or unique testing facilities. Machine aids to design and documentation and high-volume production equipment thus became available to meet a demanding schedule.

5.1.1 Circuit packs

Circuit packs are FB and FC coded packs, approximately 4 × 7 in., using 946B and 946C connectors, respectively. The 946B provides 41 pinouts, of which 36 may be used for signal levels, 2 for power, and 3 for ground. The 946C provides for 82 pinouts with 76 usable for signal leads.

The circuit packs themselves are 4- and 6-layer multilayer boards arranged to mount a maximum of 42 sixteen-pin dual-in-line packages in a 6 by 7 array. When larger devices are used, the array is disrupted slightly. Machine wire-wrapped models were initially built and tested, and then artwork was generated completely automatically for the multilayer boards.

5.1.2 Units

The assembly of circuit packs, apparatus mountings, backplane, mounting plate, and wiring is called a unit. The unit is the most important functional building block in the message switch.

Unit design uses 1A technology also. 80C apparatus mountings are used to contain the circuit packs—a maximum of 14 circuit packs can be mounted, on ½-in. centers, in each mounting. Three mountings can be mounted on each 4- by 26-in. mounting plate used to attach a unit to the frame. The units are front-removable from the frame to allow for easier maintenance.

The 946-type connector of the circuit pack plugs into a 947-type connector of the unit. The 947 connectors are mounted directly to the unit, and a 4-layer backplane is reflow-soldered onto the connectors. The backplanes are nominally 0.100-in. thick, 4-in. high, and vary in width depending upon the number of connectors that are required. Signal ground and +5V are distributed to each of the 947 connectors from this backplane. In this manner, a low-impedance power-ground plane is approximated.

The backplane system thus formed is a grid of 0.025-in. square pins on 0.125-in. centers. Signal leads are 30-gauge wires automatically wrapped by Gardiner Denver machines at Western Electric Northern Illinois Works. The machine aids used in the design and manufacture of these units minimize the variability among units.

The unit usually includes the Duplex Bus Selector (DBS). The interface between the peripheral circuits and the DBS is 5V TTL, which allows a lead length of no more than about 24 in. Figure 6 shows a typical unit, with the DBS integrated within. This particular unit also contains 48V to 5V and 48V to ±12V converters. This has also been done in other units when space permits. The tick marks in the illustration represent circuit packs of a fully equipped unit. In this case, an ALA unit has DBS, LAS (Line Adapter Selector), three power units, and from 1 to 16 ALA circuits, each consisting of three circuit packs.

5.1.3 Frame design

The units are front mounted in 1A equipment frames which are 7 ft tall overall, providing 76 in. of mounting space, and are nominally 2 ft, 2 in. wide. Much of the equipment mounted in the frames requires 18 in. depth, and so for uniformity all message switch frames are 18 in. deep.

Since the units are highly connectorized, the frames may be considered to be convenient mounting arrangements for various combinations of units. Other units may also be incorporated into these frames as required.

Most frames have one configuration; the frames are filled with equipment and apparatus as the system grows. The synchronous line adapter (SLA) frame has more flexibility, because synchronous communication can be any of three speeds and either analog or digital. Each speed and format requires different hardware to interface the synchro-

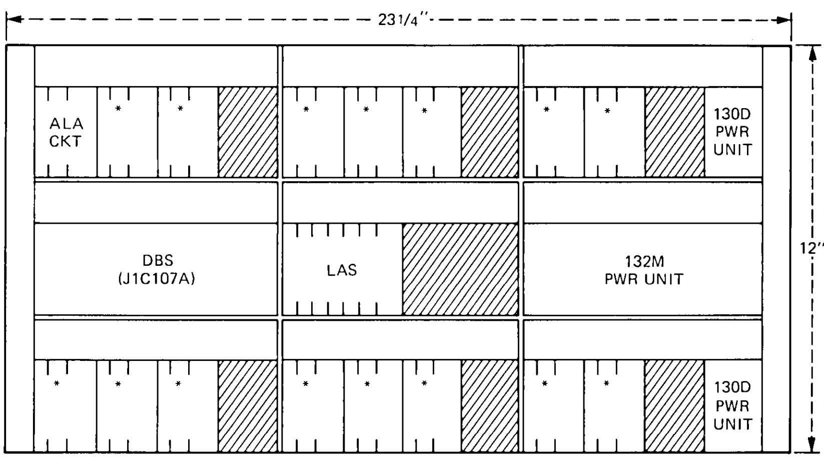


Fig. 6—Asynchronous line adapter unit.

nous line adapter. The five resulting SLA frame configurations are shown in Fig. 7. Here, DS is Data Set, DAS is Data Auxiliary Set, and DSU is Data Service Unit. The numbers to the left of the frames are distances from the floor, in inches. As can be seen in the figure, all frames are identical up to location 26. Similarly, above that location the alternative unit always appears at the same location, regardless of configuration, e.g., if a 46A1 data mounting is required at all, it will start at location 38.

The five resulting SLA frame configurations are actually quite similar, being different only in the types and combinations of data sets and DSUs incorporated.

5.1.4 Cabling and interconnection

Interconnection from one unit to another is accomplished by cable assemblies terminated at each end by 942- or 943-type connectors. This family of connectors provides 10 or 20 box contacts in a plastic housing attached to a small printed-circuit "paddleboard." The connector is used to mate with one quadrant of wire-wrap pins on the 947 connector while allowing the use of wire-wrap connections underneath. Flat flexible cable is used in some applications, but multipair switchboard cable is used in most. Provisions are made for resistor termination of the cable, if required, on the paddleboard.

Connections from data sets use KS connectors which match them, and connection to the distribution frames use KSed Blue Ribbon* connectors and standard central office cabling.

5.1.5 Office layout

A typical message switch has about 20 frames of equipment. Figure 8 shows a typical maximum size message switch. The control complex frames, containing the auxiliary 3A Processor System, has a fixed configuration required by interconnection limitations. The data bus to the processor has a maximum length, and as a result ALA frames must be adjacent to one another and so must DLA frames. The office layout of Fig. 8 produces a compact, well-organized system. If office space requires, other layouts subject to the above requirements are permitted.

Since the message switch is expected to be installed in an existing building and will utilize the type of power plant specified for ESS, the cable duct, lighting, and other metal work are those used in new ESS installations.

* Registered trademark of Amphenol, Inc.

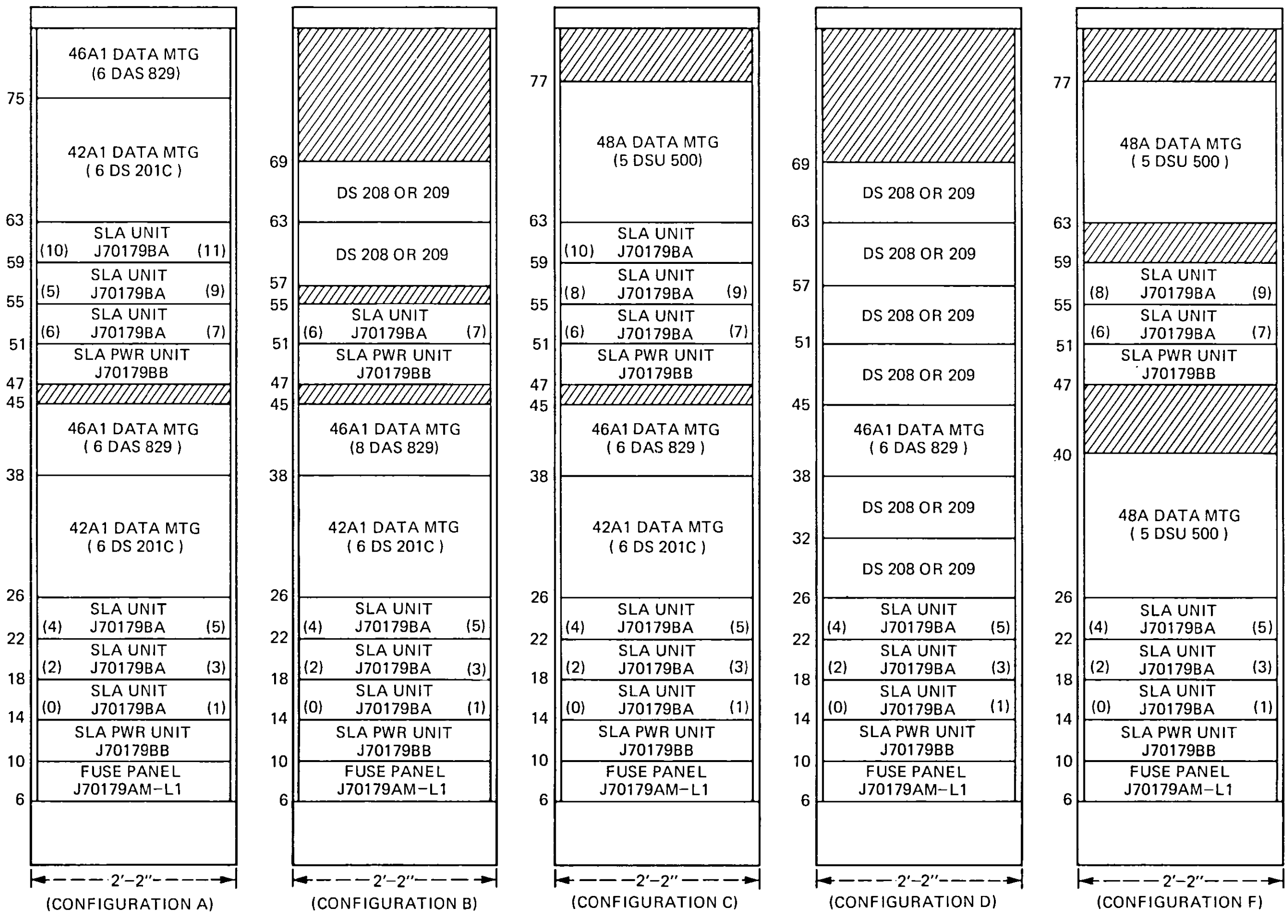
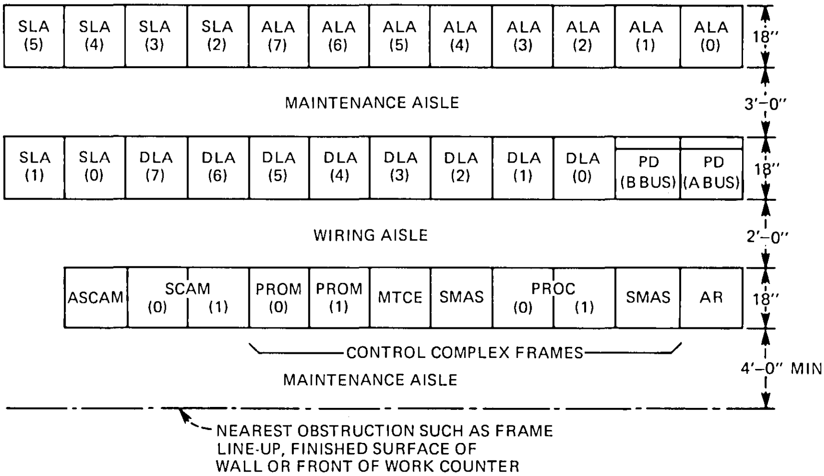


Fig. 7—Synchronous line adapter frame.



LEGEND:
ALA – ASYNCHRONOUS LINE ADAPTER
DLA – DIAL LINE ADAPTER
SLA – SYNCHRONOUS LINE ADAPTER
PD – POWER DISTRIBUTION
*ASCAM – AUXILLIARY SWITCH CONTROL AND MONITOR
SCAM – SWITCH CONTROL AND MONITOR
PROM – PROMATS – PROGRAMMABLE MAGNETIC TAPE SYSTEM
MTCS – MAINTENANCE
SMAS – SUPPLEMENTARY MAIN STORE
PROC – PROCESSOR
AR – AUDIO RESPONSE

*NOT GENERALLY REQUIRED

Fig. 8—Typical floor plan layout with PD frames.

5.2 Data Station Selector

The 1A Data Station Selector (DSS) is designed to be mounted in a variety of environments: ESS or other type central offices or on customer premises.

As indicated in Fig. 9, it connects up to 61 polled Transaction terminals to two asynchronous circuits of the message switch. As a relatively small and self-contained entity, it also incorporates testing access and facilities termination (e.g., Data Auxiliary Set). A relatively large amount of analog circuitry is involved, and data set style packaging was chosen instead of 1A technology (see Fig. 9).

The DSS is a single shelf unit 23 in. wide, which requires 10 in. vertical frame space. It can be mounted in 12-in. deep frames wherever space is available. For customer premises application, a KS-20018 series cabinet is used and a 110V ac and −48V dc converter is required.

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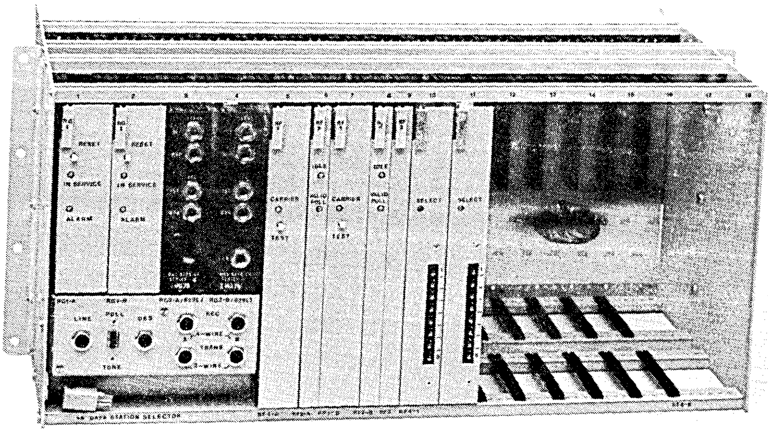

Fig. 9—1A Data Station Selector.

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Transaction Network, Telephones, and Terminals:

Transaction Network Operational Programs

By E. J. RODRIGUEZ

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The Transaction Network Operational Programs provide the logic for switching data messages between terminals and Customer Service Centers. These programs also perform administrative and maintenance tasks. This paper describes program organization and various software functions.

I. INTRODUCTION

The stored program for the Transaction Network (TN) directs the operation of equipment that provides switched communications of short data messages between terminals and Customer Service Centers and between two different Customer Service Centers. The system is designed to meet operational requirements differing from those imposed on other stored program switching systems, such as the No. 1 Electronic Switching System (ESS).[1] Unlike such line-switched systems, a message-switched system provides no intrinsic end-to-end verification of the communication path or delivery of the message. The originating user relys on the system to properly deliver accepted messages to the appropriate destinations. This places stringent requirements on the message switching system to provide message protection, assurance of delivery, and privacy.

The TN stored program is described in three parts: the call processing programs which support the various service features and protocols, the maintenance programs which maintain an operational system in the presence of troubles and diagnose the faulty units, and the administrative programs which allow the telephone company to input office parameters and customer information into memory and to obtain traffic and maintenance measurements reports and billing information. This paper provides an overview of the various programs. Companion papers cover the hardware structure and service capabilities.

II. MESSAGE SWITCH

The message switching vehicle for TN is the 3A Processor. The controlling unit of the 3A complex is the 3A Central Control (3A CC), which is also used in the No. 2B ESS and No. 3 ESS installations. It is duplicated to provide continuous real-time operation with a high degree of system reliability. Attached to each 3A CC are a serial input/output channel (which serves low speed devices such as teletypewriters), several parallel input/output channels (which serve various input/output devices), and a Direct Memory Access (DMA) channel. Figure 1 is a diagram of the 3A Processor.

Basically, one 3A Processor always has active control over the system, while the other 3A Processor operates in a standby mode. Each 3A Processor has its own dedicated main memory. The on-line processor normally keeps both the on-line and stand-by memories up to date so that the standby processor can assume control of the system with an up-to-date storage area.

From a software point of view, the 3A Processor is supported by the Extended Operating System (EOS). This system consists of a set of program modules used by the TN programs to manage the effective use

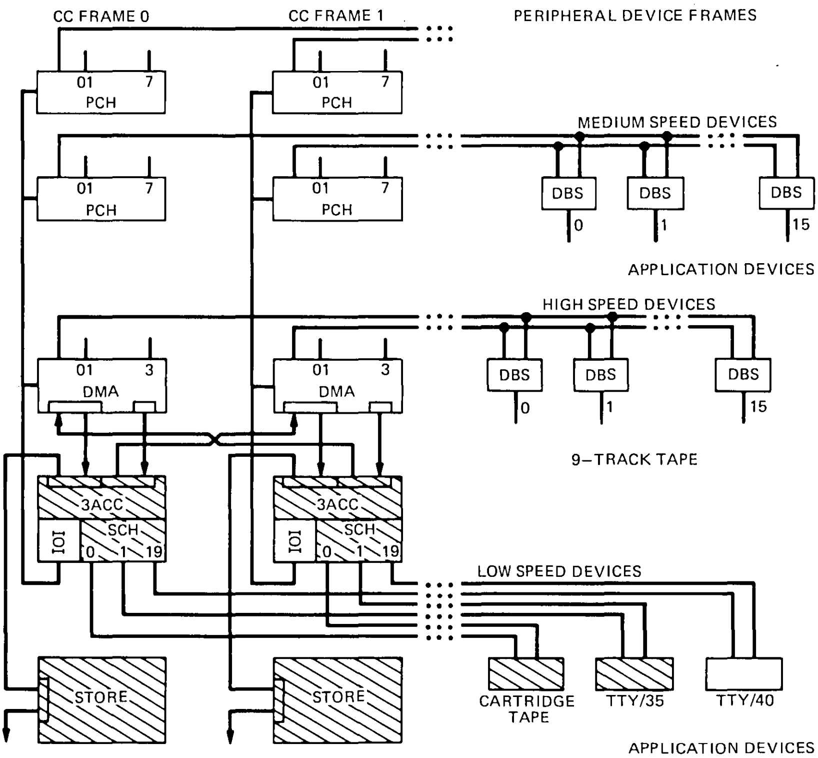


Fig. 1—3A Processor configuration.

of the processor resources and provide the basic maintenance philosophy of ESS.

EOS provides services such as timer control, event control, current-process control, interprocess communication, input/output control, and maintenance control. It also meets the stringent ESS service requirements by providing automatic reconfiguration, recovery phases, EOS audits, and processor diagnostics. These four elements enable the system to continue processing in the presence of 3A Processor hardware and software errors. In addition, EOS provides services to the TN software to successfully implement these elements as applicable for TN specific hardware and software.

III. SOFTWARE ORGANIZATION

The TN software can be divided into three categories: call processing, maintenance, and administration. It is made up of 43 cooperating asynchronous tasks* listed in Table I. Some of these tasks are executed on a scheduled basis using the timer facilities provided by EOS. The remaining tasks are executed upon demand using the interprocess communication facilities also found in EOS. Call processing tasks are assigned higher priorities than maintenance and administrative tasks.

Each task is allocated storage at system generation time, and all tasks residing in the system operate in a write-protected mode. Programs that are used infrequently (e.g., some administrative and maintenance type programs) reside on a cartridge tape and are brought into an overlay buffer in memory as the need arises.

The TN software (excluding EOS) consists of approximately 200,000 program store words. Table II illustrates the functional division of the software. Specific descriptions of the call processing, maintenance, and administration software are given in the following sections.

IV. CALL PROCESSING

The purposes of the TN call processing programs are to (*i*) respond rapidly in real time to the demands for service received from the polled, dial-in, and synchronous networks,[3] (*ii*) provide a large variety of service features, (*iii*) be reliable, and (*iv*) be capable of meeting various installation configurations. Basically, a data message received by the TN message switch passes through three stages of processing: (*i*) detection of a request for service, (*ii*) routing of the input message (along with validation of heading information) to a delivery queue, and (*iii*) servicing of the delivery queue and transmission of each message to its destination.

* A task is a computation that may be done concurrently with other computations (Ref. 2).

Table I — Transaction Network tasks in order of priority

Priority	Task Name
1	High Priority TN Initialization Task
2	Processor Switch Task
3	Synchronous Error Handler Task
4	Synchronous Time-Outs Task
4	Dial Line Adapter Driver Task
4	Synchronous Service Message Task
5	Audio Response Unit Driver Task
5	Dial Reallocation Slowdown Task
5	Polled Initialization Task
5	Synchronous Input Task
5	Synchronous Output Task
6	Audit Buffer and Recovery Task
7	Synchronous Recovery Task
8	AMA Recording
8	Dial Call Processing Message Task
8	Dial Protocol Timer Task
9	Polled Call Processing Background Task
10	Dialed Test Unit Scheduler
11	Polled Recovery Task
11	Memory Reallocation Monitor
11	Dialed Recovery Task
12	Dial Periodic Maintenance Task
13	Polled Periodic Maintenance Task
13	Switched Control and Monitor Task
14	System Status Panel Message Task
14	Input Message Handler Task
15	2-Second Status and Maintenance Traffic Scan Task
16	10-Second Status and Maintenance Traffic Scan Task
17	Quarter-Hourly Traffic Task
17	Diagnostic Message Handler Task
18	Hourly Traffic Task
19	Daily Traffic Task
19	Synchronous Recovery Task
20	Recent Changes and Verification Handler Task
21	ARU Loading Monitor
22	Maintenance 100-Second Scan
23	Synchronous Periodic Maintenance
24	Maintenance Hourly Task
25	Maintenance Daily Task
26	Cartridge Update Task
26	System Status Panel Task
27	Periodic Buffer Audit Task
28	Periodic Control Block Audit Task

Table II — Functional division of Transaction Network programs

Function	Percent
Call processing: polled, dial-in, synchronous	32
Maintenance: diagnostics, periodic, recovery	29
Administration—billing, traffic, recent changes, reallocation	29
Miscellaneous routines	10
	100%

4.1 Call processing concepts and definitions

Even though the polled, dial-in, and synchronous call processing tasks perform different functions and operate differently, some concepts followed by all call processing programs are basic. These are covered in the following sections.

4.1.1 Message format

A message consists of a heading field and a text field. The heading field is delimited by start of heading (SOH) and start of text (STX) characters, and it contains four items of information: (*i*) the called number, (*ii*) the calling number, (*iii*) the class of service character (CSCH), which identifies the type of service subscribed to by the polled and dial-in terminals and by the Customer Service Centers, and (*iv*) the message status field which indicates irregularities not covered by the data link protocols. The text field is delimited by the STX and end-of-text (ETX) characters. In some protocols, following the ETX is the Longitudinal Redundancy Check (LRC) character, which is used to detect possible transmission errors.

4.1.2 Data link protocols

Telephones, terminals, and Customer Service Center computers communicate with the message switch by following a protocol. A protocol is a detailed orderly procedure designed to ensure the successful transmission of messages from the origination to the destination points. Generally, it begins with a request for permission to transmit a message (bid). If the bid is accepted, then the message is transmitted, and if found acceptable by the destination, an acknowledgment (ACK) is returned to the originating station. The originating station concludes the transmission session by sending an end-of-transmission (EOT) sequence. If the message is not accepted, then a negative acknowledgment (NAK) is sent to the originating station, and error recovery procedures follow.

Presently, the TN call processing software supports five different protocols: three dial-in,[4] one polled,[5] and one synchronous.[6] Each protocol contains different message formats and error recovery procedures, as appropriate to the terminal capabilities and functions.

4.1.3 Buffers

As messages arrive in the message switch, they are temporarily stored in buffers. A common buffer pool serves requests from the polled, dial-in, and synchronous call processing programs. Any call processing program may request one or more message buffers at a time. Depending on the buffer utilization, the request may or may not be satisfied. If fewer buffers than requested are returned to the call processing programs, the buffer task indicates how many buffers are returned. Also, the buffer task maintains a register in memory which can be accessed at any time by the call processing programs indicating the buffer utilization. This number is used by call processing programs during peak periods to control the rate of message acceptance by the message switch.

4.1.4 Standard buffer format

Since messages arrive at the message switch with different heading and text fields (depending on the protocol), the call processing programs temporarily buffer all messages in a standard format. These buffers are in the Standard Buffer Format (SBF)—see Fig. 2. At this point, all messages found in the message switch are similar in structure.

4.1.5 Control blocks

Control blocks are dedicated areas of storage of varied size (from one word to several hundred words), which describe the characteristics of a customer service, a hardware device, or the state of the software. These blocks are created via teletypewriter commands, and their number depends on the size of the installation and the number of customers served by a particular message switch. Since there are various types of control blocks in the system, a directory is required to allow software access to the control blocks. This directory is called the Master Block Array (MBA). Figure 3 is a pictorial representation of the MBA.

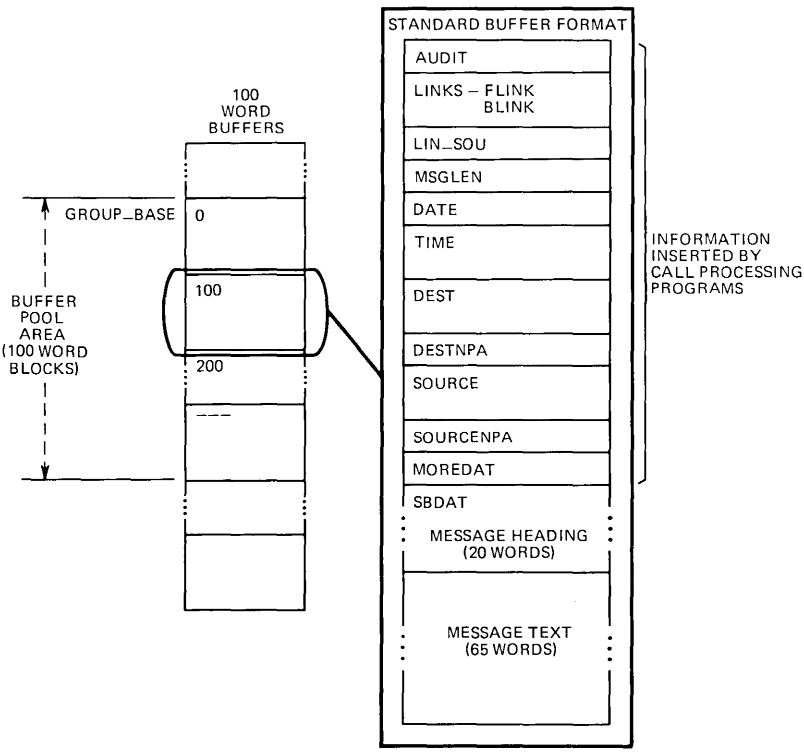


Fig. 2—Standard buffer format structure.

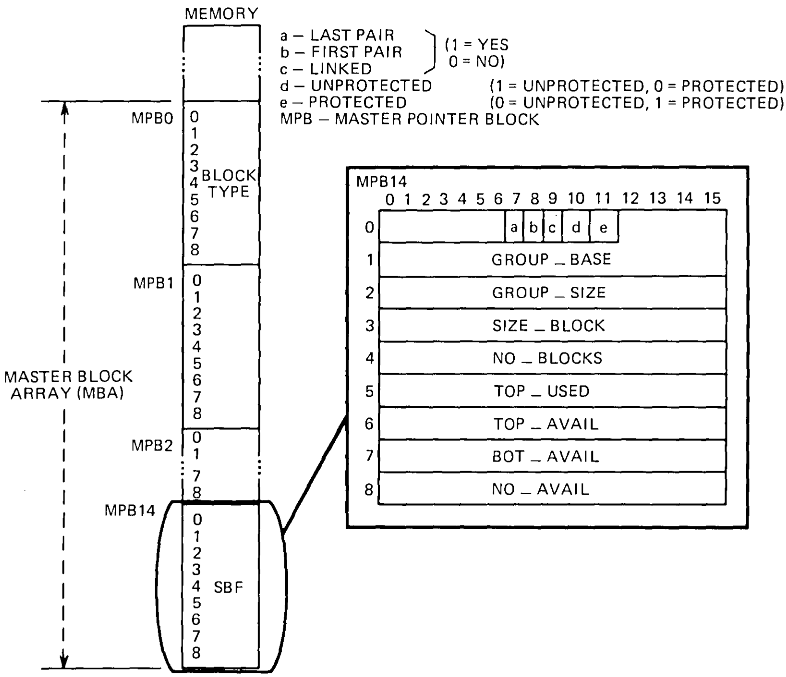


Fig. 3—Master block array.

4.1.6 Foreground and background tasks

All call processing programs serving the polled, dial-in, and synchronous networks follow the same type of organization. A foreground task performs the real-time operations (e.g., input and output), and a background task performs less real-time-sensitive operations (e.g., validity checks in the heading field, routing). Usually a background task is executed as a result of a request by a foreground task or another background task. A background task does not communicate directly with a foreground task.

4.1.7 Service messages

Service messages are messages between a polled terminal or the Customer Service Center and the message switch. They are used for testing purposes or to change the state of a synchronous line or group. A directory number of 0999 is assigned to the TN message switch to designate it for reception or origination of service messages.

4.2 Call processing overview

Figure 4 illustrates in general terms the steps followed by the call processing programs from reception of a message through its delivery. When the foreground call processing software detects activity from a TN peripheral device, it immediately requests a buffer from the buffer pool. Message characters are read one at a time and stored in the Standard Buffer Format. After the last character (ETX or LRC character) of the message is received, the protocol is completed and various validity and routing checks are performed. If no irregularities are found, then the address of the buffer containing the recently received message is sent via EOS to the background call processing task handling the delivery of the message. This task performs further validity checks, after which the foreground task transmits it to the destination. The foreground task completes the protocol and then awakens the billing task, via EOS, and sends it the buffer address. The billing task obtains the necessary information from the buffer to bill the message and releases the buffer back to the buffer pool.

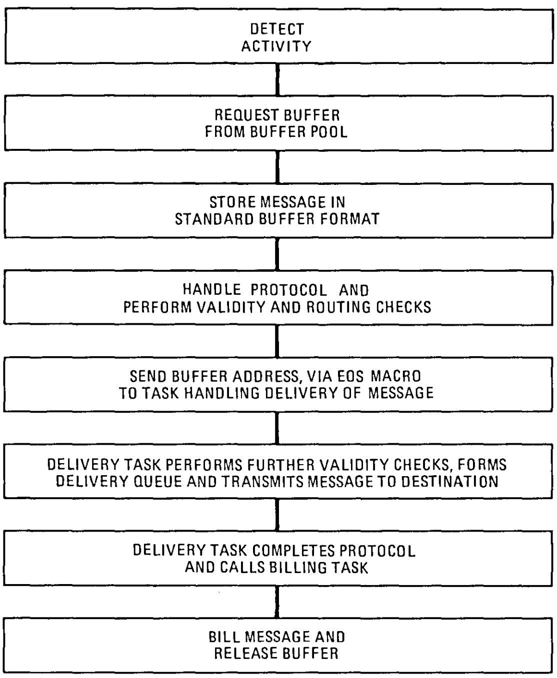


Fig. 4—Call processing overview.

4.3 Polled call processing

4.3.1 Polled access circuit

The basic building block of the polled network is the polled access circuit (PAC). It consists of dualized Data Station Selectors (DSSs) and Asynchronous Line Adapters (ALAs) served by two different Line Adapter Selectors (LASs), as shown in Fig. 5. In normal operation, half the terminals associated with a DSS are assigned to each ALA associated with that DSS. When a hardware unit (LAS, ALA, or DSS) or a transmission facility in one-half of a PAC is found to be defective, the unit or the facility is taken out of service and the terminals normally served on the defective half of the PAC are then served by the other half. This permits continued operation of all terminals in a PAC with somewhat slower service.

4.3.2 Polled control blocks

The polled call processing software controls the various polled lines and terminals via three different types of control blocks:

(*i*) The Asynchronous Line Controls Blocks (ALCBs), which contain all the information necessary to control a polled line. This includes such items as the state of the ALA, the state of one-half the PAC, the buffer address for a particular message, time-out indicators, the state of the protocol, traffic counters, retry counters, etc. There is one ALCB for each ALA, so that a PAC requires two ALCBs, one for each half of it.

(*ii*) The Terminal Control Blocks (TCBs), which contain the primary and secondary polling addresses to reach a terminal from either half of

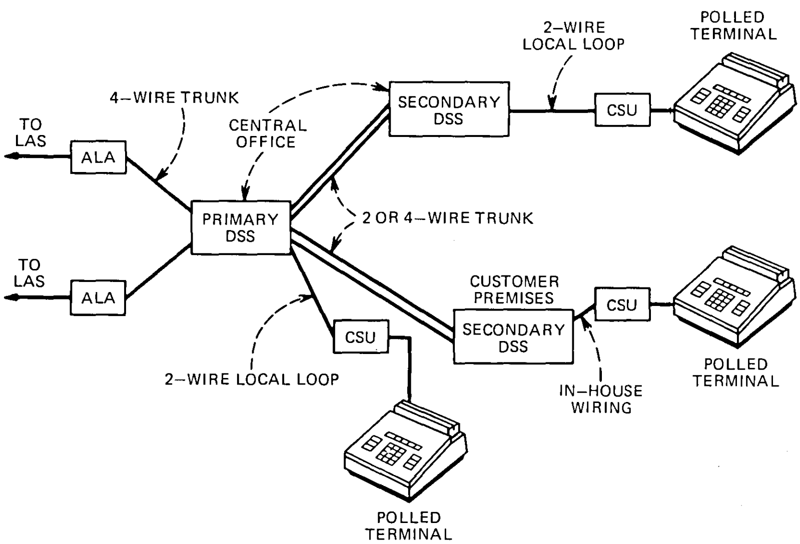


Fig. 5—Possible polled access circuit configuration.

a PAC, terminal options, and the number of the ALA serving the terminal. TCBs are arranged in memory by terminal number (from 1000 to 7999), but they are in linked lists according to polling order.

(*iii*) The Restricted Service Lists (RSLs), which contain up to ten Customer Service Center numbers that a restricted polled terminal may access.

4.3.3 Polled call processing operation

Polled call processing operates on a 50-ms scanning cycle. Every ALA is checked for activity on each cycle. This is done by first checking activity in the LASs serving the ALAs and, if activity is found, by then checking if one or more of the 16 ALAs served by an LAS indicates activity. An ALA indicates activity if it (*i*) needs polling addresses to be loaded, (*ii*) has received a message from a polled terminal, or (*iii*) has space available for output in its 64-character output buffer.

4.3.3.1 ***Polling.*** The ALA is capable of autonomously polling via an internal circulator. Polling addresses are loaded into the ALA from the message switch. After an initialization of the polled side hardware, the ALCBs are set to the POLLING state. This causes the LOAD POLLS routine to be called, which turns off the ALA circulation, outputs the polling addresses into the ALA by traversing the TCBs associated with it, and then turns on the circulator again.

Once the polls are loaded in the ALA and the circulator is turned on, the ALA transmits polls to each terminal without further direction from the message switch. Recirculation of the poll characters reduces the message switch work load. Interruption of the polling sequence occurs when a terminal begins transmission of an inquiry message or the message switch begins transmission of a response message to a terminal. In both cases, the ALA buffer containing the poll addresses is cleared.

4.3.3.2 ***Reading.*** When an ALA indicates activity and the RDA (receive data available) status bit is set, then the logical state of the line shifts to READING. As characters arrive in the ALA from the polled terminal, they are stored in its 64-character input buffer. The characters are then read by the message switch during each 50-ms scanning cycle, using a special microcoded communications instruction. This instruction stores the characters in a specified address, traps on special characters (e.g. SOH, STX, ETX), and computes the LRC sum. After the entire message is received and message format checks are made, the protocol is continued. An unsatisfactory message causes a NAK sequence to be sent to the terminal, and a finite number of retransmissions are attempted. A satisfactory message causes the program to send an ACK reply to the terminal. In either case, an EOT reply is expected from the terminal and the line state shifts to EOT-WAIT.

If the EOT reply is received after an ACK sequence has been sent to the terminal, then the message is further checked and routed to its destination. Otherwise, it is discarded. In both cases, polling resumes. Before the message is sent to the task handling final delivery of the message, the following actions are taken by the polled call processing program:

(*i*) It verifies the format of the message heading to make sure field separators are found and the information is reasonable.

(*ii*) It checks whether the terminal is restricted or unrestricted. If restricted, the Restricted Service List (RSL) is checked to be sure it contains a valid Customer Service Center number. If unrestricted, it verifies that the Customer Service Center number is within range.

(*iii*) It checks the length of the message text so the TN 128-character limitation is not exceeded.

(*iv*) It fetches and stores the time and date.

(*v*) It converts the called and calling numbers into binary format.

In the event any errors are found, the message is returned to the polled terminal with an appropriate message status indicator.

4.3.3.3 Writing. A message sent by a Customer Service Center to a polled terminal is routed from the synchronous call processing background task, using EOS calls, to the polled background task. This task is normally in the "wait" state, and it is not executed until it is awakened by the synchronous background or polled foreground call processing tasks. The polled background task then checks the message for validity, makes sure the terminal addressed is in service, and that the line queue has not overflowed. If the message is to be delivered to a restricted polled terminal, it cross-checks the TCB and RSL to make sure the message route is authorized. If, while performing validity checks, the background task finds an irregularity, it then inserts a message status indicator and returns the message to the synchronous background call processing task. If all validity checks pass and if the line is in the POLLING state, the process is interrupted and the line state changes to WRITING. On the next 50-ms scan, the line state for the particular ALA is found in the WRITING mode, and the actual output of the message is then started. If the line is not in the POLLING state, the message is added to the line queue.

After the last character in the message (LRC) is transmitted, the line state is set to ACK-WAIT and then an ACK or NAK reply is expected from the terminal. At this point in the protocol, one of four things can happen: (*i*) the ACK reply is received, (*ii*) a NAK reply is received, (*iii*) something else is received, or (*iv*) nothing is received. Case (*i*) is the normal termination to the protocol, and the message is considered delivered. The billing task is then awakened, and polling is resumed on the line. In case (*ii*), the message is retransmitted on the same line one more time and then retried twice on the other half of the PAC before it is returned to the Customer Service Center. In cases (*iii*) and (*iv*), an ENQ (Enquiry) character is sent to the terminal up to three times to solicit the ACK reply.

Then in case (*iii*) the message is retried, at most twice on the main line and twice on the other half of the PAC before returning it. In case (*iv*), the message is retried only once on the other half of the PAC. Figure 6 illustrates the POLLING, READING, and WRITING process.

4.4 Dial call processing

4.4.1 Dial lines and protocols

The purpose of dial call processing is to process all transactions from the dial-in network using dial-in protocols. There are three protocols involved:

(*i*) Voice only: the simplest of the three. Inputs are *TOUCH-TONE*® characters, and output is automatic voice response only.

(*ii*) Voice/KAT: transmits automatic voice and/or Key Answer Tone (KAT) responses to the terminal. Inputs are *TOUCH-TONE* characters.

(*iii*) Data: transmits FSK responses to the terminal. Inputs are *TOUCH-TONE* characters.

In the dial-in network, a Line Adapter Selector (LAS) serves up to 16

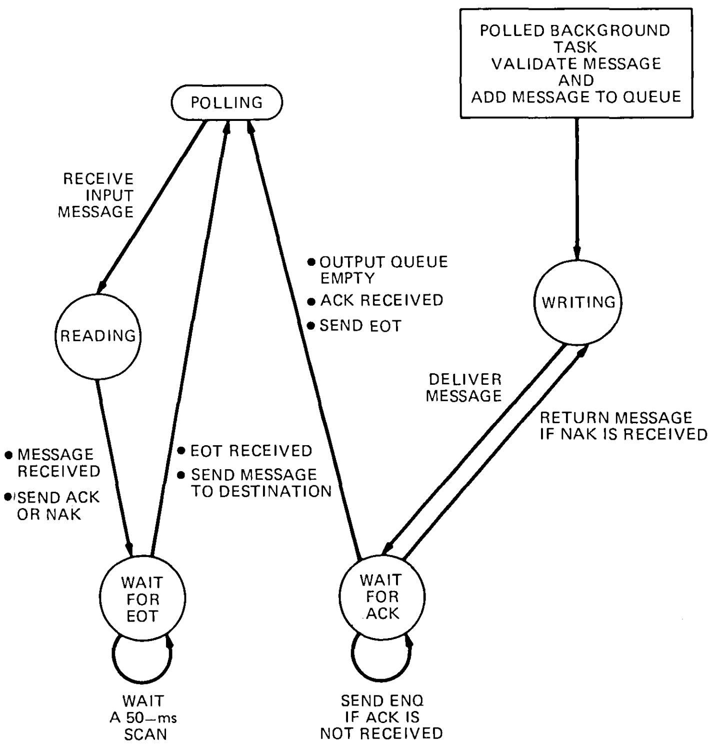


Fig. 6—Overview of polled network call processing.

Dial Line Adapters (DLAs). Each DLA, in turn, is connected to a 407A data set. The DLA serves as an interface among the 407A data set, the LAS, and the Audio Response Unit (ARU) which is used to automatically output the voice responses. The access lines to the 407A data sets appear in a line hunting group on a switching machine in the telephone network and are assigned a telephone number to access the message switch. To serve the various dial-in protocols, two different types of line hunting groups are supported. One serves the protocols which use voice responses. The other is dedicated to the FSK response protocol. Figure 7 shows the dial network configuration.

4.4.2 Dial control blocks

Dial call processing software controls the dial lines and the ARU via four different types of control blocks. These are:

(*i*) The Dial Line Control Blocks (DLCBs), which contain all the

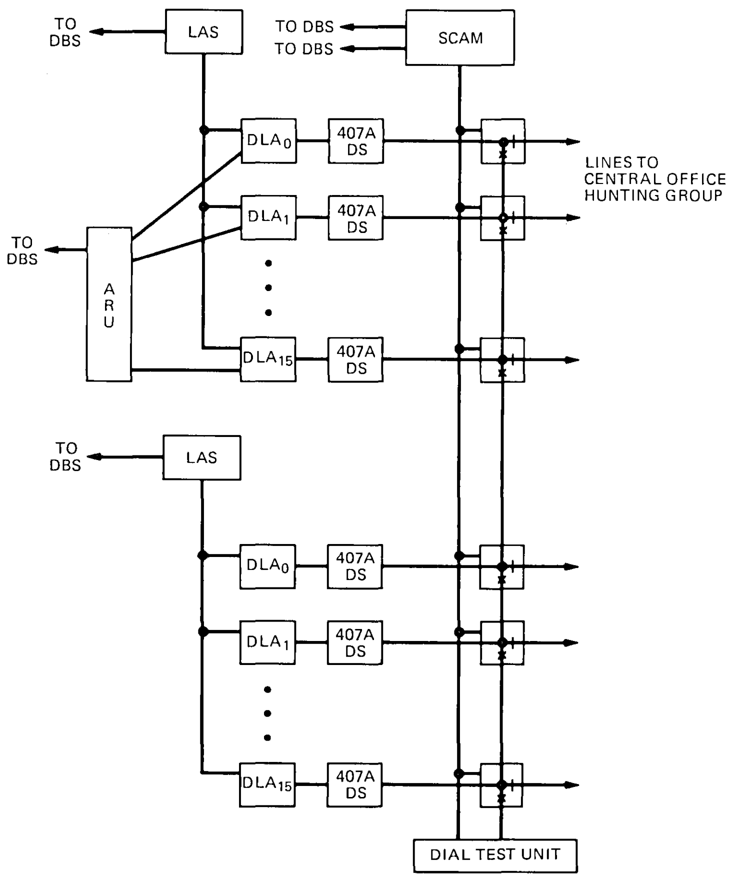


Fig. 7—Dial-in network configuration.

information needed to control the processing of a dial call. Items found in a DLCB are state of the dial line, pointer to the message buffer, state of the protocol, flags indicating if the ARU is producing speech on the line, etc.

(*ii*) The Line Hunting Group Control Blocks (LHGCBs), which define dial lines used for FSK responses or voice responses.

(*iii*) The Audio Response Unit Control Block (ARUCBs), which contain ARU status information and identify DLA ports connected to the ARU.

(*iv*) The speech list which contains the ARU memory addresses of the speech segments making up the ARU vocabulary.

4.4.3 Dial call processing operation

The dial call processing software (Fig. 8) consists of three tasks. Two tasks operate in the foreground environment, and they control input/output operations to the DLAs and ARU units; the other task operates in a background environment and handles timers and non-real time message processing operations.

4.4.3.1 ***Dial Line Adapter driver.*** The DLA driver operates on a scanning basis every 70 ms. Its basic function is to handle all DLA input/output operations.

Every scanning cycle, the DLA driver checks to see if any LASs serving DLAs have DLA service requests. If no LAS shows a request, then the DLA driver releases control until the next scan. Otherwise, the first LAS showing a service request is queried to see which DLAs are requesting service. If a DLA shows activity but is in a maintenance mode, it is skipped, and another DLA requesting service is checked. If none are found on that LAS, the next LAS showing a service request is examined.

A DLA service request consists of any of the following situations:

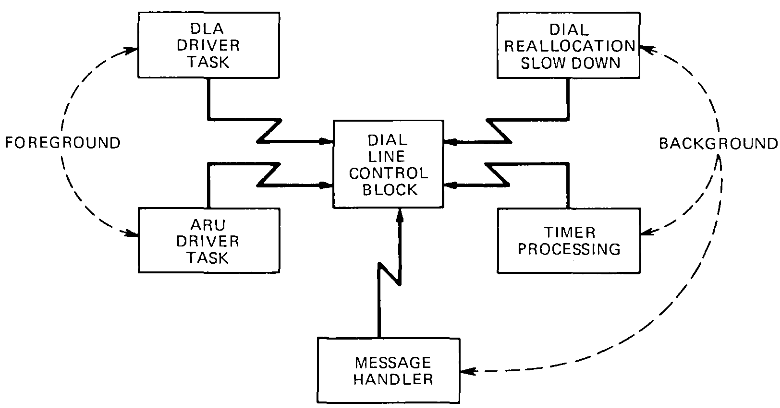


Fig. 8—Dial call processing—task communications.

(*i*) Line Ringing: the DLA driver answers the call and sends a 2025-Hz automatic answer signal on the line.
(*ii*) *TOUCH-TONE* input characters: the DLA driver processes the character and handles the protocol sequence.
(*iii*) FSK output characters: the DLA signals the message switch that it is ready for output.
(*iv*) Intercharacter timeouts: the DLA signals the message switch that the timeout between characters has elapsed. The protocol then will take appropriate action.
(*v*) Calling party disconnect: the DLA notifies the message switch of a line disconnect and awakens the billing task.

The DLA driver, in general, handles all protocol sequences. When the protocol is completed and if the message has passed all validity tests, the DLA driver sends the address of the buffer containing the message, via an EOS call, to the synchronous background call processing task.

4.4.3.2 Audio Response Unit (ARU) driver. The ARU is an output peripheral device used in TN to produce voice responses by piecing together digitized speech segments. It is operated from the message switch via an ARU driver. The ARU driver is executed every 100 ms, and its main purpose is to provide an ARU with addresses so speech can be generated in selected dial lines. Once speech has begun to be generated on a line, the ARU has to be given ARU memory addresses every $\frac{1}{6}$ second. The ARU driver controls each line connected to it by referencing the DLCB. Silence is generated on any port whose DLA is not active or does not have a message to be sent to it.

4.4.3.3 Dial background message task. The dial background message task receives messages via EOS from the synchronous background call processing task. This task performs validity checks on the message. If irregularities are found, it returns the message to the synchronous background call processing task via EOS. Otherwise, it determines the protocol response type and either activates the ARU driver by setting a flag in the DLCB or causes activity on the DLA by initializing it. The DLA driver then will sense the service request and output the message.

The dial background task is also awakened when one of the several protocol timers elapses. Usually, a timeout causes a call to be disconnected.

4.5 Synchronous call processing

4.5.1 Synchronous line

Synchronous lines are used for communications with the Customer Service Center (CSC). Figure 9 illustrates the synchronous line arrangement. The synchronous line consists of a Synchronous Line Adapter (SLA), an analog data set or data service unit (DSU), and a dedicated line facility (analog or digital) which provides the communi-

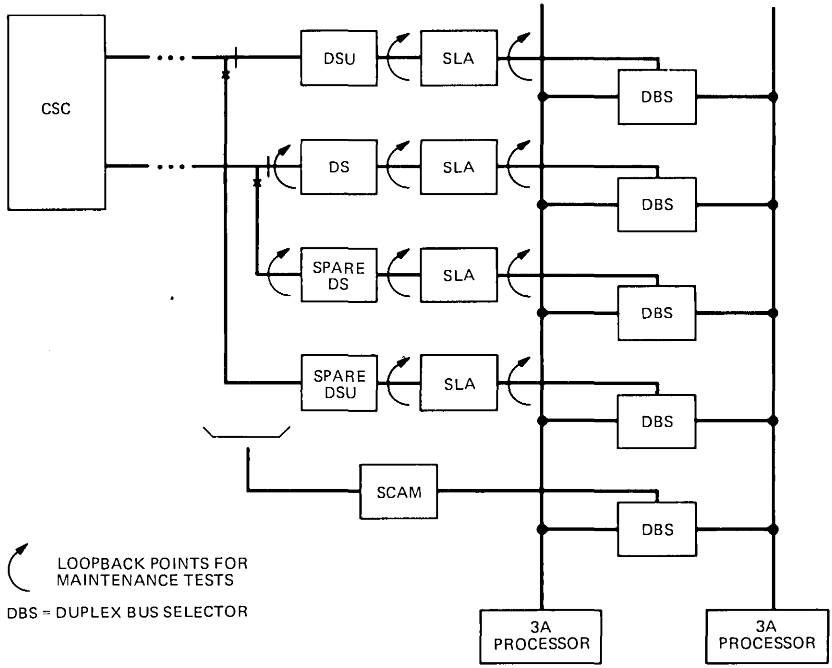


Fig. 9—Synchronous access line configurations.

cations link with the CSC. In addition, for reliability purposes, associated with synchronous lines of the same type (same speed, modem or DSU, and transmission facility type) is an SLA/data set or data service unit spare combination which can be switched in automatically if the normal synchronous port becomes defective. Figure 9 illustrates the synchronous line arrangement. Switching of the spare SLA/modem or DSU combination is through the Switch Control and Monitor (SCAM).

4.5.2 Synchronous groups and forwarding

A collection of synchronous lines communicating with a Customer Service Center (CSC) comprises a line "group." A CSC may subscribe to more than one line group. A line group is addressed as a single entity, but it may contain one or more synchronous lines. The synchronous call processing programs evenly distribute message traffic over all members of a line group.

The CSC may also select to have messages forwarded to an alternate CSC when it is inoperable or overloaded, or a line group is out of service.

4.5.3 Synchronous control blocks

Synchronous call processing software controls the various synchronous lines via two different types of control blocks:

(*i*) The Synchronous Line Control Blocks (SLCBs), which describe the characteristics of a synchronous line (speed, analog or digital, SLA spare) and the current state of the line and protocol, and contain pointers to the line message queues.

(*ii*) The Synchronous Group Control Blocks (SGCBs) which contain information about the lines making up the group, forwarding (or alternate delivery) CSC, pointer for message queues, etc.

4.5.4 Synchronous call processing operation

The synchronous call processing is interrupt driven. A foreground routine called the Synchronous Interrupt Service Routine (SISR) services all interrupts issued by the various SLAs by saving the current state of the 3A Processor, enabling higher priority interrupts, identifying the interrupting SLA, and transferring control to the appropriate state driver. After the state dependent driver executes, the SISR determines if any other SLAs require service. If so, they are serviced; if not, the interrupt is cleared and the prior 3A Processor state is restored, allowing lower priority tasks to execute.

4.5.4.1 State dependent drivers. The state dependent drivers can be classified into four categories: (*i*) the protocol driver which controls the processing of communications with CSCs, (*ii*) the diagnostic driver which controls the execution of SLA diagnostics, (*iii*) the test driver which is used when periodic tests are performed on the SLA, and (*iv*) the clear interrupt driver which is used when a faulty SLA is suspected and all interrupts from it are to be ignored.

4.5.4.2 Protocol driver. The protocol driver, which presently supports binary synchronous communications procedures, is in one of three states:

(*i*) The control state indicates that the line is idle. In this state, either the TN message switch or the CSC can initiate a request.

(*ii*) The receive state indicates that the message switch is receiving from the CSC.

(*iii*) The transmit state indicates that the message switch is transmitting to a CSC.

Within a receive or transmit state, substates are defined that describe the exact position of a message transmission within the protocol. The protocol driver decodes the current state and sub-state, handles the data transmission or reception based on the allowed actions in the current state, and advances to a new state as needed.

The transmit state handles the grouping of messages into records and records into blocks. It also handles many of the allowed transmit options for synchronous lines. Some of these options are: record size, block size, number of records per block, number of blocks per transmission, message prefix, message suffix, optional heading control characters and separators, and deletion or insertion of SOH on intermediate records within a block.

The receive state separates blocks into records and records into messages. It also handles many of the allowed received options for a synchronous line. These options are similar to the transmit options previously listed.

4.5.4.3 ***Message queues.*** The interface between the Synchronous Interrupt Service Routine (SISR) and the synchronous background tasks is via various queues and EOS events. The queues depend upon the direction of the message and whether the message is a data message or a service message.

Messages to be transmitted to a CSC are placed in a group queue by the synchronous call processing background task. The background task looks for a line in the group that is in the control state. If a line is found, it is initiated by executing (from the background task) a command to the SLA to force it to cause an interrupt. The SISR then checks the group queue, moves the message into a queue, transmits the message to the CSC and, if successful delivery of the message is accomplished, awakens the billing task. If no synchronous lines are found in the control state, this means that all lines are being used. Before returning a line to the control state, the group queue is checked and if any messages are found, they are delivered. In either case, service messages are given priority of delivery over data messages.

Messages received from a CSC are first placed in an input line queue. If the message is received correctly, it is then moved to a synchronous input queue if it is a data message or to a service message input queue if it is a service message. These are special queues which are not associated with a group or line since the routing information has not been decoded at this time. The synchronous background task is informed of queue entries by an EOS event.

4.5.4.4 ***Synchronous background receive task.*** The synchronous background receive task retrieves messages from the synchronous input queue and converts them into the Standard Buffer Format (SBF). This involves moving the various items of the heading into SBF specified locations and inserting the heading field, record, and group separators.

The background receive task then proceeds to check such things as the message sequence number, the message status characters, and the called and calling number fields. A message is returned to the sender if it fails any of the preceding tests. A check is made to determine if the specified calling number is either the true calling number or the number of the group forwarded to by the specified calling number. If the calling number is invalid, the message is returned. As described below, all screening of messages is based on the options for the specified calling number as opposed to the actual (alternate) calling number.

If the called number is a group number (i.e., a CSC-to-CSC call), a check is made of the Class of Service Character (CSCH) to determine if it is appropriate for CSC-to-CSC communications. If this or other tests fail, the message is returned. Assuming a valid called number, the message is then routed to either the polled or dial background task or to the synchronous background transmit task.

4.5.4.5 Synchronous background transmit task. Through EOS, the synchronous background transmit task receives messages from the polled, dial-in, and synchronous call processing programs.

The message status characters of the received message are examined to determine if the message is being returned to the CSC because it cannot be delivered to the called number or if the message is a data message intended for the CSC. If the message is being returned, an attempt is made to deliver the message to the group that originally sent the message. This group may not be the group identified as the destination in the message heading because the initial inquiry may have been forwarded.

Based on the destination group number and the synchronous group control block, the calling number and Class of Service Character are screened. The calling number identifies what type of terminal (polled, dial, or another CSC) originated the message and the Class of Service Character identifies the type of call (unrestricted, restricted, etc). If the message fails any part of the screening, the message is returned to the sender with the appropriate message status characters included on the message heading.

After a message passes screening, the state of the called group and the length of the called group queue are examined. If the called group cannot accept the message, an attempt is made to forward the message to another group, provided the called group has a forwarding point specified in its SGCB. Once a destination group has been determined, the message is added to the group message queue for the destination group. The SISR then removes messages from the group queue and transmits them to a CSC.

4.5.4.6 Service messages. As previously mentioned, service messages are used to coordinate CSC and TN activities for a synchronous line group and the lines in the group. A special service message task handles all service messages.

Processing the service message heading is similar to processing data message headings. Processing the service message text depends upon the type of service message. The service message types are SET STATE REQUEST, SET STATE ACK, REPORT STATE REQUEST, REPORT STATE ACK, HALT WAIT REQUEST, HALT WAIT ACK, ECHO REQUEST, and

ECHO ACK. Request messages are accepted only if the TN has not issued an unanswered request and thus is not waiting for an acknowledgment message (e.g., SET STATE ACK). Unaccepted request messages are returned to the CSC. The exceptions to this are a HALT WAIT REQUEST and a REPORT STATE REQUEST. A HALT WAIT REQUEST is accepted at any time. This request serves as an acknowledgment to all outstanding requests. A REPORT STATE REQUEST serves as a signal for the TN to repeat the last request if the REPORT STATE REQUEST is received while the TN is waiting for an acknowledgment.

Acknowledgment messages are accepted only if a request of the same type is outstanding and the service message sequence number of the acknowledgment is the same as the sequence number transmitted with the request. Unaccepted acknowledgments are returned to the CSC. The processing of a service message request requires the generation of an acknowledgment for each request received.

Service message requests from the TN to the CSC are initiated by maintenance and recovery tasks. These tasks pass a message to the service message task describing the type of service message they want transmitted to the CSC. The service message task then creates the complete service message and coordinates its transmission to the CSC. If the message is a SET STATE REQUEST for one line or more, then the service message task will determine if the group state should be changed. If it should, a group SET STATE REQUEST is also generated and transmitted to the CSC.

The service message task will automatically send a HALT WAIT REQUEST if a TN-initiated request is not acknowledged within one minute. Following the receipt of the acknowledgment to the HALT WAIT (or after another minute), the original request is repeated. If this second request is not acknowledged within one minute, the synchronous recovery program is invoked for the line over which the requests were sent.

4.6 Billing

The billing task is usually in the "wait" state, and it is awakened by the polled, dial-in, and synchronous call processing programs whenever a message has been successfully delivered to the destination point. For example, the call to the billing task for a message originated by a polled terminal is done by the synchronous call processing task after it was successfully transmitted to the Customer Service Center (see Fig. 4).

When the billing task is awakened, the address of the buffer containing a message in the Standard Buffer Format (SBF) is passed to it. The billing task then obtains from the SBF items such as the called and calling numbers, the number of characters in the text of the message, message status information, and the connection time. It formats this information into records compatible with the Automatic Message Accounting (AMA) standards and then writes the records on a 1600-b/in. 9-track magnetic tape.

Once the billing task has obtained all the information necessary from the SBF, it calls the buffer task which releases the buffer to the common buffer pool. At this point, the processing related to the delivery of a message terminates.

The 9-track magnetic tape is generated from a *Pro*grammed *Ma*gnetic *T*ape *S*ystem (PROMATS). Duplicate PROMATS drives are used for reliability purposes. Therefore, another function of the billing task is to control the operation of PROMATS.

V. GENERAL ADMINISTRATION AND MAINTENANCE PLANS

The dependability, administration, and maintainability objectives, when applied to stored program switching systems, define the need, in computer programming terms, for an on-line, real-time, high-availability machine.[7] This requires careful initial systems planning in basic redundancy configurations, in the human interface to the machine, and in hardware-software tradeoffs. Approximately two-thirds of the total TN software is dedicated to maintenance and administrative programs that are used to manage system redundancy, control diagnostic routines, make performance measurements, and provide communications with the craftsperson. It is the need to keep the message switch operational during periods of growth and change of customer services, the need to maintain calls in progress during switches to standby equipment, and the requirement for providing simultaneous on-line communications with a number of craftspersons that adds extensively to the program structure and makes maintenance more than simply a matter of diagnostics.

5.1 Operator interface to message switch

The major communications vehicle between the message switch and the craftsperson is by teletypewriter. In addition, audible alarms and visual displays are used to alert the craftsperson to trouble conditions which are subsequently more fully reported on a teletypewriter. Manual controls are also available for taking restart action when the system has lost its "sanity" to the point where it can no longer interpret teletypewriter input commands.

5.1.1 Teletypewriter facilities

A typical TN installation will include four teletypewriter facilities:

(*i*) Maintenance: This TTY reports all system maintenance activity (troubles detected, diagnostic results, maintenance and traffic registers) and accepts all system input messages (maintenance and other).

(*ii*) Service Order: This TTY is used to create tables in memory to reflect changes in customer information (directory numbers, features, billing arrangements, etc.).

(*iii*) Traffic: This TTY provides traffic data according to defined schedules. Specific data can be requested and the schedule can be changed by input messages.

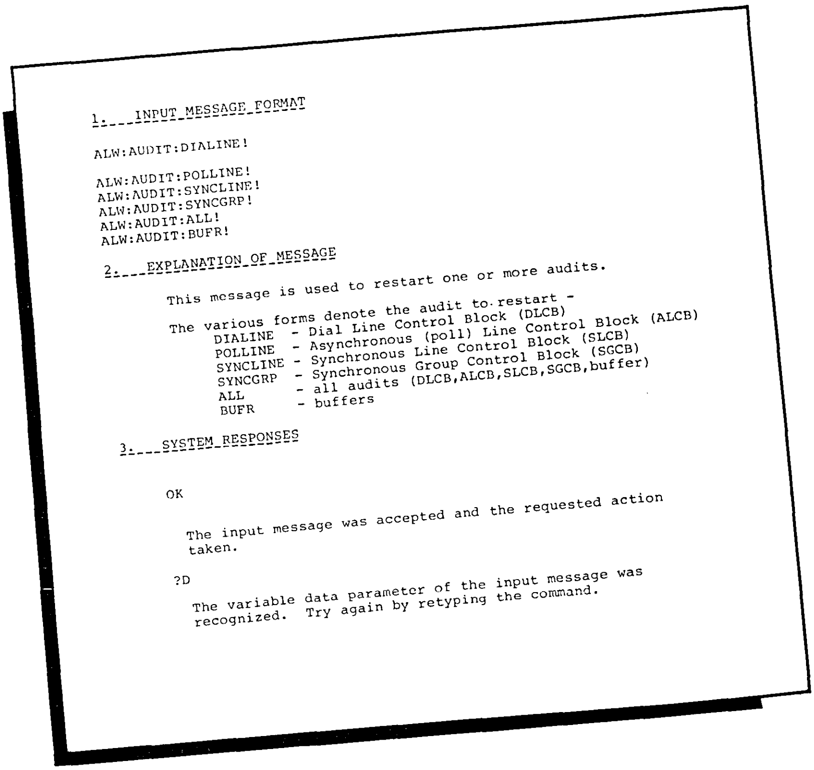
(*iv*) Repair: This TTY reports equipment failures in a remote telephone company service bureau.

5.1.2 Documentation

The human interface to the message switch is built on a hierarchy of documents with which the craftsperson must be familiar.

The Input Message (IM) and Output Message (OM) Manuals define all possible teletypewriter messages which are programmed into the machine and lists all acceptable input requests and the expected response to them. Figure 10 shows a typical input message entry.

When the output message gives specific diagnostic data, the OM points to a Trouble Locating Manual (TLM) which provides a description of


```
1.___INPUT_MESSAGE_FORMAT

ALW:AUDIT:DIALINE!

ALW:AUDIT:POLLINE!
ALW:AUDIT:SYNCLINE!
ALW:AUDIT:SYNCGRP!
ALW:AUDIT:ALL!
ALW:AUDIT:BUFR!
2.___EXPLANATION_OF_MESSAGE

     This message is used to restart one or more audits.

     The various forms denote the audit to restart -
          DIALINE  - Dial Line Control Block (DLCB)
          POLLINE  - Asynchronous (poll) Line Control Block (ALCB)
          SYNCLINE - Synchronous Line Control Block (SLCB)
          SYNCGRP  - Synchronous Group Control Block (SGCB)
          ALL      - all audits (DLCB,ALCB,SLCB,SGCB,buffer)
          BUFR     - buffers

3.___SYSTEM_RESPONSES

     OK

      The input message was accepted and the requested action
      taken.

     ?D

      The variable data parameter of the input message was
      recognized.  Try again by retyping the command.
```

Fig. 10—Audit input message entry.

the trouble number printed in the output message and indicates a specific set of suspected circuit packs. Should this information prove inadequate (that is, replacement of packs does not clear the trouble), repair procedures might then involve reference to the more basic maintenance documents, including program listings and schematic drawings.

A series of internal Bell System documents called Bell System Practices (BSPs) including Task Oriented Practices (TOPS) is also provided as basic training documents. These documents give overall system descriptions in addition to detailed operational and administrative procedures to be followed by the craftsperson. They contain extensive cross references.

VI. MAINTENANCE PROGRAMS

Every TN peripheral hardware device has features to facilitate maintenance of the network from the message switch. In addition, reliability of service is achieved by providing:

(*i*) Dualized line adapter transmission facilities and Data Station Selectors (DSSs) in the polled network.

(*ii*) Multiple dial-in ports in central office line hunting groups for terminals which access the message switch by way of the dial network.

(*iii*) A way of sparing Synchronous Line Adapters and modems or data service units of a particular speed and type with one backup. Therefore, the number of spares depends on line speeds (2400, 4800, or 9600 b/s) and the type of channels (analog or digital) involved.

The actual process of maintaining TN (from a software point of view) consists of four areas: *trouble detection, system recovery, diagnostics,* and *service verification.* Trouble detection is the process of recognizing the existence of a hardware error. Recovery is the process of bypassing a hardware error, usually by switching to a new unit or initiating other software corrective action. Diagnostics is the process of isolating a fault to a particular device or circuit board. Service verification procedures allow for automatic rechecks on service restoral. These four areas of maintenance are discussed in Sections 6.1 to 6.4.

6.1 Trouble detection

Four techniques are used to detect errors: self-checking hardware, periodic testing, audits, and protocols. The self-checking hardware usually consists of encoding and decoding instructions and data words into an m-out-of-n code or a parity code. Periodic testing is the process of executing software tests on hardware that is not self-checking. Audit programs protect the TN software from the effects of data mutilation by detecting and correcting errors in the various control blocks and message buffers. Protocols are used to transmit and receive data from a remote station. Failures in the protocol indicate possible hardware errors. Protocol checks include block check character codes such as the Longitudinal Redundancy Check (LRC), message length errors, format errors, or time-out errors. In addition, detection of excessive transient error counts in a hardware device may indicate a trouble condition. A transient error is defined as an incorrect operation of a hardware device which does not reoccur on a subsequent retry of the same operation.

6.1.1 Hardware checks

Three hardware methods are available for indicating faults to the 3A Processor: hardware initialization, interrupts, and status information. Hardware initialization is the process of initializing hardware registers to a predefined state and passing control to a particular software routine which can analyze the reason for the initialization and take appropriate action. Certain less severe faults cause interrupts to the processor rather than a hardware initialization. For example, faults in the serial channel or the memory on the off-line processor cause interrupts. The final method of indicating faults is status information. The processor hardware maintains status registers on the state of the processor and peripheral devices. Also, success/failure status is provided at the completion of every input/output (I/O) instruction which helps detect hardware and/or transient faults.

6.1.2 Periodic maintenance

Periodic maintenance programs, as the name implies, run on a periodic basis. They attempt to detect hardware faults. In general, periodic maintenance programs perform loopback tests on the various devices. The following examples illustrate how periodic maintenance is performed:

(*i*) The synchronous periodic maintenance programs test that every line has been active during a specified time interval. If a line had been idle for a full time interval (e.g., last 5 minutes), a service message is generated to test the line. If this service message fails to reach the Customer Service Center computer, recovery routines are automatically invoked.

(*ii*) In the polled network, the test message generator associated with a DSS is polled on a periodic time interval (e.g., every 10 minutes). This causes an 11-word message to be returned to the Message Switch which contains status information on polled terminal loops and the DSS power supply. A valid test message generator response performs two functions: (*a*) it allows the polled periodic maintenance programs to verify that the various hardware elements of the polled network (DBS, LAS, ALAs, transmission facilities) are performing properly, (*b*) it allows the periodic maintenance programs to analyze the loop current of all active polled terminals on that polled line.

6.1.3 Audits

The TN programs depend heavily on data stored in the various control blocks to record the states of messages and of system hardware and software resources. Hardware errors, program bugs, and incorrect manual operations can mutilate data in the various control blocks, causing messages to be mishandled and leaving system resources in unusable states. In addition, data errors could propagate throughout the call store data causing service to degrade, possibly creating the need for a system initialization (Section 6.2) to recover from errors.

Some of these errors are eliminated by defensive programming techniques. However, some types of errors would require a prohibitive amount of processor time to prevent, and still other more subtle errors could not be readily found using defensive programming techniques. Hence, audit programs are needed to protect the Transaction Network software from the effects of data multilation. These programs detect and correct errors in the various control blocks and message buffers.

6.1.3.1 Memory partitions. Memory is partitioned into two general regions by the 3A Processor hardware: write protected regions and read/write regions. Write protected regions are subdivided into two classes. Class I is always write-protected and contains such items as programs and constants. Class II is usually write-protected and contains data areas that change infrequently. Read/write regions contain transient data areas that change frequently due to call processing or maintenance actions and are defined as Class III regions. Audit programs are written to protect the read/write regions.

6.1.3.2 Types of audits. Audits are performed mainly on the polled, dial-in, and synchronous control blocks and on the buffers used in the system to temporarily store messages. The type of audits performed depend on the format and contents of the control block or buffer. The various audits performed are described in the next five paragraphs.

Linked List Audit. Control blocks are usually linked using a circular, double-linked list. Each element in the list consists of a data field and a header. The header consists of three fields: the forward link pointer which points to the next element in the list, the backward link pointer which points to the previous element in the list, and the audit word which contains a start-of-list bit, an end-of-list bit, a middle-of-list bit, and an element-type field. These bits indicate if the control block is the first, last, or middle in the list. Audit programs can use the properties of linked lists to verify that a control block belongs to a particular list and that the control blocks are interconnected properly. Audit programs can also check the audit word to verify the validity of control blocks. Correction of a bad control block interconnection can also be accomplished by using the forward pointer, the backward pointer, or the element type.

Status Field Audits. Associated with each piece of equipment in the TN are status fields which describe the current state of the equipment. One status field describes whether the equipment is active, standby, out-of-service, or unavailable. Another field, for example, describes whether data are being transmitted or received. An error in a status field could have unpredictable results. Therefore, all status fields are encoded into an m-out-of-n code or a parity code. For example, a 1-out-of-4 code could be used to describe active, standby, out-of-service, or unavailable conditions. By encoding the various status fields, audit programs can verify the correctness of the code.

Message Buffer Audits. Message buffers residing temporarily in the Message Switch are in the so-called Standard Buffer Format (SBF). The SBF is divided in two parts, the heading and the text. The heading follows a predetermined format and has a certain number of fields. Therefore, audit programs can quickly verify any violation of the heading format. A Longitudinal Redundancy Check (LRC) character is calculated for the text portion of the SBF and stored as the last entry. Audit programs calculate the LRC character for the text portion of the SBF and compare it with the already existing LRC character in the SBF to verify that the text portion of the SBF has not been overwritten.

Consistency Checks Audits. Certain other checks are made by the audit programs on transient data areas by examining the properties of the data. These checks consist of checking data words for a minimum value, a maximum value, a finite set of values, a unique value, a common value, a redundant value, or certain bits which are always zeros or ones.

Timeout Audits. Timeout audits are performed on message buffers. These audits are performed every 5 minutes. If the same message is found in a buffer during the execution of two timeout audits, this buffer is released back to the common buffer pool.

6.1.3.3 Audit control. Audit programs run as background tasks with a low priority status. Most audit programs can be initiated/inhibited via teletypewriter request. An audit failure is reported via a message printed on the maintenance teletypewriter.

6.2 System recovery

In a complex program-controlled system such as TN, hardware or software malfunctions can occur which result in improper call processing actions. The purpose of recovery software is to respond to a report from a call processing program or from a maintenance program of a software or suspected hardware fault. In the case of a suspected hardware fault, the software will either confirm that the fault exists, or it will dismiss the report. If recovery software recognizes a device as being faulty (see Section 6.2.1), it will report the trouble via a teletypewriter message so that craft personnel can take appropriate repair actions. Alarms and system status panel lamps are also activated. Communication line(s) associated with the faulty hardware are removed from service, reconfiguration is attempted (for example, if a polled line is removed from service, its traffic load is assumed by the other half of a polled access circuit), and call processing is alerted of the present hardware configuration. If the fault prevents access to a Duplex Bus Selector (DBS), a processor switch is attempted.

In the case of software faults, correction techniques such as audits are applied. Occassionally, however, problems arise which are serious enough that severe recovery action, known as initialization (see Section 6.2.2), is necessary.

6.2.1 Fault isolation

Isolation of a faulty device in the TN is based upon a multistep test process. When recovery programs are notified of suspected trouble in the polled, dial-in, or synchronous networks, the specific line or circuit number, but not the faulty unit, is identified. For example, a polled line includes a Duplex Bus Selector (DBS), Line Adapter Selector (LAS), Asynchronous Line Adapter (ALA), Data Station Selectors (DSSs) and interoffice facilities between a DSS and ALA and between two DSSs. Isolation of a fault in a polled line consists of performing loopbacks, as shown in Fig. 11, at the various network points until a failure is detected.

6.2.2 Initialization

The severity of an initialization determines the degree to which service is disrupted. Seven labels of severity or phases are provided so that increasingly drastic initialization actions can be performed until proper operation is resumed. This is determined by letting the system run for about 90 seconds in a particular initialization level.

6.2.2.1 ***Initialization levels.*** The initialization levels represent a compromise between maximizing speed of recovery and minimizing disruption of TN service. Seven levels are provided:

(*i*) Level 1: Only the task running at the time of initialization is restarted. An attempt is made by the task to restart the line or group doing input/output operations when the initialization occurred. This is done by referencing the registers as they were before the initialization. All messages being received on that line are aborted, and all messages destined for the line are rerouted to it.

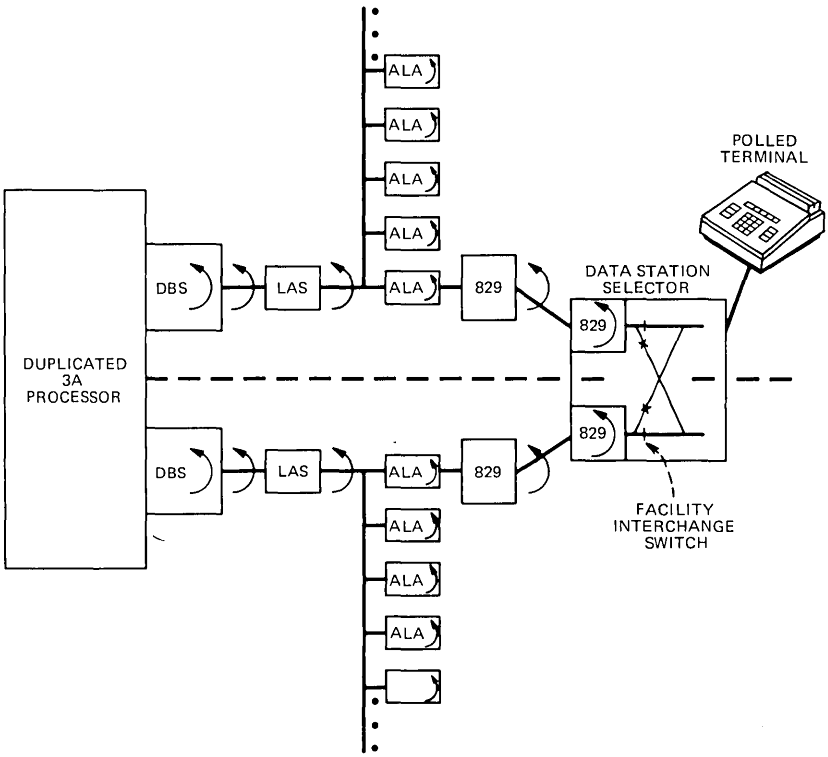


Fig. 11—Asynchronous polled access line loopbacks (↰).

(*ii*) Level 2: Only the running task is restarted. But now, since Level 1 obviously failed, it is necessary to do something more drastic. All line and group control blocks handled by the running task are audited, and those which fail audits are initialized to a known state. The messages that had been destined for those lines are then rerouted to them.

(*iii*) Level 3: This is the first level at which all tasks in the system are restarted. An initialization similar to Level 2 is executed for each task. The major difference is that queue pointers in the line and group control blocks are treated as special cases. If the line control block fails the audit, then the queue pointers are audited. If they fail, then the system is initialized to the next level. Otherwise, only the line control block which failed audits and the associated hardware are initialized.

(*iv*) Level 4: At this level a last effort is made to recover system sanity before all transient data are reinitialized. All line and group control blocks are reconstructed from write-protected data, with the exception of the queue pointers. They are audited and, if the audit fails, the level is escalated.

(*v*) Level 5: For Levels 5 and 6, the EOS will reinitialize all transient data. For Level 5, each task will initialize all transient data (line control blocks, queues, etc.). All the message buffers will then be audited. Those which pass audits will be routed to their appropriate destination. All messages in progress will be lost.

(*vi*) Level 6: All transient data are reinitialized. All hardware is reinitialized. All message buffers are relinked onto the available list. All messages in the system are lost.

(*vii*) Level 7: If Level 6 initialization also fails, then a bootstrap occurs and all programs and data areas are reloaded from the cartridge tape.

6.3 Diagnostics

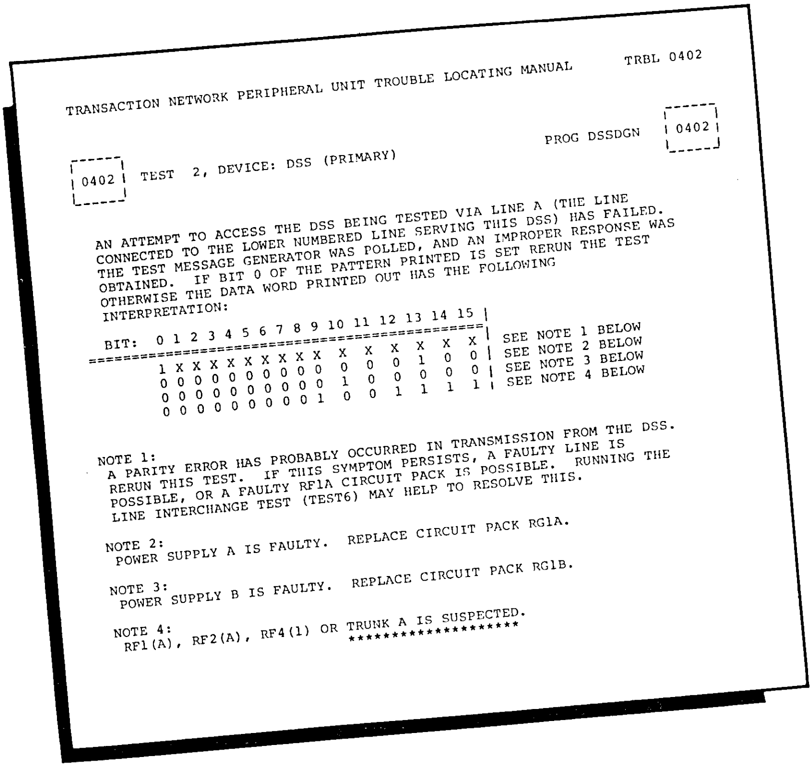
The objective of diagnostics programs is to produce a teletypewriter printout which isolates a fault to as few circuit packs, cables, power units, and wiring areas or installation options as possible. In TN, diagnostics are only executed in response to a teletypewriter input message. A failure in a diagnostic is reported by a trouble number. This trouble number is used as an index into the Trouble Locating Manual (see Fig. 12), where a description of the failed test is found, along with important cautions and comments and the list of suspected circuit packs.

The diagnostic programs are also used for restoring equipment to service after repair and for testing new equipment additions. A new piece of equipment is not allowed into service until diagnostics pass all tests.

Although there are many common elements among the several TN peripheral unit diagnostics, each device diagnostic must be intimately tailored to the design of the hardware unit being diagnosed. To accommodate this situation, the diagnostics have been designed in a table-driven structure; a unique table exists for each hardware device being diagnosed. All diagnostic programs are brought into an overlay buffer in memory from the cartridge tape as requested.

6.4 Service verification: alarms

Teletypewriter output messages which report trouble conditions are assigned one of three alarm levels: critical, major, or minor. These levels are represented by printing *C, **, or * prior to the output message. Also, audible alarms and lamp indicators are activated according to the output message alarm level.



```
TRANSACTION NETWORK PERIPHERAL UNIT TROUBLE LOCATING MANUAL          TRBL 0402

                                                         PROG DSSDGN   0402

 0402  TEST  2, DEVICE: DSS (PRIMARY)

AN ATTEMPT TO ACCESS THE DSS BEING TESTED VIA LINE A (THE LINE
CONNECTED TO THE LOWER NUMBERED LINE SERVING THIS DSS) HAS FAILED.
THE TEST MESSAGE GENERATOR WAS POLLED, AND AN IMPROPER RESPONSE WAS
OBTAINED.  IF BIT 0 OF THE PATTERN PRINTED IS SET RERUN THE TEST
OTHERWISE THE DATA WORD PRINTED OUT HAS THE FOLLOWING
INTERPRETATION:

BIT:  0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 |
=============================================| SEE NOTE 1 BELOW
      1 X X X X X X X X X  X  X  X  X  X  X | SEE NOTE 2 BELOW
      0 0 0 0 0 0 0 0 0 0  0  0  0  1  0  0 | SEE NOTE 3 BELOW
      0 0 0 0 0 0 0 0 0 0  1  0  0  0  0  0 | SEE NOTE 4 BELOW
      0 0 0 0 0 0 0 0 0 1  0  0  1  1  1  1 |

NOTE 1:
 A PARITY ERROR HAS PROBABLY OCCURRED IN TRANSMISSION FROM THE DSS.
 RERUN THIS TEST.  IF THIS SYMPTOM PERSISTS, A FAULTY LINE IS
 POSSIBLE, OR A FAULTY RF1A CIRCUIT PACK IS POSSIBLE.  RUNNING THE
 LINE INTERCHANGE TEST (TEST6) MAY HELP TO RESOLVE THIS.

NOTE 2:
 POWER SUPPLY A IS FAULTY.  REPLACE CIRCUIT PACK RG1A.

NOTE 3:
 POWER SUPPLY B IS FAULTY.  REPLACE CIRCUIT PACK RG1B.

NOTE 4:
 RF1(A), RF2(A), RF4(1) OR TRUNK A IS SUSPECTED.
                           ********************
```

Fig. 12—Trouble locating manual description for trouble number 402.

VII. ADMINISTRATION PROGRAMS

7.1 Background

Administrative functions for the Transaction Network (TN) may be loosely categorized as either those dealing with system or customer changes and growth or those necessary for ongoing operations and system evaluation. Reallocations and service order changes clearly belong in the first group, while maintenance and traffic measurements fit into the second.

Basically, the software administrative functions for TN are:

(*i*) *Reallocations.* Reallocation programs are designed to deal with major network office and customer equipment growth, and are also used for general allocation of memory whenever new storage is added to the system. One example is the case in which the number of previously allocated control blocks are nearing a high percentage of usage. Consequently, new storage must be allocated to the block concerned. Since it is required that all blocks of a certain type occupy contiguous memory, overlapping could occur which then requires a rearrangement of all blocks concerned. The reallocation procedure is intended to be performed much less often than the service order changes and is inherently more complex.

(ii) Service Order Changes. Service order change programs are required to provide a craftsperson or service order clerk with the means to update system memory to reflect changes which are subscriber-originated (e.g., initiate, cancel, or modify a service) as well as changes to system parameters resulting from relatively minor office equipment and network rearrangements, (e.g., addition of a DSS to a growing shopping center previously served by individual lines). The service order change procedures are designed for quick response and for daily use.

(iii) Maintenance and Traffic Measurements. Maintenance and traffic measurements are made by the TN message switch as a result of trouble conditions and call processing. The data are used by the Dial Administration and Network Services group to engineer the system's memory, peripheral equipment, and transmission facilities and by the maintenance forces to evaluate system performance. When these data indicate the need for minor software or hardware reconfigurations, the service order change programs are utilized. If more extensive changes are required, reallocations are used.

(ii) Audio Response Unit (ARU) Memory Loading. One major administrative task which does not clearly fit into either of the two categories previously mentioned is the ARU memory loading. This function requires a program which will initially load the ARU memories from a cartridge tape associated with the TN message switch, as well as reload them after an ARU memory error or vocabulary change.

A factor affecting the organization of the administrative programs is that many of the tasks (with the exception of maintenance and traffic measurement programs) are executed infrequently compared to the call-processing programs. To allocate the 3A Processor main memory in an efficient manner, some administrative programs are stored in the cartridge tape and loaded into memory as needed. This use of the cartridge tape system to store the nonresident programs allows more main memory to be allocated to control blocks and message buffers which grow proportionately as the network expands.

Programs residing in the cartridge tape are called *nonresident* programs. Associated with these nonresident programs are some *resident* programs called "overlay monitors," which are equipped to accept teletypewriter (TTY) messages from the TTY handler programs and then take the necessary steps to bring the required administrative programs from the cartridge tape into a buffer area of memory. Once the particular program has been loaded, the input message data is processed and the required actions are taken. Control then passes back to the "overlay monitor" program which is then ready to accept a new message.

The various administrative functions are described in more detail in Sections 7.2 through 7.5.

7.2 Reallocation programs

7.2.1 General considerations

The TN system requires the capability to allocate and reclaim memory for any existing control block or table. This facility is necessary to accommodate major office equipment and customer growth, and general reorganizations of existing control blocks as new storage is added to the system. The service order change programs are not capable of dealing with such reorganizations because they are only equipped to handle minor additions to, deletions from, and changes to existing data structures.

As an example, whenever the number of polled terminal control blocks (TCBs) used approaches a certain percentage of the total number of blocks allocated, then, to insure enough blocks for future expansion, the number of blocks available must be increased. Such a reallocation would probably impact other memory blocks as well, resulting in a general reorganization of the entire memory in which some groups of blocks will either expand or contract.

Reallocations are not procedures to be performed regularly, but are intended to be used as needed to reflect the changing system capacity. Furthermore, the nature of the reallocation process is such that it should only be performed at a time of minimal network activity such as late night or weekends. New call processing is suspended, allowing the processor to reach a stable state while the blocks in memory are actually being changed. Because of the infrequency of reallocation, the programs required to implement this function reside on a cartridge tape.

The reallocation program can perform in three modes: Normal, Initial, or Top. In the Normal mode, the changes specified by the craftsperson are made to the currently existing data structure and data in the existing control blocks are preserved through reallocation. In the Initial mode, all previously existing allocations are destroyed and the memory is reconfigured from scratch. In the Top mode, a new system memory size may be specified without changing the number of control blocks allocated. In this case, the allocated blocks, which are stored at the top (high addresses) of memory are moved to the new top of memory.

7.2.2 Reallocation program organization

The reallocation programs consist of a resident input message handler and a nonresident master reallocation program. One function of the input message handler is simply to accept an input message from an operator and load the master reallocation program into memory. The master program responds to subsequent TTY input messages which define the new memory layout (Section 7.2.3 discusses the procedure further). This layout results in a new Master Block Array (MBA). The MBA is essentially a blueprint of the various types of memory blocks. An MBA is made up of a series of contiguous nine-word blocks, each of which defines the layout in memory of one type of memory block or table. Figure 3 illustrates the type of information stored in the contiguous nine-word blocks.

Once a new MBA has been created, the reallocation portion of the master program uses it to restructure memory. During the course of the reallocation, this program also accepts TTY messages which verify the validity of the input data. When the master program is no longer required, a separate TTY message is used to deactivate it, i.e., it is erased from memory.

7.2.3 Reallocation procedure

When it is necessary to perform a reallocation, a list is prepared which contains all the data needed to construct a new Master Block Array. The craftsperson initiates the process by typing an input message from the maintenance TTY to start the procedure previously described. The existing MBA is copied into a work area of memory. Subsequent TTY input messages are used to change the various entries in this "scratch" MBA. When no further modifications are to be made, the craftsperson indicates this by requesting a printout of the essential elements of the new MBA to compare it with the original list of inputs. After this verification step, the craftsperson initiates a system slowdown. That is, the reallocation program informs the call processing programs not to undertake any new calls and to leave all current activity in a stable quiescent state. The duplex mode of operation in the 3A Processors is then suspended temporarily by the reallocation program by putting the standby processor in an out-of-service mode. Meanwhile, the on-line processor continues normal operations. The real reallocation process then begins in the off-line processor. The reallocation program accomplishes this by comparing the old MBA with the scratch MBA and then shifting and expanding the various control blocks and overwriting the original MBA in the off-line processor memory. When this step is completed, a processor switch occurs (the off-line processor becomes on-line), and an output message is typed to indicate that the reallocation has been performed in one store, which is now the on-line store. The craftsperson lets the system run for a while to ensure that it is operating normally. Then the new off-line main store is updated via another TTY message. Both main stores now contain the same information.

7.3 Service order change programs

As previously mentioned, service order changes are required to reflect updates in system memory to subscriber-originated changes as well as to changes in system parameters resulting from office equipment and network rearrangements and/or growth.

Service order changes are initiated from either the service order or maintenance teletypewriter. Each TTY input message covers a specific type of change activity and is associated with a particular type of control block. Typically, each message is executed by a different service order change subroutine. However, in some cases more than one service order change input is handled by a single subroutine. Since service order changes are not procedures that are performed often (compared to call processing and certain maintenance programs), these programs are nonresident and are loaded from the cartridge tape as needed.

7.3.1 Service order change program organization

All service order change input messages are routed to a resident service order change input message handler. This program functions as a monitor in that it decides (based on which input message was sent) which programs will be needed to execute the requested action. Once this has been determined, it initiates the retrieval of the appropriate non-resident program into memory. When this is done, control is transferred to the subroutine in the nonresident program which will actually respond to the service order change request. During this phase of processing, control is not passed back to the input message handler program until the requested action has been either completed or aborted due to some input error. In the case of a successful completion, the input message handler issues a completion message to the originating TTY. If an error was detected, it issues an error message with a code indicating the reason for the failure. The input message handler is then ready to accept a new input message.

7.3.2 Processor control and memory protection

Since service order changes modify protected system memory, steps have to be taken to insure system recovery in case of an initialization during a service order change (regardless of how the initialization was caused). This is accomplished by performing the changes in the on-line memory while the off-line memory is out of service (i.e., frozen in a previous state). This configuration is obtained at the beginning of the service order change session by typing a begin service order change input message. Then all the required messages can be typed. When the session is completed, an input message is used to restore the offline processor back to the standby mode. Doing this copies the on-line memory (containing the recent changes) into the off-line memory so that the two are again identical. If an initialization were to occur before the service order change was completed, control would be transferred to the off-line processor and all the changes for that session would be lost. This is a small price to pay for the advantage of not having to reload memory from the cartridge tape.

Another safety feature consists of a time-out if no new messages are typed within 5 minutes of the last one. This prevents the off-line processor from being locked in the out-of-service state for an excessive idle period. The time-out causes the off-line memory to be updated and the processor to be placed back in the standby mode. An output message is issued, alerting the craftsperson to the fact that this has occurred.

7.3.3 Service order change verification

Part of the service order change package contains a group of programs that can cause the contents of certain control blocks to be printed on the TTY. These programs fall under the general heading of "verifications." The TTY input messages which perform this function are handled similarly to the service order change messages (i.e., by the input message handler).

7.3.4 Description of service order change/verification message processing

The input message handler is an event-driven task. In other words, the program is entered whenever a TTY input message is directed to it. Upon entry into the program, an immediate check is made to determine which one of the following situations has occurred:

(*i*) A single line message was sent: In this case, a check is made to determine if a message was already in progress. If so, then the new message is rejected (an RL—Repeat Later—response is issued), and processing of the in-progress message is resumed. If another message was not in progress, the new one is accepted, the overlay buffer is seized, and the appropriate nonresident programs are retrieved. In addition, a PF—Printout Follows—is issued. Control is then transferred to the program which will actually process the input data. Control is passed back to the input message handler when the processing program has either completed or detected an error. The input message handler releases the overlay buffer, generates an appropriate TTY output message, and prepares for another input message.

(*ii*) First line of multiline message was sent: This situation is handled exactly as in (*i*) above, except that a PF is not issued unless an error message is to be printed. Successful completion means that the input message handler will accept the next line of the multiline message. In this case, the only response to the TTY is a carriage return and line feed which is a signal to the craftsperson to enter the next line. Meanwhile, the processing (nonresident) program is waiting for the next line of the message.

(*iii*) Middle line of a multiline message sent: This is handled by simply accepting the line and entering the processing program at the point left off by the previous line. Errors and successful completion are handled as in (*i*) above.

(*iv*) Last line of a multiline message sent: Again, this results in the line being accepted and entering the processing program at the point left off by the previous line. A PF is issued by the processing program. Control then reverts back to the input message handler which issues either an error message or a completion message. At this point, the overlay buffer is released and the input message handler waits for the next message.

7.4 Maintenance and traffic measurement programs

Maintenance and traffic measurements are intended to provide (*i*) a means of monitoring message flow through the system, in terms of completed messages and ineffective attempts, (*ii*) usage of resources in the system, and (*iii*) trouble information about resources in the system. The data are intended to help engineer changes to the TN network for growth and optimization of existing equipment given the existing traffic requirements, and to help localize and identify faults affecting quality of service. Traffic data are put out through a dedicated TTY facility on assigned quarterly, hourly, and daily schedules, or on demand. Various combinations of the three basic types of measurements (peg counts, usage, and overflow) are performed in the traffic measurements. Maintenance measurements are printed on a daily basis, or on demand on the maintenance teletypewriter; they deal primarily with equipment outages and transient faults.

The maintenance and traffic measurement programs are divided into scanning tasks and reporting tasks. The scanning tasks are activated every 2, 10, or 100 seconds; their main function is to accumulate counts of various kinds. The reporting tasks print the maintenance and traffic reports.

The quarterly, hourly, and daily traffic reports and the maintenance reports all have different formats.

Traffic reports are printed according to a schedule selected by the telephone company and inputted via teletypewriter facilities. This schedule is stored in memory in the Traffic Work Table.

7.5 ARU loading

The TN message switch utilizes two ARUs, each independently serving 76 dial-in ports. The ARU speech memory is a semiconductor RAM which is loaded from a special magnetic tape cartridge through the message switch. This tape contains all the speech segments to be loaded into the ARU and tables to be loaded into the 3A Processor memory which contain the ARU speech segment addresses.

The ARU loading is controlled by a nonresident program which is manually activated depending on whether the ARU is to be loaded due to:

(*i*) An initial start-up procedure.
(*ii*) Recovery from a fault condition (e.g., power failure).

(*iii*) A vocabulary update.

Only one ARU is loaded at a time, and all dial-in ports served by the ARU are busied out during the loading process which takes approximately 10 minutes.

VIII. SUMMARY

The foregoing discussion has provided the general organization and structure of the operational TN software, an explanation of the functional tasks performed by the various programs, and a description of the call processing, maintenance, and administrative functions. The author has attempted to provide insight into the techniques and considerations used in the development of operational TN programs.

IX. ACKNOWLEDGMENTS

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Transaction Network, Telephones, and Terminals:

Maintenance and Administration

by L. R. BEAUMONT and K. W. SUSSMAN

(Manuscript received June 6, 1978)

This paper describes the maintenance and administration plans which have been developed for the Transaction Network to provide a reliable and maintainable new service while fitting into the existing operating telephone company environment. The polled access network is used as an example to show how high reliability is obtained and how the procedures developed to manage the daily activities are used.

I. INTRODUCTION

Transaction Network Service and the equipment and operational programs developed to implement the message switch communications system which provides the service are described in Refs. 1 to 4. The service has been designed to operate in the existing operating telephone company environment, using existing facilities, craft forces, and administrative and maintenance organizations. To meet the objectives of a highly reliable, available, and maintainable total service, procedures have been developed which fit the service to its operating environment.

This paper describes those maintenance and administrative capabilities and procedures.

II. TRANSACTION NETWORK CUSTOMER SERVICE BUREAU

A single organization, the Transaction Network Customer Service Bureau (TNCSB), has responsibility for the overall end-to-end control and quality of customer service. The TNCSB is located in an existing special service organization serving the area in which Transaction Network (TN) operates and has the following responsibilities:

(*i*) Remain staffed 24 hours a day, seven days a week.

(*ii*) Input all service order information (called "recent change" messages) into the message switch.

(*iii*) Receive any messages automatically sent to it by the TN.

(*iv*) Receive and analyze all customer trouble reports.

(*v*) Perform remote testing in association with message switch or Switching Control Center personnel to sectionalize troubles based on customer trouble reports or automatically generated trouble reports.

(*vi*) Maintain office records on the TN.

(*vii*) Serve as an interface between TN customers and other Bell System offices to resolve problems.

(*viii*) Monitor and coordinate all order and maintenance activity.

The next section of this paper describes the facilities provided by TN to allow the TNCSB to perform these functions.

III. MAINTENANCE FEATURES OF THE TRANSACTION NETWORK SYSTEM

3.1 Introduction

The preceding section discussed the responsibilities of the TNCSB in coordinating the maintenance activities needed to insure that TN provides reliable service. In this section, the hardware and software features available within TN to provide for this maintenance are described in general, and the maintenance features of the polled access circuits (PAC) are described in detail.

3.2 Available maintenance features

3.2.1 Processor maintenance

Since all features, including maintenance, of TN are provided via control of the central processor, it is essential that the processor itself be reliable and maintainable. In TN this is accomplished by using a duplicated Auxiliary 3A Processor (Ref. 5). One processor operates on-line, and the other is normally in a standby mode, ready to become the active processor within milliseconds. Each processor includes its own central control, associated memory, and input/output (I/O) channels. During normal operation, the memories of both the on-line processor and the off-line processor are written into simultaneously from the working on-line unit. The 3A Processor maintains parity over every word in its main store, and over every general and special register, including those used to access the I/O channels. During the execution of every instruction, after the datum is gated to the data bus internal to the processor, its parity is checked. If this parity is incorrect, an error interrupt is generated. This interrupt results in a switch to the standby processor.

In addition to parity checks on every datum gated onto the data bus, the 3A Processor has two other major hardware features designed to increase its reliability. The first is a duplicated data manipulation logic (DML) unit, and the second is the program timer.

Since parity is not preserved over logical and arithmetic functions, parity checking is not suitable to ensure that these functions have been performed correctly. Each 3A Processor contains two data manipulation logic units. To execute any instruction which requires a logical or arithmetic operation, each of the two DML units performs the computation, then their results are compared. Failure of the two DML units to match indicates that one is in error and generates an error interrupt. This interrupt results in a switch to the standby processor.

It is also possible for the 3A Processor to stop executing machine instructions. This could occur if the contents of memory were destroyed, for example, or if an error condition was first encountered while interrupts were blocked. To ensure a minimal service outage in the instance of these faults, a program timer is provided. The programs executing in the processor are responsible for resetting this timer periodically. If it is not reset, it causes a Maintenance Reset Function (MRF) in *both* processors, causing the one without the fault to resume processing.

In addition to these hardware features designed to provide processor reliability, the processor is supplied with software audits also designed to provide increased reliability. A low priority task[4] continually compares the contents of the off-line processor's main store to the contents of the on-line processor's main store. A mismatch is indicative of a memory failure. The mismatch is recorded by a TTY message.

3.2.2 I/O channel maintenance

The reliability gained from the automatic maintenance features of the 3A Processor is considered sufficiently high to allow the processor to control the maintenance of the remainder of the network, without further regard to a processor failure. What has been provided with TN is the ability to rapidly identify equipment containing a hardware fault, and the further ability to chose alternative equipment for providing service to any customer in the event of any independent hardware fault in the network, with the exception of a failure in the access to a single polled terminal. In addition to the ability to identify failed equipment and to reconfigure the network, the capability to diagnose the failed equipment is also provided. This ability allows craft personnel to locate the circuit pack or other circuit element responsible for the equipment failure and to verify that it has been properly repaired.

Figure 1 illustrates how each TN peripheral device is interfaced to the duplex 3A Processor. Each processor is equipped with a single Main-

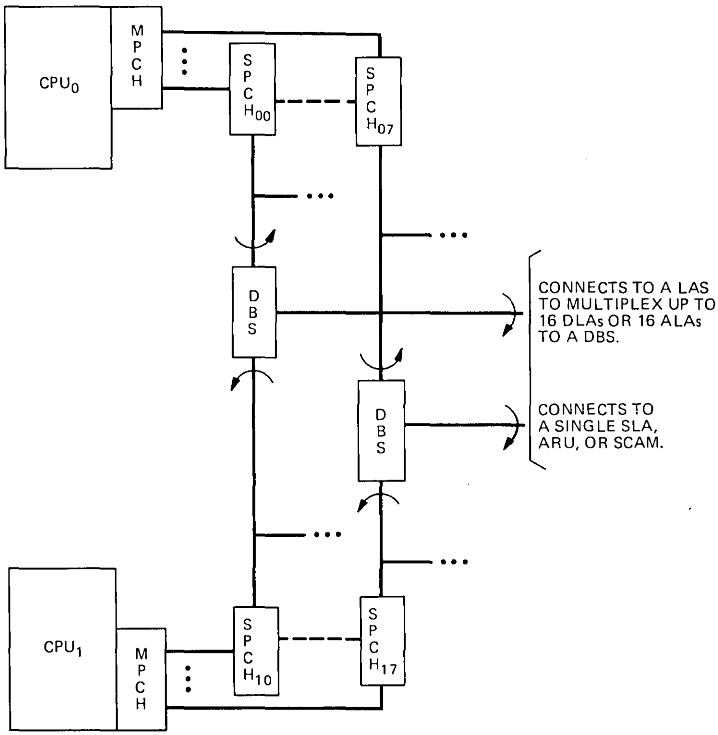

Fig. 1—Switch configuration.

Parallel Channel (MPCH), which is equipped with from two to eight subparallel channels (SPCH). Each subparallel channel serves from 1 to 16 Duplex Bus Selectors (DBS). Each TN peripheral device is connected to a DBS. This I/O channel arrangement allows either processor to connect to each of the peripheral units, allowing continued service in the event of a processor switch.

The DBS has a status register, a bus loopback register, and the ability to respond to commands from the on-line processor. These hardware maintenance facilities are sufficiently complete to allow the software to determine if the on-line processor is able to properly access its DBS port. This constitutes a test of the MPCH and the SPCH as well as the DBS port. Failure of this test is the stimulus used to request a processor switch as part of the network reconfiguration strategy.

A strict protocol involving timing of control signals and parity checking of the data being sent must be observed between the processor and the peripherals on the I/O channel. This serves as a continual check on the operation of the channel. Failure of the protocol initiates recovery programs responsible for maintaining the affected device.

3.2.3 Polled network maintenance

Figure 2 shows the polled network configuration. A polled access circuit is comprised of two polled access lines that serve a collection of terminals connected to a Data Station Selector (DSS), which itself is dualized. Each polled access line consists of a port of the message switch, a line facility, and one-half of the common portion of a DSS. Each polled network port of the message switch consists of a line adapter including an integrated modem (Asynchronous Line Adapter ALA). Sixteen ALAs are multiplexed into a single DBS by one Line Adapter Selector (LAS). Each facility is terminated at both ends by an 829 Data Auxiliary Set, one located at the ALA and the other included in the DSS. The DSS serves a collection of terminals, each connected to it via an unduplicated facility. See Ref. 3 for a complete description of this polled access network equipment.

During normal operation, both access lines in the dualized arrangement are active; polling, receipt of inquiry messages, and delivery of response messages take place on each line independent of the other. When it is necessary to suspend service over one of these paths for

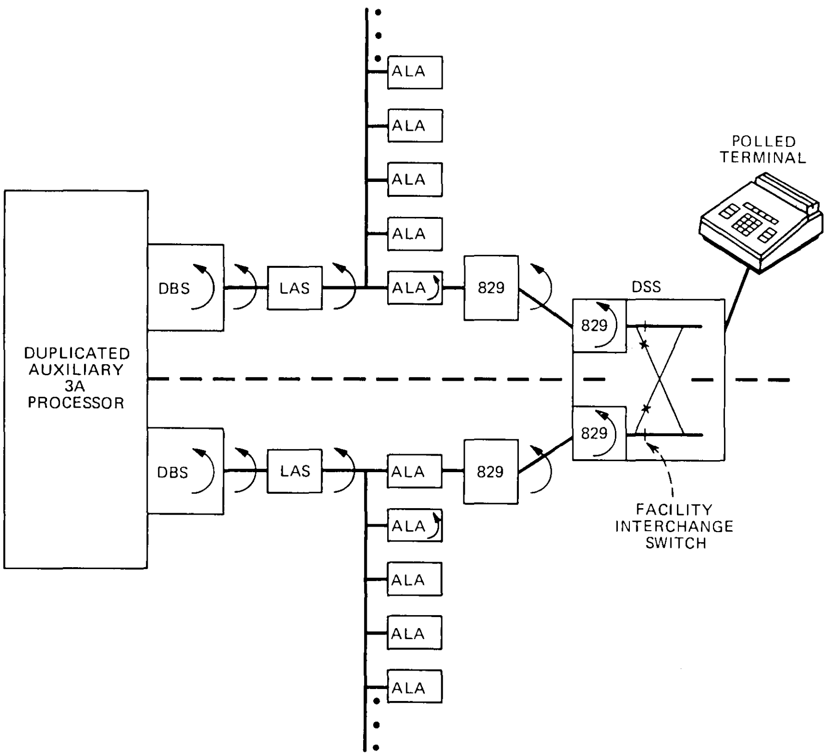

Fig. 2—Asynchronous polled access line configuration.

maintenance purposes, it is possible to carry the combined terminal traffic load over the other (buddy) line. The network can thus be reconfigured to allow maintenance activity (testing, diagnosis, or repair) on any one of a pair of access circuits, while retaining service (at a somewhat reduced level) to all terminals served by the pair.

Polled call processing programs and other software known as polled periodic maintenance provide surveillance over the polled network. Whenever a problem is suspected by either of these programs, another program called the polled recovery task is automatically invoked to investigate and act upon the suspected problem.

Polled call processing provides surveillance of the network by continually checking that each I/O order sent to the periphery obeys the protocol defined for the channel. Failure of an I/O order indicates a fault in the polled network. Polled periodic maintenance provides surveillance by utilizing a transponder located in each half of each DSS. This transponder is called the DSS test message generator. Upon command, the DSS transmits to the message switch a fixed-length message containing maintenance information regarding the DSS and the loops served by it. Failure of periodic maintenance to be able to obtain this message indicates a fault in the polled access circuit.

An error, suspected either by polled call processing detecting a failed I/O instruction or by polled periodic maintenance failing to obtain a valid test message upon command to a DSS, causes the polled recovery task to take action on the indicated polled access circuit. The polled recovery task uses the maintenance features provided by the hardware to resolve the fault to one of the following:

(*i*) A power supply serving the ALA unit.
(*ii*) The DBS serving the ALA unit.
(*iii*) The LAS.
(*iv*) The ALA.
(*v*) A facility to the DSS.
(*vi*) The DSS.
(*vii*) No trouble found.

In cases (*i*) to (*iii*), service is suspended on the lines served by one DBS. This would be a minimum of one line and a maximum of sixteen lines. In cases (*iv*) to (*vi*), service is suspended on only the one line. In case (*vii*), only a counter is incremented. If the count rises above a threshold before being periodically reset, however, the associated line is removed from service. Whenever a line is removed from service, craft personnel are alerted by a TTY output message, a lamp on the processor's System Status Panel, and via an audible alarm. The system is also reconfigured to provide service despite the fault, if such a configuration exists.

After the system has automatically detected, isolated, and announced a hardware fault, craft action is needed to deal with the problem. Since the network has also been automatically reconfigured to provide service despite the fault, immediate craft action is not vital, but rapid personnel response is desirable to repair the fault promptly.

If a DBS, LAS, ALA, or DSS was reported as faulty, the craftsperson can utilize diagnostics provided by the software to further isolate the fault. Under control of a TTY command, the specified device is exercised by the diagnostic in a sequence of tests designed to provide maximum resolution of any fault existing in the device. If one of these tests fails, a trouble number is printed on the TTY. When this number is looked up in the trouble locating manual (TLM), a detailed description is provided of what function of the device the failing test was exercising, how it failed, and what circuit pack of the device is probably at fault. Furthermore, a detailed repair procedure for each device is provided. These tools guide craft in performing the appropriate repair. When the device is successfully repaired, the diagnostic will end with an all-tests passed (ATP) printout whenever it is run. After an ATP printout is obtained on the device which was faulty, the device can be restored to normal service, causing the network to be reconfigured to include the restored device.

If the facility to the DSS is reported as faulty, standard repair procedures may be used because the facility is accessible at either end via the 829 DAS. The DSS diagnostic is used to verify that the repairs were successfully made to the facilities. Once the repairs are successfully completed, the affected line can be restored to service.

The DSS hardware provides surveillance of the loops to individual polled terminals. As part of the test message which can be sent by the DSS to the message switch, a bit for each loop served by the DSS is included. This bit is cleared by the DSS for every loop which is open. Polled periodic maintenance uses this information, along with a mask used as a record of which terminals are installed, to announce that a loop is open.

3.2.4 Dialed network and CSC maintenance

The concepts of fault detection and isolation, network reconfiguration, fault diagnosis and repair, and restoring devices to service, which were explained in detail above for the polled network, apply in principle to both the dial network and the CSC network. These networks are not dualized. The CSC network maintains a spare Synchronous Line Adapter/Data Set combination for each type (speed) of service. This can be switched in for maintenance purposes via a relay controlled by the Switch Control and Monitor (SCAM). The dial network relies upon replication to deal with hardware faults. The SCAM can be used to operate a relay to make any dialed port appear busy to the hunting group. Subsequent calls to the network will not use a busied-out port until it is restored. The SCAM also controls loop-back relays used to test the data sets in each of these networks.

IV. ADMINISTRATION

The preceding sections have defined the maintenance capabilities and procedures that have been developed for the Transaction Network. This section discusses the administrative procedures designed to enable an operating telephone company (OTC) to manage the daily activities necessary to successfully operate the service. These procedures cover the activities required to respond to customer requirements for new and/or additional service, maintain the record systems that define the service provided, and generate administrative reports that aid in managing the service.

The provision of service to a Transaction III terminal on an existing Transaction Network polled access circuit will be used as the vehicle to describe these administrative procedures.

4.1 Service order process

The process by which a request for service is translated into the provision of that service is known as the service order process. The process begins with the customer negotiation phase where the OTC marketing representative works with the customer to define the service required, including the appropriate service options. A document called a service order is generated and is the source document used by all the OTC departments involved. The departments add information to the service order as each phase of activity is concluded until the service has been provided and the service order is filed in an in-service file.

The initial service order generated by the marketing representative is sent to: comptrollers to begin the billing record generation, engineering for circuit layout and engineering if required, network administration for port and number assignment, plant assignment for local cable pair and frame assignment, and the Transaction Network Customer Service Bureau (TNCSB) for coordination of these efforts and review. The results of the above activities lead to a work order which directs the activities of the local Central Office, message switch, Customer Installation and Repair, and Repair Service Bureau craft forces to install and perform the pre-service tests. Upon completion, the billing record, circuit layout, and line records are put in final form and the service order is placed in the in-service file at the TNCSB.

Example: In this example, the customer wants to install a Transaction III terminal and obtain restricted polled access service to a specified set of Customer Service Centers (Restricted Service List 001 on the message switch) which this customer is entitled to use. The Transaction III terminal is optioned for the terminal ID feature and the ALL-DIGITS option is not appropriate in this case. (See Section 4.5 for definitions of these features.) The CSCs have optioned to pay for all messages from and to the restricted polled terminals.

4.2 Network administration

The network administrator is responsible for assembling all recent change data (see Section 4.6). Most recent change data consist of assignments prepared by the network administrator, equipment arrangements prepared by the equipment engineer, general office arrangements prepared by the network design engineer, and customer data collected by the marketing representative. Forms have been developed (see Section 4.5) which, when completed, contain all the information necessary for the preparation of recent change messages which create control blocks in the message switch to define the services installed. These forms are the manual versions of the Office Records System under development for the Transaction Network Service.

4.3 Number plan assignments

The network administrator assigns a unique seven-digit number to each polled terminal, CSC group and line, and dial-in port on the message switch. This number appears on all administrative records and reports, identifies all stations under control of the message switch, and is the basis for call routing in the network. To accommodate the Transaction Network Service multiple exchange billing plan, the network administrator additionally assigns a three-digit Transaction Network Exchange (TNE) code to each station which uniquely defines each exchange in the serving area. The TNE of the calling and called party is included in the billing record written by the message switch but is not used for routing purposes, i.e., for billing, a 10-digit plan is used, but for routing only 7 digits are necessary.

4.3.1 Message switch

Each Transaction Network message switch is assigned a unique three-digit number from the range 300 to 899. This three-digit number is the prefix of the seven-digit number plan, i.e., every station served by message switch 300 has a number of the form

300 XXXX,

where X is any digit from 0 through 9.

4.3.2 CSC assignments XXXX = 0010 → 0998

CSC groups are assigned numbers in ascending order in the range 0010 to 0499. Numbers in the range 0000 to 0009 are reserved for implied and abbreviated addressing. CSC lines are assigned numbers in descending order in the range 0998 to 0500 to identify the individual lines within the group for maintenance and service message purposes.

4.3.3 Service message assignment XXXX = 0999

The number 0999 is reserved for the routing of service messages from polled terminals and CSCs to and from the message switch.

4.3.4 Polled terminal assignment XXXX = 1000 → 7999

Polled terminals are assigned numbers in ascending order in the range 1000 to 7999. The number assigned to a specific terminal remains with that terminal while on the message switch, independent of any physical movement of the terminal or reconfiguration of the serving polled access circuit.

4.3.5 Dial-in port assignments XXXX = 8000 → 8999

Numbers within the range of 8000 to 8999 are uniquely preassigned to dial-in ports based on the hardware used. These ports may be assigned to any telephone number.

4.3.6 Reserved XXXX = 9000 → 9999

Numbers within this range are reserved for future application.

4.3.7 TNE codes

TNE codes are assigned from the range of numbers 200 to 299 on the message switch. The numbers in the range 000 to 199 are reserved for future use.

4.4 Polled access network administration

4.4.1 Assignment

The network administrator assigns each polled terminal to a port on a Data Station Selector (see Refs. 3 and 6) and to a polling list on the polled access circuit. To enhance the availability of service to a multiple terminal/single location customer, the administrator will spread the assignments over different port cards on the DSS and assign the terminals equally to both polling lists for the DSS.

The network administrator using traffic estimates for the polled terminal provided by the marketing representative assigns the terminal to a polling list after determining that the access delay obtained will still meet the 1.25-second objective. An attempt is made to maintain a load balance between the two halves of the polled access circuit. The relationship between traffic and access delay is discussed in Sections 4.4.2 and 4.4.3.

4.4.2 Traffic considerations

The amount of traffic that can be carried on half a polled access circuit is a function of the number of terminals served and the number of messages transmitted by the terminals. To be consistent with existing traffic practices, the traffic is expressed in CCS (hundred call seconds), and the "holding time" for a message is converted from an estimate of the text characters in the message by adding 30 characters for message heading and protocol overhead and multiplying by the character time of 8.33 milliseconds.

The number of CCS of traffic is calculated in the normal fashion using the average busy season (ABS) busy hour transaction rate and the sum of the inquiry and response holding times.

4.4.3 Traffic curves

Figure 3 shows the relationship between total CCS on a polled access circuit half and the number of terminals generating that CCS to yield a constant average access delay of 1.25 seconds. The inquiry plus response holding time of the average message is the parameter of the figure.

Example: In this example, assume that the restricted-access polled terminal is assigned the number 7271003 in TNE 200. The network administrator uses traffic measurements (see Section 4.8) for the polled access circuit which has a primary DSS in the central office that serves the terminal to determine if the terminal can be added to the circuit.

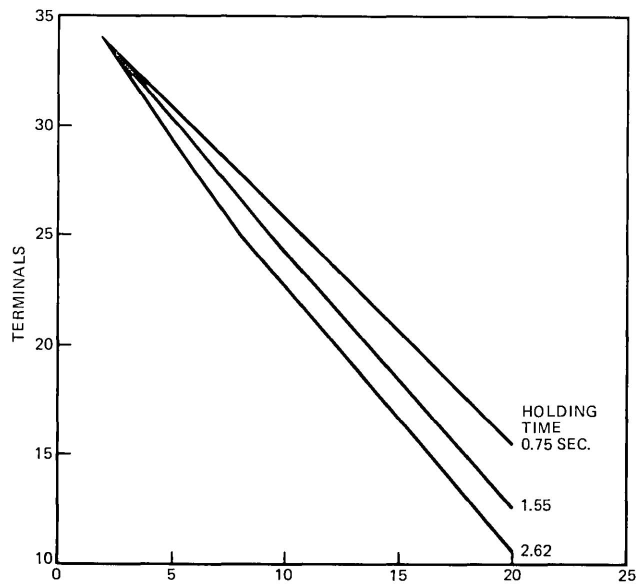

Fig. 3—PAC capacity.

Using the traffic estimate provided by the marketing representative, the administrator checks that the access delay objective is still met with the addition of the terminal and then assigns the terminal to the eleventh DSS port and the polling list corresponding to the odd-numbered line adapter unit. For this example, line adapter units 0 and 1 and circuit number 0 are used. This information will be entered on office records which are discussed in following sections.

4.5 Office records

Forms have been developed which, when completed, contain all the information necessary for the preparation of recent change messages. These forms are in the format of records used in the Office Records System currently under development.

Example—Data Station Selector Record: Figure 4 shows a Data Station Selector Record which contains the information required to prepare recent change messages for the polled terminals served by a specific DSS. An additional form is used to define terminals served by any secondary DSSs connected to the specified primary DSS.

The TNE of the polled access circuit and the prefix of the Message Switch are filled in the heading entry along with the city and state of the Message Switch location. The following paragraphs define the entries on the form.

Item 00–This entry immediately below the heading designates the DSS as a primary or secondary and identifies the even-numbered asynchronous line adapter hardware (ALAH) unit and asynchronous line adapter (ALA) unit number. If the DSS is a secondary, the lowest numbered primary DSS port serving the secondary is also entered.

ALA Unit—The number of the ALA unit which serves the specific terminal on the DSS. Range 00 to 15.

ALA Circuit—The number of the ALA circuits which serve the DSS. Range 00 to 15.

Terminal Port—The primary DSS ports to which terminals are assigned. (Ports 0, 7, 63 are never assigned to terminals, but are included for completeness.) Ports assigned to secondary DSS or reserved for that assignment are not listed in this column.

Secondary Port—On a record for a primary DSS, the port which serves a secondary DSS or is reserved for that use. On a record for a secondary DSS, the primary port which polls the corresponding Secondary Terminal Port.

Secondary Buddy Port—The primary DSS port which serves the secondary DSS in addition to the primary DSS port listed under Secondary Port.

Secondary Terminal Port—The secondary DSS ports to which terminals are assigned. (Ports 0, 7, 63 are never assigned to terminals, but are included for completeness.)

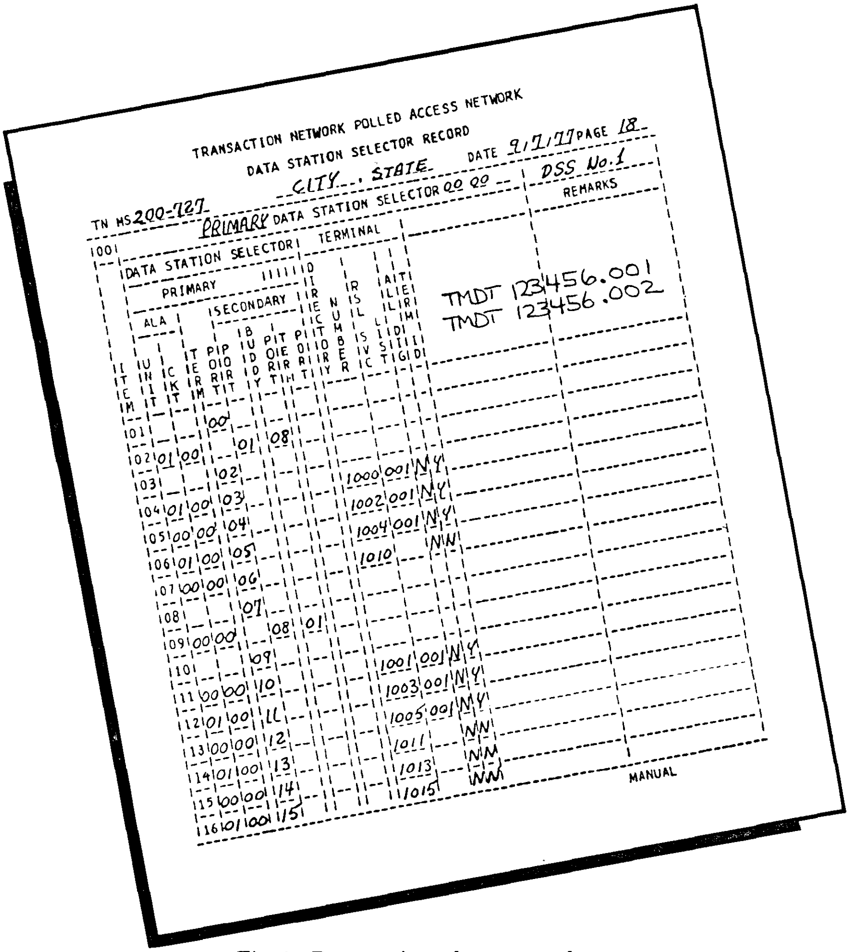

Fig. 4—Data station selector record.

Directory Number—The last four digits of the seven-digit number assigned to the polled terminal (also known as the terminal ID). Range 1000 to 7999.

Restricted Service List—The number of the restricted service list which is assigned to a restricted terminal. Range 001 to 255.

All Digits—Specifies if the full seven-digit number of the CSC must be transmitted to the polled terminal in response messages. Y = Yes, N = No.

Terminal ID—Specifies if the last two digits of the terminal ID are transmitted by the polled terminal in control sequences. Y = Yes, N = No. For Transaction III terminals, always enter Y.

Example: In the example, the entries in Item 12 as entered by the network administrator define the assignment parameters for terminal 727 1003.

4.6 Recent changes

Recent change messages entered into the message switch from a teletypewriter are the means by which the memory of the switch is updated to define new services, additions, and/or modifications to existing services on the Transaction Network. The recent change messages are first entered into the on-line memory, while the off-line memory is maintained in its previous state. When the recent change messages have been successfully entered, the off-line memory is updated. The ability to verify recent change messages is provided, and checks are built into the message switch to audit the data entered.

Example: In this example, Item 12 of Fig. 4 defines the data entries for the recent change messages necessary to add terminal 727 1003 into service.

To define the control block for terminal 1003, the following recent change message is entered:

RCP:NEWTERM:DN727, 1003
LINE 1,0
POLL 11!

where RCP signifies a recent change message for a polled terminal, NEWTERM defines an addition, and DN stands for directory number. The entries following LINE are ALAH and ALA numbers on Item 12 and the entry following POLL is the terminal port entry on Item 12. / signifies another line follows and ! ends the message.

To assign the terminal to restricted service list 001, enter:

RCP:TERM (727, 1003), LINE (1, 0), RSL 001!

To define the ALLDIGITS and TERM ID options chosen, enter:

RCP:TERM (727, 1003), LINE (1, 0), ALLDIG, NO!

RCP:TERM (727, 1003), LINE (1, 0), TIDREQ, YES!

where the No and Yes entries are read from Item 12.

Earlier, a recent change message was entered to define that the CSCs in RSL 001 have optioned to pay for all messages from restricted terminals in that group.

RCP:RSL 001, CSC!

This message is entered when the CSCs belonging to RSL 001 are initially defined.

4.7 Common Language Circuit Identification

Each circuit required in the establishment of the Transaction Network Service is identified using a CLCI for special services. This code will appear on circuit and service orders and all related records and should be included in the remarks column of the office records forms.

Example of CLCI: Each circuit from the message switch to a primary DSS or between DSSs has the following format:

CIRCUIT 1 TMDT XXXXXX.001

CIRCUIT 2 TMDT XXXXXX.002

where XXXXXX is a serial number assigned by the OTC. The circuit between a DSS and a polled terminal has the format

$$\text{TND}\ {}^{\text{T}}_{\text{C}}\ \text{TNE NXX XXXX}$$

where T is used for OTC-provided terminals, C is used for customer-provided terminals, TNE is the exchange of the polled terminals, and NXX XXXX is the seven-digit directory number of the polled terminal.

Example: In this example, the CLCI for the circuits to the DSS are assigned:

CIRCUIT 1 TMDT 123456.001

CIRCUIT 2 TMDT 123456.002

as shown on Fig. 4.

The circuit between the DSS and the terminal being assigned is:

TNDT 200 727 1003

4.8 Traffic measurements

The objectives of the traffic measurement plan are to provide data that will allow engineering of the traffic sensitive elements of the service, provide grade of service indications to allow for assignments and rearrangements, and provide information for traffic forecasting.

Although Transaction Network Service differs technically from regular telephone service, the basic call processing is similar. This has allowed the measurements and procedures to be kept in terms used in currently administering telephone switching systems.

Measurements are reported on quarterly (Q), hourly (H), and daily (D) schedules. All measurements on a particular schedule can be reported on the hour, half hour, or quarter hour by setting the Traffic Work Table from the administrative teletypewriter. The reporting interval may range over any period, continuous or disjoint, of the day.

Measurements are divided into calling type or function—polled, dial-in, CSC, buffer, and miscellaneous. Within each category, the measurements are of two types, office total or unit measurement. Office total refers to the total of the defined events occurring at the message switch. The office total measurements are structured similarly for the polled, dial, and CSC categories and are specifically applicable to the determination of real-time capacity. Unit measurements are line or group measurements within a calling type and are applicable to the engineering of polled access circuits, line hunting groups, and CSC lines, and are available on a special-study basis.

Example of Traffic Measurements—Polled Access Network Measurements: The office totals include counts of all calls originated by the polled terminals served by the message switch. The calls are further broken down into categories of ineffective attempts, and completed calls are calculated as the difference between originating calls and ineffective (service messages are not counted as completed calls). The ineffectives are totaled and also calculated as a percentage of originating calls. Retransmitted response messages, service messages, and DSS test messages are counted separately.

The unit measurements on each half of a polled access circuit are used in engineering and assignment purposes. They include peg counts of originating and terminating calls, line usage, and maintenance usage. In addition, originating and terminating calls for individual terminals on both halves of a polled access circuit are available on demand for use when reconfiguration of terminals on a polled access circuit is under study.

Example: The network administrator would request unit measurements on both halves of the polled access circuit in question and, using the traffic curve shown in Fig. 3, would determine which half to add the polled terminal to.

V. SUMMARY

This paper has described the maintenance and administrative goals and practices developed for the Transaction Network Service. The principal considerations have been to provide reliable, available, and maintainable service to customers while fitting this new service to the existing operating telephone company environment.

VI. ACKNOWLEDGMENTS

The ideas presented in this paper are the results of cooperation among numerous people of the Transaction Systems Department, the Transaction Network Communications Department, and the Auxiliary Processor Systems Department of Bell Laboratories.

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Transaction Network, Telephones, and Terminals:

Polled Access Interface

by T. H. GORDON and R. E. REID

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The Polled Access Interface of the Transaction Network is described in this article. Topics discussed are: characteristics of the service, such as number plan and message format, protocol and error recovery procedures, and architecture and system capacity.

I. INTRODUCTION

Transaction Network Service as described in an accompanying paper[1] provides the means of transmitting messages among a number of different Transaction telephones or terminals and Customer Service Centers via a message switch. This paper describes the Polled Access Interface (and the corresponding network) which interconnects polled terminals such as the Transaction III terminal[2] and the Transaction Network message switch. The emphasis is on service features and terminal interface protocol. Engineering, maintenance, and administration of the Polled Access Network are described in Ref. 3.

II. POLLED ACCESS INTERFACE

The Polled Access Network is a set of voice grade facilities and newly designed switching and control devices dedicated to Transaction Network Service. Transaction Network Service can be provided without a polled interface. The intent of the polled interface is to provide faster access time to the Transaction Network message switch and higher transmit speeds than are obtained using Transaction telephones and dialed connections.[4] The polled interface is attractive economically for customers originating several transactions in a busy hour.

2.1 Access delay and transmission characteristics

Each terminal connected to the Polled Access Network may transmit only when polled by the network. Messages are sent to the terminal only after the terminal has been selected by the network. Terminals are polled sufficiently often so that the average delay between a request for service (depression of the END key on a Transaction III terminal) and a poll received by the terminal is 1.25 seconds.

To minimize the cost of access, terminal transmission is half duplex, asynchronous over a two-wire facility to the serving central office. Frequency-shift-keying modulation at 1200 baud is used. Messages are made up of 10-bit characters, each consisting of a 7-bit ASCII code word, an even parity bit, a start bit, and a stop bit. Each message is error-checked using the character parity and a Longitudinal Redundancy Check character at the end of the message. As a result of this error detection scheme, less than one message in 10,000,000 is expected to pass through the polled network with an undetected error.

2.2 Service and status messages

In addition to messages sent to Customer Service Centers, a terminal may originate a service message that will be returned by the message switch to the terminal. This feature provides a service check for the customer and maintenance personnel. Messages that are undeliverable to Customer Service Centers will be returned to the terminal by the message switch with a two-digit status indicator defining the reason for nondelivery (Table I).

Table I — Polled access message status

Contents of Message Status Subfield *xy*	Irregularity Defined
Class I Reception Irregularities	
10	Heading format error
11	Maximum text length exceeded
12	Improper use of characters
14	Protocol error
Class II Routing Irregularities	
30	No such number
31	Number changed
32	Improper class of service
33	Invalid called number
Class III Irregularities Preventing Forwarding	
50	Called station unavailable
51	Called station queue overflow
53	Transaction network trouble

2.3 Addressing

Seven-digit Transaction Network numbers in the range NXX-1000 through NXX-7999 are assigned to polled terminals and NXX-0010 through NXX-0499 to Customer Service Centers. NXX-0999 is reserved for the message switch itself. The switch number, NXX, is initially restricted to the range 300–899. Both the called and calling numbers appear in each message. The switch number and leading zeros in the last four digits may be omitted. Service messages are identified by 999 as the called number, i.e., they are addressed to the message switch.

2.4 Restricted service

As a service option, polled terminals may be restricted to calling or being called by no more than 10 prespecified Customer Service Centers. When this option is elected, the terminal must address a Customer Service Center by sending a single digit, 1-9, or no address. The single-digit addresses are translated by the message switch to full addresses. The message switch will assume an implied address if none is sent by a restricted terminal. Messages sent by such terminals with addresses other than a single digit will be screened by the message switch and returned with error status.

III. POLLED ACCESS CIRCUIT

The Polled Access Network consists of many Polled Access Circuits (PAC). Each PAC (Fig. 1) contains a primary Data Station Selector (DSS), its associated pair of Polled Asynchronous Line Adapters (ALA), optional secondary (tandem) DSS, and the transmission facilities required to interconnect these as well as loops to reach the terminals. The design is such that all equipment which serves more than one terminal is normally duplicated and each loop is transformer-coupled to both halves of its DSS so that each terminal can be accessed from either side. This

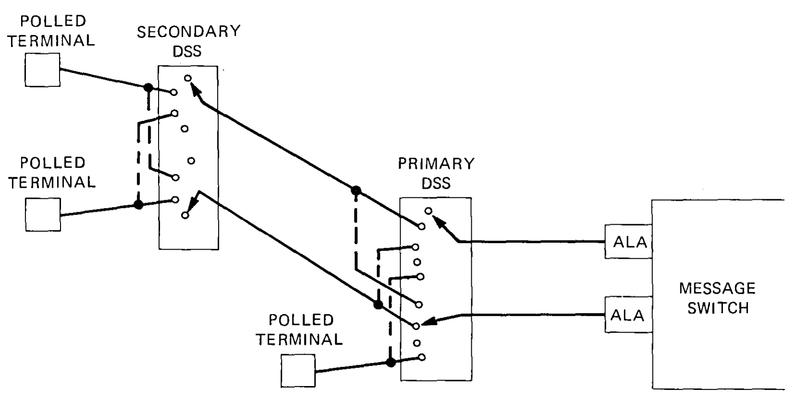

Fig. 1—Polled Access Circuit.

facilitates alternate routing which is used for transmission error recovery (see Section 4.2). The terminals served by one PAC are normally divided into two groups, each served by half of the PAC. When a hardware fault arises, the entire load is shifted to the other side of the DSS so that the problem can be diagnosed and isolated. Because this load shifting potentially places double the load on one side of the DSS, service (access delay) is degraded for the duration of the problem. It is possible that both sides of the PAC can address the same terminal at the same time. If this were to happen, then the two lines would "talk" to each other. It is up to the call processing software to ensure that this does not happen (Section 4.2), except in those cases where this capacity is used for maintenance and fault diagnosis.

3.1 Polling operation

A list of polling characters is loaded into the Asynchronous Line Adapter (ALA) by the message switch. The ALA will continuously sequence through the polling list, transmitting one character at a time to the primary Data Station Selector. The polling signal format is shown in Fig. 2. Polling characters are detected by the DSS and cause it to switch to the line specified by the polling character. The part of the signal following the poll character (called the specific poll) is transmitted to the terminal connected to the selected line. Receipt of this signal (10.5 milliseconds of 1200 Hz followed by 8.5 milliseconds of 900 Hz) alerts the terminal that it may transmit. If the terminal is ready to transmit, it must respond by raising carrier within 10 ms after the period of 1200-Hz signal ends. The length of the silent or no signal interval between poll characters is a function of the propagation delay of the circuit. The signal sent to poll the next terminal in sequence is ignored.

If a secondary DSS is connected to the primary, then a two-character poll is sent when it is desired to select a terminal on the secondary DSS. The first poll character is acted upon by the primary and selects the secondary DSS access line. The second poll character selects the desired terminal. Primary and secondary poll characters are distinguished by the value of the highest order bit in the poll address. Because the primary

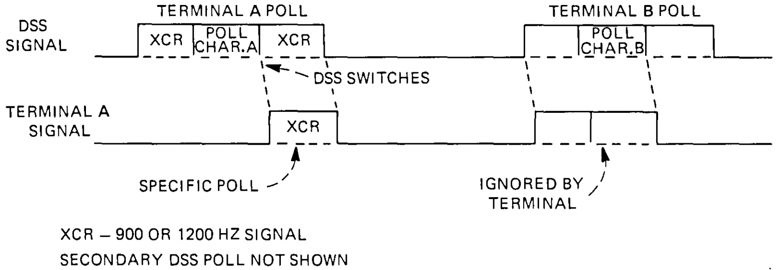

Fig. 2—Polling sequence.

DSS will ignore secondary poll characters, subsequent terminals after the first on a secondary DSS can be polled using a single secondary poll character.

To deliver a message to a terminal, the poll address of the terminal is transmitted followed by an interval of 1200 Hz and the message characters. The absence of a no-signal interval and the presence of control characters in the message alert the terminal to the arrival of a message.

The method of operation described above negates the need to send a unique poll address to the terminal because no other terminal can receive the poll signal. The polling time is held to a minimum by sending the shortest signal sufficient for reliable polling. The total time required to poll a terminal including set-up of the DSS, poll carrier, and silent interval is on the order of 68 ms.

3.2 Message format

The message formats (Fig. 3) of an inquiry message from the terminal and the response message from a Customer Service Center as seen by the terminal are similar. The leading interval of 1200-Hz marking carrier is required because of the half-duplex transmission mode. The receivers at the message switch, DSS, and terminals must be alerted by detection of carrier that a message is imminent. Each message is preceded by a Blind Alert (BAL) character that causes the DSS to ignore the characters that follow. The heading of the message is delimited by the Start of Header (SOH) and the Start of Text (STX) characters. The text field can contain up to 128 characters. With the exception of certain control characters, i.e., SOH, STX, ETX, DLE, SYN, and ETB, the text field is unrestricted by Transaction Network. The End of Text (ETX) character

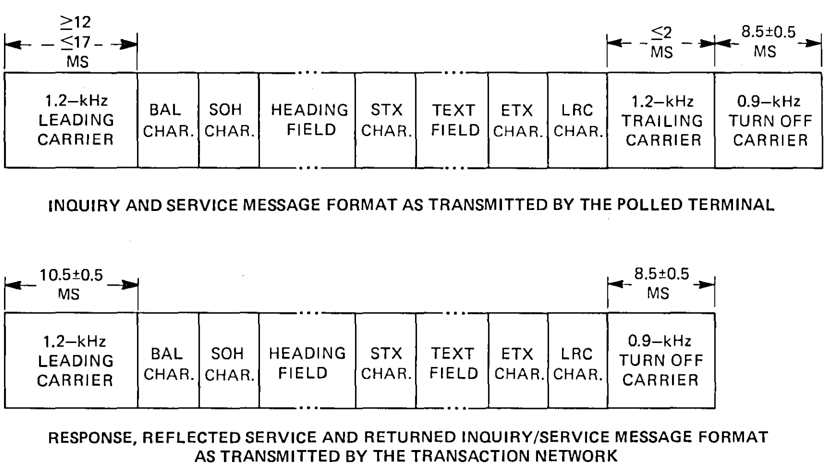

Fig. 3—Polled access data messages transferred across the interface.

UNRESTRICTED TERMINAL

STATION IDENTIFIER 2 DIGITS MAXIMUM 40→5F (HEX)	RS	CALLED NUMBER 7 DIGITS MAXIMUM 000→998	FS	CALLING NUMBER (TID) ALWAYS 4 DIGITS 1000→7999

RESTRICTED TERMINAL – ABBREVIATED ADDRESSING

STATION IDENTIFIER 2 DIGITS MAXIMUM 40→5F (HEX)	RS	CALLED NUMBER SINGLE DIGIT 1→9	FS	CALLING NUMBER (TID) ALWAYS 4 DIGITS 1000→799

RESTRICTED TERMINAL – IMPLIED ADDRESSING

STATION IDENTIFIER 2 DIGITS MAXIMUM 40→5F (HEX)	FS	CALLING NUMBER (TID) ALWAYS 4 DIGITS 1000→7999

Fig. 4—Polled access inquiry message—heading field format.

is followed by the Longitudinal Redundancy Check character. This character is the exclusive OR of all characters from SOH through ETX excluding SOH. Turn-off carrier (900-Hz) is used throughout to stabilize the data set outputs before the signal is dropped. The drop in carrier unblinds the DSS so that the next address signal may be interpreted.

Service messages and undelivered messages returned by Transaction Network have the same format.

The heading fields are defined in Fig. 4. The station identifier is assigned by Transaction Network to identify terminal type and is used only in inquiry messages. When the called or calling number refers to the terminal, only the last four digits are used. The status field identifies the reason for a returned message and is used only in those messages. The field separators, RS, FS, and GS, are those defined in the ASCII code.

3.3 Capacity

The number of terminals supported on a Polled Access Circuit is limited by the access delay service criterion. In addition to the number of terminals, access delay is a function of the polling time (including DSS addressing time), the calling rate, and the message length distribution of inquiries and responses. A detailed analysis of access delay leads to an equivalence with the problem of cyclicly served queues (see, for example, Ref. 5) which, depending upon the assumptions about the call arrival and serving process, can become intractable for more than a few terminals.

For light traffic loads, a reasonably accurate approximate analysis can be obtained by assuming that the probability of a message waiting at a given terminal is independent of arrivals from other terminals and is constant over time with the value

$$p = \lambda C,$$

where λ is the terminal calling rate and C the average polling cycle time. The length of a polling cycle is the time to poll N terminals at a rate $1/T$ per second and to transmit any messages waiting. The number k of messages waiting is binomially distributed, $b(k; N, p)$. Inquiries and responses are assumed to be identically and independently distributed. The average polling cycle time is then

$$C = N[T + p(\tau_1 + \tau_2)],$$

where τ_1 is the inquiry transmit time and τ_2 is the response transmit time.

Access delay is the time from a message arrival until a poll occurs for that message. With random arrivals, the average access delay becomes

$$D = [C^2 + Np(1 - p)(\tau_1^2 + \tau_2^2)]/2C.$$

The access delay is somewhat greater than half the average cycle time, reflecting the fact that random arrivals will more likely fall in long polling cycles than short ones.

Average access delay is tabulated as a function of the number of terminals on a polled line (two polled lines per DSS) and the hourly calling rate in Table II. In this table, the text of all inquiry messages are assumed to be 64 characters and the text of response messages 32 characters. The polling time for a Polled Access Circuit is nominally 68 ms. Typically, 32 Transaction terminals can be supported on one polled line at a calling rate of 8 busy hour calls per terminal.

IV. MESSAGE TRANSFER PROTOCOL

Four control sequences (Fig. 5) are used to indicate acknowledgment (ACK) or nonacknowledgment (NAK) of a message, to request a repeat of a control sequence (ENQ), and to terminate transmission (EOT). Control sequences in conjunction with counters and timers assure that the message switch will not end an exchange with a terminal in an ambiguous state. They also allow the message switch to maintain control.

Table II — Polled access delay

Terminals	20	22	24	26	28	30	32	34
Total Hourly Calling Rate								
100	0.72	0.79	0.86	0.93	1.00	1.07	1.14	1.21
200	0.76	0.83	0.90	0.98	1.05	1.12	1.20	1.27
300	0.80	0.87	0.95	1.03	1.10	1.18	1.26	1.33
400	0.84	0.92	1.00	1.08	1.16	1.24	1.32	1.40
500	0.89	0.97	1.05	1.14	1.22	1.30	1.39	1.47
600	0.94	1.03	1.11	1.20	1.29	1.37	1.46	1.55

Poll time = 68 ms.
Inquiry message = 64 characters.
Response message = 32 characters.

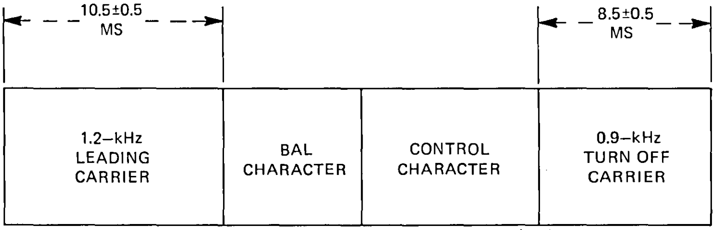

Fig. 5—Polled access control sequence transmitted by the Transaction Network.

As shown in Fig. 5, all normal transmissions of these control sequences are preceded by the BAL character to prevent the DSS from switching. Therefore, the DSS remains addressed to the same port until the protocol is completed. However, all retransmissions of ACK, NAK, and ENQ are preceded by the terminal poll address to ensure that the DSS connection has not dropped, or to overcome transient misoperation of the DSS.

4.1 Inquiry message

The normal transmission of an inquiry is depicted in Fig. 6a. When a terminal which is forward-armed receives a poll, it transmits its message. If the message switch receives the message and does not detect a transmission error or serious format error, it transmits an ACK control sequence to the terminal. The terminal then responds with an EOT control sequence. After the message switch resumes polling, the inquiry message undergoes testing for reception and routing irregularities before it is forwarded to the destination. The detection of any errors will result in a return of the inquiry with the appropriate message status inserted (Table I).

4.1.1 Garbled inquiry from the terminal (Fig. 6b)

If a transmission error or serious format error (Table III) is detected by the message switch, a NAK will be transmitted after carrier from the terminal has dropped.* The terminal will respond with the EOT control sequence. Upon receiving the EOT, the message switch will discard any history of the message as well as the inquiry itself and will resume polling.

The next time the terminal is polled, the same inquiry may be retransmitted and, if successful, a normal message transfer takes place. If not, then the same procedure is repeated for a total of four attempts. It is the responsibility of the terminal to count these retries since the message switch does not maintain any history of an inquiry. After three retries, the terminal ceases retransmission and displays the appropriate error code.[2]

* If carrier does not drop, the DSS will time out and the terminal will be taken out of the polling cycle.

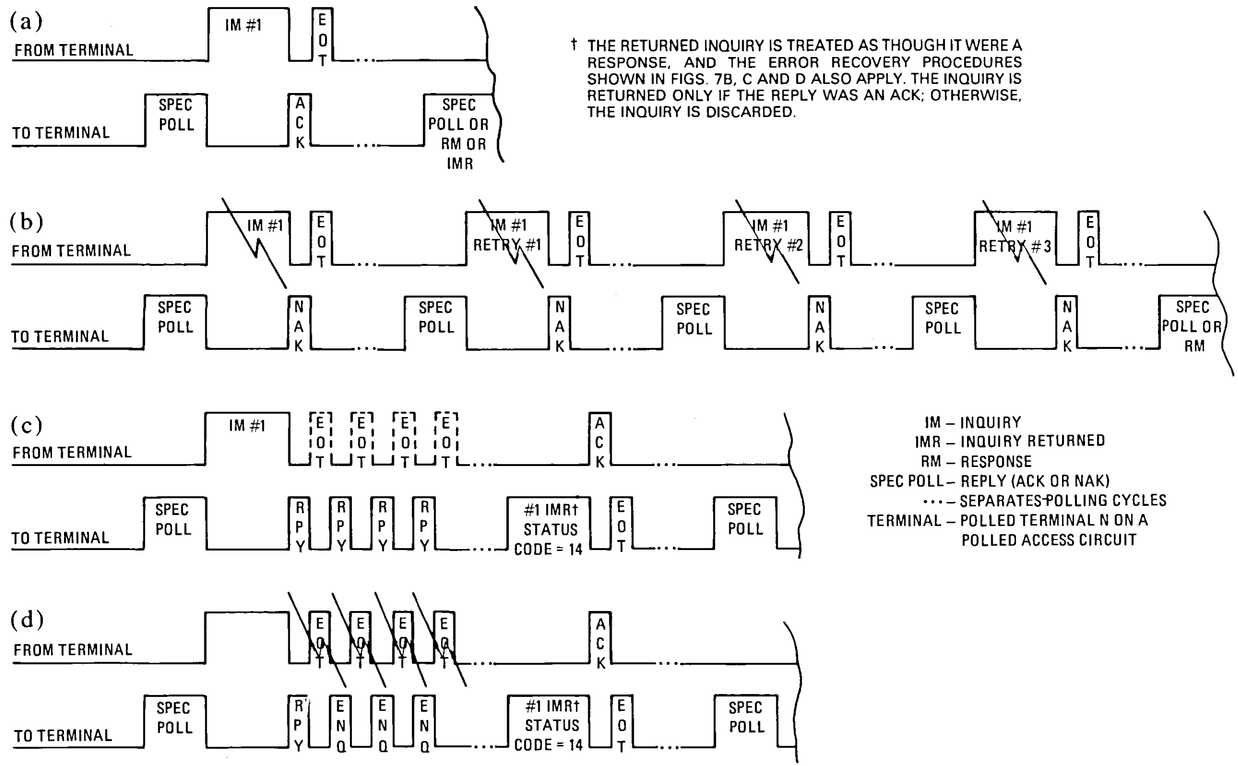

Fig. 6—(a) Normal inquiry transfer. (b) Garbled inquiry from the terminal. (c) Lost termination from the terminal. (d) Garbled termination from the terminal.

Table III — Polled access events resulting in negative acknowledgment

• Message received with character parity or LRC error.
• Received TID does not compare with the expected TID.
• The SOH, STX and ETX characters out of sequence or multiple appearances thereof.
• Appearance of an ENQ character after the SOH character but before the ETX character is received.

4.1.2 Lost EOT from the terminal

If the message switch does not receive the EOT (Fig. 6c), then the ACK or NAK is retransmitted up to three times. If, however, a garbled EOT is received (Fig. 6d), then ENQ will be sent to the terminal to try to obtain the proper termination. If the EOT is never successfully received and the original message had been acknowledged, then it is returned to the terminal with message status set to 14 (protocol error). Otherwise, the original inquiry is discarded and polling is resumed on the line.

4.2 Response messages

When a response message is ready for transfer to the terminal, the message switch will interrupt polling and transmit the message. If the message is received properly by the terminal, then an ACK sequence will be transmitted to the message switch, which responds with the EOT sequence to conclude the protocol and resume polling. This is the normal scenario and is depicted in Fig. 7a. Before discussing the error recovery strategy, it is necessary to understand the algorithm used to queue the messages.

4.2.1 Queuing of messages for output

The response error recovery utilizes the alternate routing capability of the PAC. A scheme is required which will insure that the same terminal will never be addressed from both sides of the PAC at the same time. To accomplish this, a flag is maintained for each polled terminal and a retry counter is kept with each message. Responses are then queued on the appropriate line on a first-come-first-served basis. The following algorithm is invoked whenever it is necessary to transmit a response:

(*i*) Search the output queue for the first message which obeys the following criterion: It is either destined for a terminal that is not currently undergoing retries or destined for a terminal that is undergoing retries, and the message retry counter is not zero.
(*ii*) Move the message found to the top of the queue.
(*iii*) If no such message is found or if the queue is empty, then resume normal polling.

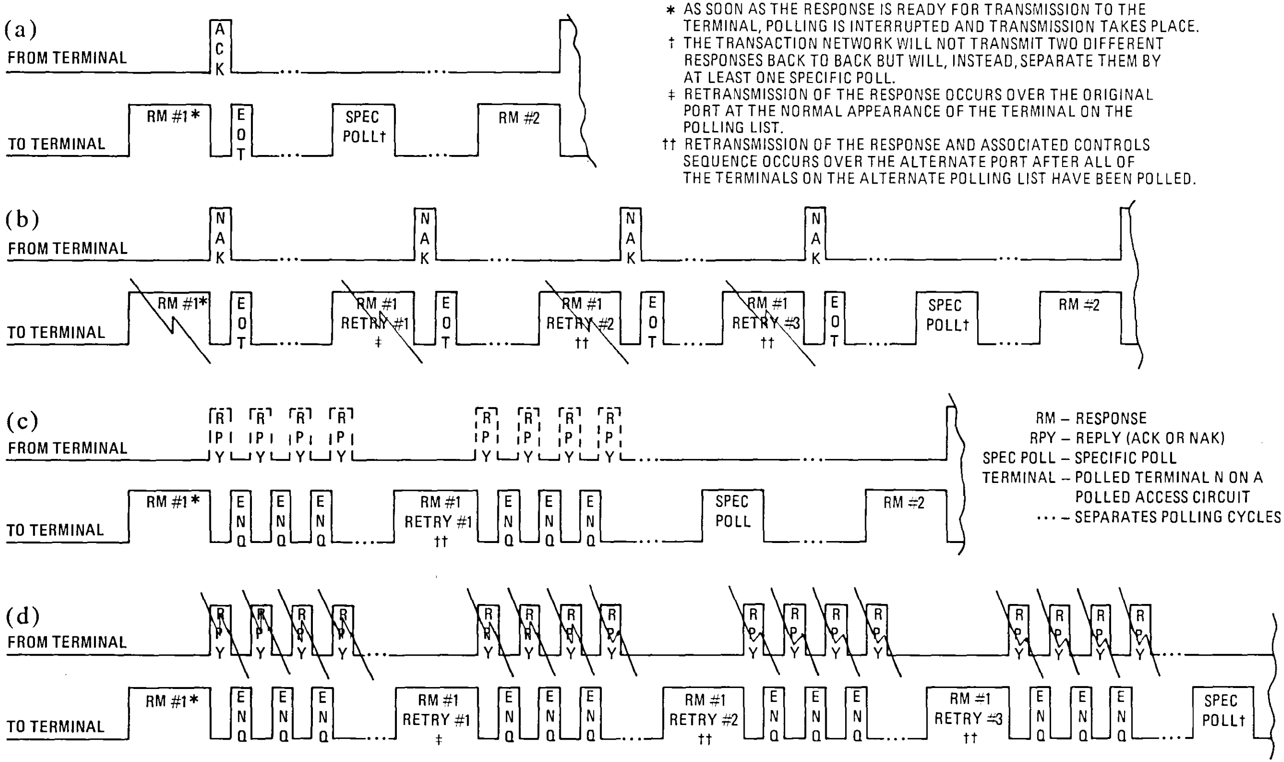

Fig. 7—(a) Normal response transfer. (b) Garbled response from the Transaction Network. (c) Lost reply from the terminal. (d) Garbled reply from the terminal.

Table IV — Action taken by a protocol recovery as a function of current state and input

Number of Message Retries =		0	0	0	0	1	1	1	1	2	2	2	2	3	3	3	3
Number of Control Sequence = Retries		0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
Receive From Terminal	NACK	A	A	A	A	B	B	B	B	A	A	A	A	D	D	D	D
	Nothing	C	C	C	B	C	C	C	D	D	D	D	D	D	D	D	D
	Garbled Response	C	C	C	A	C	C	C	B	C	C	C	A	C	C	C	D

Actions:

A. Retransmit message over this line. Increment message retry counter. Set control sequence counter to 0.
B. Retransmit message over the alternate line. Increment message retry counter. Set control sequence counter to 0.
C. Transmit ENQ and increment control sequence retry counter.
D. Return message to sender.

4.2.2 Response error recovery

After the transmission of a response, if the ACK is not received, then a memoryless recovery strategy is followed which depends only on the present state of the protocol and the input. This algorithm is illustrated in Table IV. It has the advantage that it only requires one counter for each line as well as the RETRY counter for the message. The rows from the table are illustrated in Figs. 7b, 7c, and 7d. However, it is possible to receive the three possible inputs in any order. Note that the algorithm always moves from left to right across the table and therefore the message is always disposed of.

V. SUMMARY

The goal of rapid and reliable transfer of short data messages for applications such as credit verification has been realized in the polled network by using a combination of duplicated common equipment and a robust protocol recovery strategy. Economical data transmission is provided by the Data Station Selector, which allows concentration of two-wire local loops onto regular telephone channels while providing a rapid polling scheme.

VI. ACKNOWLEDGMENT

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Transaction Network, Telephones, and Terminals:

Dial Access Interface

By K. L. COHEN and R. F. RICCA

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The basic purpose of the Transaction Network is to switch messages between remote stations and Customer Service Centers and between CSCs. The access method may be either polled or dial-in. Dial-In Service is included in TN to provide economical access to the message switch for low volume users. This paper describes the Dial-In Access Network which involves three protocols between dial telephones and the message switch.

I. INTRODUCTION

The three Dial-In protocols in Transaction Network (TN) range from a simple protocol with no transmission error recovery capabilities to a more complex protocol which includes error recovery and rigorous checks for transmission irregularities between the telephone and the TN message switch (MS). The simplest, the Voice Response protocol, uses audio-prompting messages for input error correction and only audio responses from the message switch. The Voice/Keyed Answer Tone (KAT) protocol employs no error-correcting facility, but can be used with automatic telephones that transmit control sequences, some of which help detect transmission errors. The types of responses from the Customer Service Center (CSC) that are allowed in the Voice/KAT protocol are either a Keyed Answer Tone by itself or in combination with a voice message. Last is the Data Response protocol which has a facility for transmission error correction and whose responses from the message switch use frequency-shift keying (FSK).

Once access to the MS has been established,[1] the user may enter single or multiple inquiries before a response message is received. This, in fact, may be necessary if the CSC requires a message whose length exceeds the TN maximum of 128 characters. Although multiple inquiries with a single response are permitted, multiple responses are not. The user may continue to enter sets of inquiry-response messages until the CSC requests a disconnect or until all transactions are completed.

II. DIAL-IN SERVICE

2.1 Dial-in access

Any user wishing to transmit data to the MS using a dial-in telephone must establish a line connection by dialing a number in a Line Hunting Group (LHG) which terminates on the MS. The LHG will be designed for a service objective of 1 percent blocking in a time consistent with the busy hour of the average busy season.

An LHG is designated as being for Data Response calls or for Voice Response and Voice/KAT calls. Any dial-in port, which consists of a 407A Data Set and a Dial Line Adapter (DLA), can transmit FSK. However, only those ports connected to the Audio Response Unit (ARU) associated with the message switch can transmit voice. The system is configured for a maximum of 256 dial-in ports, of which there is a maximum of 152 audio ports (76 on each of two ARUs). The separation of LHGs, therefore, yields more efficient usage of the system resources. To enhance service availability, the ports in a voice designated LHG are distributed across the two ARUs.

2.2 Transmission characteristics

2.2.1 Input

Data sent to the message switch from a dial telephone must be transmitted as *TOUCH-TONE** frequencies at a rate not exceeding 10 characters per second. The 407A Data Set, as part of a dial-in port, translates these frequencies into a double 1-out-of-4 hexadecimal encoding.[2†] This encoding is then translated by the dial call processing software[3] into the ASCII[‡] representation of the input that will be sent across the MS. See Table I for the translation of the *TOUCH-TONE* signal input to ASCII characters.

2.2.2 Output

Data display responses are transmitted to telephones from the DLA[4] as frequency shift keying at a rate of 150 bits per second. Each transmission is preceded by at least 20 ms of line-charging carrier at the mark frequency. A mark or space bit is represented by 2225 or 2025 Hz, re-

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* Registered service mark of AT&T Co.

† A double 1-out-of-4 encoding means that only 1 bit out of 4 bits can be a one. This encoding is also called 2-out-of-8 code, although this is not strictly a truism. Example: 0100 0001 is a double 1-out-of-4 code and a 2-out-of-8 code. However, 1001 0000 is a 2-out-of-8 code that is not a double 1-out-of-4 code.

‡ American Standard Code for Information Interchange. This code is the mapping of binary digits to real-world symbols.

Table I — *TOUCH-TONE*-to-ASCII translation table—text field

TOUCH-TONE Signal		2 of 8	Hexa-	ASCII
Freq. (Hz)	Char.	Code	decimal	Char.
697/1209	1	11	31	1
770/1209	4	12	34	4
852/1209	7	14	37	7
941/1209	*	18	3C	<
697/1336	2	21	32	2
770/1336	5	22	35	5
852/1336	8	24	38	8
941/1336	0	28	30	0
697/1447	3	41	33	3
770/1447	6	42	36	6
852/1447	9	44	39	9
941/1447	#	48		
697/1633	a	81	3B	;
770/1633	b	82	3D	=
852/1633	c	84	3E	>
941/1633	d	88	3F	?
	#0†	48, 28	3D	=
	#1	48, 11	3A	:
	#2†	48, 21	7f	DEL

† Used only by the Voice Response protocol.

spectively. Each asynchronous FSK character is comprised of 10 bits: a start bit, one seven-bit ASCII character with the least-significant bit transmitted first, an even parity bit, and a stop bit.

Two types of Keyed Answer Tone responses can be transmitted to a telephone from a 407A Data Set. Although both are of 2025-Hz modulation, their duration times differ. One KAT signal has a duration of 1.5 seconds. This is used to activate a device that signals "approval." The other KAT signal is for a duration of 3 seconds. This response is used in conjunction with a voice message and would be the signal for the user to listen to the telephone. Although the tone frequency is generated by the hardware, the duration time is controlled by the dial call processing software. See Section 3.4 for more information.

Unlike FSK and KAT transmission, voice responses are generated by the ARU. Each audio dial-in port must be connected to an ARU port. Every $1/6$ second, the ARU sends a "speech segment" over each of its ports. The speech segment is transmitted over a 600-ohm balanced wire pair in the DLA to a hybrid in the 407A Data Set which drives the telephone line. The ARU "knows" which speech segment to speak because the dial call processing software sends the ARU an address for each speech segment to be spoken on each port every $1/6$ second.

2.3 Status messages

In general, a status message is an indication of an irregularity that occurred in the reception, routing, or forwarding of a message. The Dial-In Service has two types of status messages. One type can be considered disconnect error messages. The other is made up of prompting messages.

A disconnect error message can be either a voice or an FSK message; that is, all three protocols employ them. They are always followed by an immediate equipment disconnect. This type of status message can be caused by a reception error, a routing error, a no forward path error, or a forwarding irregularity error. The error types are divided into priority classes. The higher the number of the class, the higher the priority is. As only one disconnect error message can be sent to a telephone, the priority system helps determine which of two errors is more important. If more than one error occurs, the first one within a class and the one with highest class priority will take precedence. For example, suppose a user inputs a second inquiry with more than the allowable number of text characters (Class I error). Furthermore, suppose the first inquiry is returned because the called number is an invalid CSC (Class II error). Then the disconnect error message would be a status message of "no such number" as this error has highest priority. See Table II for possible errors with their codes.

A voice disconnect error message will be spoken only once, with no repeats. However an FSK message, if a transmission error occurs, can be retransmitted a predetermined number of times. All disconnect error messages for the Voice/KAT protocol are voiced; KAT is not used for disconnect errors.

Table II — Message status codes

Contents of Message Status Subfield XY	Irregularity Defined†
	Class I Reception Irregularities
10	Heading format error
11	Maximum text length exceeded
12	Improper use of characters
13	Inquiry message timing error
14	Protocol error
15	Invalid calling station
17	Excessive inquiry retransmission
20	Maximum response wait exceeded
	Class II Routing Irregularities
30	No such number
31	Number changed
32	Improper class of service
33	Invalid called number
	Class III Irregularities Preventing Forwarding
50	Called station unavailable
51	Called station queue overflow
53	Transaction network trouble
	Class IV Irregularities Encountered During Attempted Forwarding
73	CSC requested disconnect
74	Excessive response retransmission

† Voiced disconnect error messages input the same information using standardized phrases from the ARU vocabulary.

Prompting messages are implemented for the Voice Response protocol only. It is assumed that the input is manual and that more errors are likely to occur than if input were automatic (i.e., through use of a magnetic card reader). Prompting messages will be given only for either heading field format errors or for use of illegal character sequences in the text field. (See Section 3.2, Message Formats, for definition of the heading and text fields.) These messages are spoken as soon as the error is detected. These status messages may be repeated once. Two attempts at repeating will cause a disconnect error message. A user is allowed at most three errors (i.e., three prompting messages, not including repeats) in any one field before a disconnect error message will be voiced.

All system messages, disconnect or prompting, that are voiced are preceded by an alerting one-second burst of tones: $1/3$ second of 950 Hz, $1/3$ second of 1400 Hz, and $1/3$ second of 1800 Hz. The same burst of tones also follows each message to indicate that the message has completed.

2.4 Type of service

Basically, the Dial-In Service is an unrestricted service. The dial call processing software will send any format error-free message across the MS. However, the synchronous call processing software of TN will screen the message to ensure that the called CSC accepts messages from dial-in telephones. If it does not, then the inquiry message will be returned to the dial message task to be processed as a status message.

2.5 Addressing

The calling number subfield, contained in the heading field of the first inquiry message transmitted to the CSC, identified the MS port accessed by the user. Dial-in ports are addressable by the CSC in the range of NXX-8000 to NXX-8255, where the NXX is the TN number assigned to the MS in the range 200 through 999. This address defines a port to which a user has established a connection. (See Ref. 5 for a description of the TN numbering plan.) The CSC and the TN, however, do not know, nor can they determine, the user's telephone number. In sending a response, a problem would exist if the port address was the only indication of who was to receive the message. Consider the sequence of user A hanging up, user B connecting to the same port, and then the message for user A being received from the CSC for delivery to the telephone. User B would then get user A's message. To ensure against this, a class of service character is inserted into the inquiry message which is returned by the CSC in the response message. Each port's CSC is incremented with each connection. It ranges in value from a hexadecimal 50 through hexadecimal 5F, successively. In the previous example, although the port address is the same, the class of service character for user A and user B would be different. Thus, the message would be returned to its sender with a message status of "Invalid Class of Service Character," and user B would not get an erroneous response.

Customer Service Centers are addressed by NXX-0010 through NXX-0499, where NXX is again the TN number assigned to the message switch (note that this is not the telephone number). For Dial-In Service, the user may enter the called number subfield in the inquiry message as 2, 3, or 7 digits. For example, CSC 888-0025 may be keyed in as 25, 025, or 8880025. Any other combination, even 0025, will be flagged as an error. This error would result in a prompting message in the Voice Response protocol or in a disconnect error message in the other two protocols.

III. DIAL-IN CONNECTION

3.1 Connection procedures

The dial-in telephone addressed the TN in the same manner as any ordinary home or business telephone addresses another telephone via the Switched Telecommunications Network (STN). Ordinary telephone loops are used to connect the dial-in telephone to the Central Office. The user will be provided with the seven-digit telephone number of the LHG assigned by the telephone company.

Dialing the number will establish a connection to an idle port on the LHG required by the user's telephone. When the 407A Data Set detects the ringing signal, it informs the message switch which in turn commands the data set to go off-hook, tripping ringing. The 407A Data Set then initiates transmission of a 1.5-second, 2025-Hz tone. This tone, called an answer tone, alerts the user that the connection has been established and inputs may begin.

The answer tone informs the user that transmission of the first inquiry message must start within 15 seconds. From this point on, intercharacter spacing may not exceed 13 seconds, and the entire message must be completed within 2 minutes. Subsequent inquiry messages must start within 15 seconds after the end of a previous inquiry or response message. Failure to meet any of the above timing constraints will result in the appropriate disconnect message followed immediately by an equipment disconnect.

The response message must be received by the MS within 20 seconds after the inquiry is forwarded to the CSC. Failure to meet this timing constraint will result in a disconnect error message and an equipment disconnect. If the CSC subsequently transmits the response, it will get the message returned with a message status indicating why the response could not be forwarded.

The called number subfield contained in the heading field of the first inquiry message specifies the desired CSC. This heading is stored by the TN and attached to subsequent inquiries that consist of text only. The user, therefore, can communicate with only a single CSC per connection.

To communicate with another CSC, the user must disconnect, dial the same telephone number again, and input a different CSC's called number.

There is no limit to the number of inquiries which may be transmitted per connection, provided no disconnectable errors are committed. The CSC, however, may request a disconnect at any time.

3.2 Message formats

3.2.1 Inquiry messages

The first inquiry message (Fig. 1) always consists of a heading and a text field. In the Data Response and Voice/KAT protocols, the heading field contains a Start of Header (SOH) delimiter—a *TOUCH-TONE b* character (Table III), a station identifier subfield specifying the type of response required and a called number subfield defining the desired CSC. The TN also uses the station identifier subfield to verify that the

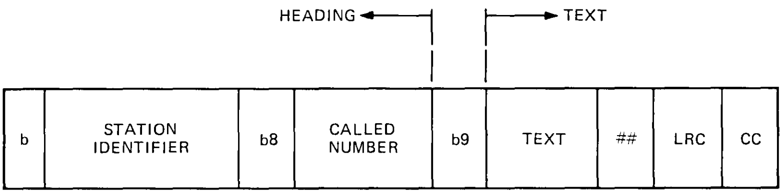

Fig. 1—First inquiry message.

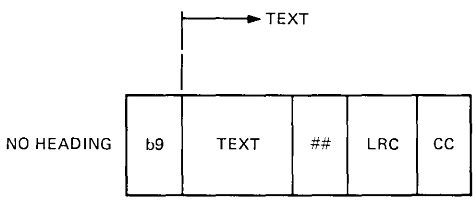

Fig. 2—Subsequent inquiry message.

Table III — Control characters used for message formatting

TOUCH-TONE Character Sequences Transmitted by the Data Response Telephone (inquiry message)	Function	ASCII Characters Transmitted by the Transaction Network (response and error messages)
b	Start of header	SOH
b8 (heading only)	Subfield delimiter	Not used
#0 (text only)†	Subfield delimiter	Not used
b9	Start of text	STX
#0†	Start of text	Not used
##	End of text	ETX
Not used	Subfield delimiter	GS

† Used only by the Voice Response protocol.

telephone has accessed the correct type of port. Both heading subfields contain only digits and are separated by the *TOUCH-TONE* *b*8 character sequence. However, in the Voice Response protocol, the heading field of an inquiry message contains only the called number; the TN will fill in the Station Identifier subfield with an ASCII 99 character sequence. The MS recognizes this type of call by the lack of the leading SOH character.

The heading and text fields are separated by the Start of Text (STX) delimiter. This is represented by a *TOUCH-TONE* #0 character sequence in the Voice Response protocol or by a *TOUCH-TONE* *b*9 character sequence in the other two protocols. The text field may contain any of the 16 possible *TOUCH-TONE* characters and cannot exceed 128 characters after translation to ASCII.

Because the *TOUCH-TONE* # character is used to alert the dial software that a control sequence is beginning, it requires special treatment. To have a # (ASCII :) character inserted in the text field, a #1 character sequence must be entered at the telephone. In the Voice Response protocol, the *TOUCH-TONE* #0 delimiter sequence serves not only as the STX character, but also as a text subfield delimiter. This delimiter is used by TN to number text subfields in prompting error messages. The Voice Response protocol also allows for the heading field or a text subfield to be deleted one at a time. The user enters a *TOUCH-TONE* #2 character sequence to do this. TN will insert the ASCII delete (DEL) character into a text subfield only upon receipt of a *TOUCH-TONE* #2 control character sequence. All other *TOUCH-TONE* text character sequences in which # is the first character are illegal except for #* (disconnect alert) which can appear at any time and ##. The character sequence ## serves as the End Of Text (ETX) delimiter and, in the cases of the Data Response and Voice/KAT protocols, is followed by two characters that are used to detect transmission errors. These characters are the Longitudinal Redundancy Check (LRC) character and the Character Count (CC) character. The LRC is a bit wise exclusive OR of all input characters from the SOH to the ETX, inclusive; the CC character is the number of characters, modulo 10, that comprised the message (SOH to LRC, inclusive).

Subsequent inquiry messages (Fig. 2) consist of a text field, bracketed by the STX and the ETX delimiters, and, if appropriate, the LRC and CC.

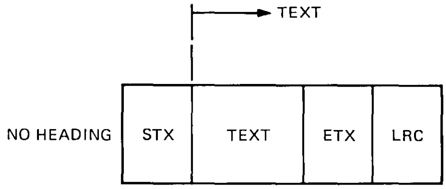

Fig. 3—Response message.

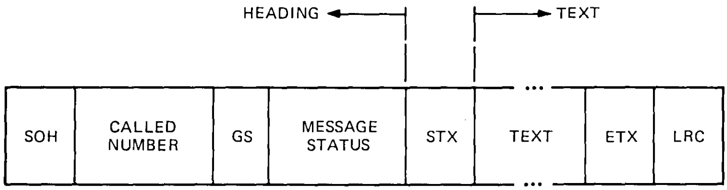

Fig. 4—Returned inquiry message/disconnect error message.

However, when the Voice Response protocol is used, the STX delimiter is omitted. Before a subsequent inquiry message is sent across the switch, the heading field, obtained from the first inquiry, is attached to preface the message.

3.2.2 Response message

The station identifier subfield contained in the heading field of a response message from the CSC specifies the type of response to be transmitted to the telephone. When a voice response is requested, the contents of the text field consists of triplets of ASCII characters specifying the phrases which comprise the message. When an FSK message is requested (Fig. 3), only the text field delimited by STX and ETX and followed by the LRC character is transmitted to the telephone.

The text field may contain any character from the ASCII character set except SOH, STX, EOT, ENQ, ACK, NAK, and DLE. A maximum of 128 characters is permitted, exclusive of STX and ETX. In the Data Response protocol, an inquiry which is returned (Fig. 4) to the telephone is considered a disconnect error message. It will include a two-digit message status subfield as part of the heading, defining the irregularity (Table II) which prevented forwarding the inquiry to the CSC. Whenever possible, the first two characters of the text will be included, bracketed by STX and ETX, and followed by the LRC character. Inquiry message irregularities detected by the other two protocols result in the appropriate voiced disconnect error message.

Table IV — Control sequences used to implement the data response protocol

TOUCH-TONE Character Sequence Transmitted by the Data Response Telephone	Function	ASCII Characters Transmitted by the Transaction Network
#3	Negative acknowledgment	NAK
#4	Positive acknowledgment	ACK
#5	End of transmission	EOT
#6	Request	Not used
#*	Disconnect	DLE EOT
Not used	P-ACK	DLE ACK
Not used	P-NAK	DLE NAK
Not used	Enquiry	ENQ

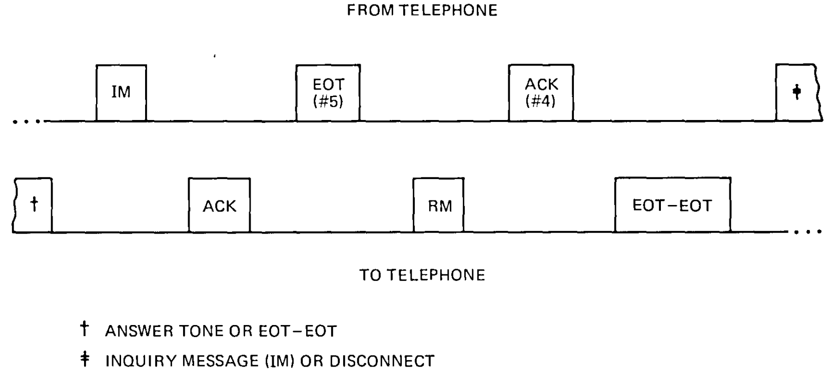

Fig. 5—Single inquiry—single response transaction.

3.3 Control sequences in data response protocol transmission

Transfer of messages across an FSK port is in accordance with a protocol which is implemented by the control sequences shown in Table IV. A normal single inquiry—single response message transfer is shown in Fig. 5. Upon receiving a positive acknowledgment (ASCII-ACK character) that the inquiry message was received without transmission errors, the telephone turns the line around by transmitting the *TOUCH-TONE* #5 character sequence indicating the end of transmission.

When a response is received from the CSC, it is forwarded to the telephone. When the telephone sends a *TOUCH-TONE* #4 character sequence to indicate that the message was received without transmission errors, the TN turns the line around with an ASCII EOT character and the telephone is then free to disconnect or launch another inquiry.

If either an inquiry or a response message contains a transmission error, the TN or the telephone, respectively, will transmit a negative acknowledgment. This control sequence is represented by either the ASCII character NAK if transmitted by the TN, or by the *TOUCH-TONE* #3 character sequence if transmitted by the telephone. The protocol requires an immediate retransmission of the message upon receipt of the negative acknowledgment. This error correction procedure will be

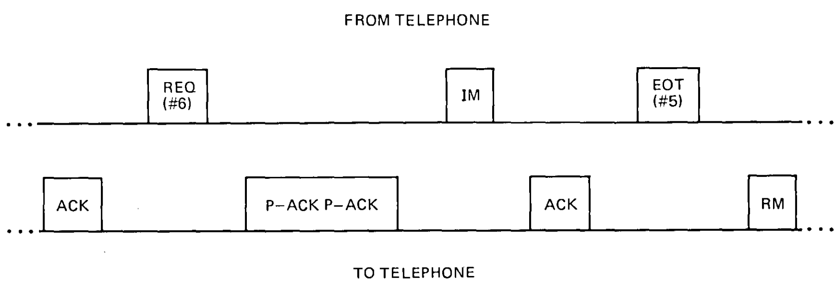

Fig. 6—Multiple inquiry—single response transaction.

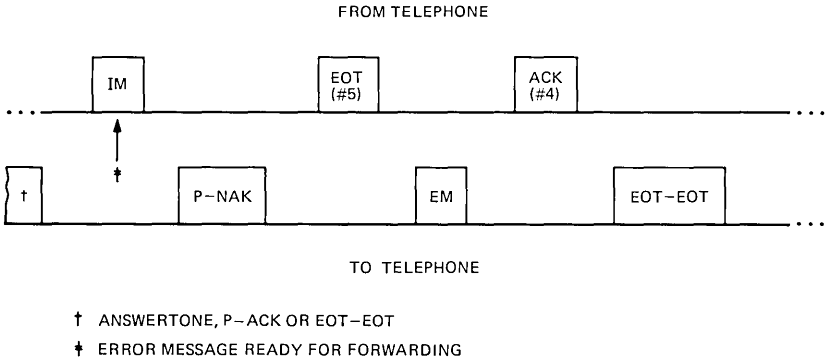

Fig. 7—Error message ready for forwarding to the telephone.

repeated for a total of three times, and if a positive acknowledgment is not received, a disconnect occurs.

To transmit multiple inquiry messages, the telephone transmits a request (REQ) instead of a line turnaround as shown in Fig. 6. The TN will acknowledge the request by transmitting a P-ACK P-ACK character sequence (request granted). The TN will transmit a P-NAK character sequence (request withheld), however, if a disconnect error message or a response message is ready for delivery to the telephone (Fig. 7). The telephone must then turn the line around.

Figure 8 outlines the error recovery procedure for lost or garbled terminations. If the telephone fails to turn the line around, the TN will retransmit the ASCII ACK character up to three times, at which point, if still unsuccessful, a disconnect takes place without any attempt to return the inquiry (error message). Figure 9 indicates that, if the telephone fails to acknowledge a response message, the TN will transmit an ASCII ENQ character up to three times. If an acknowledgment has still not been received at this point, a disconnect takes place and the response message is returned to the CSC marked undeliverable.

3.4 Control sequences in Voice/KAT protocol transmission

The Voice/KAT protocol includes a means for conveying short responses to the user, such as "Transaction Approved," without resorting to the ARU. This is accomplished by keyed answer tones which are generated by turning the 407A Data Set tone generator on and then off after a specified interval of time has elapsed.

3.4.1 "Green" tone

A "green" tone consists of a 1.5-second, 2025-Hz burst transmitted by the TN to the telephone. The CSC requests the TN to transmit this tone by inserting an ASCII 02 character sequence in the station identifier subfield of a response message heading; the text field will be null. This

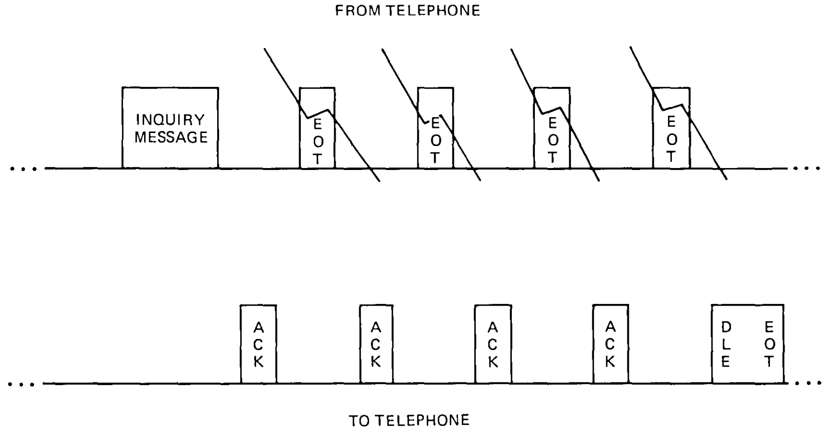

Fig. 8—Lost or garbled termination from telephone.

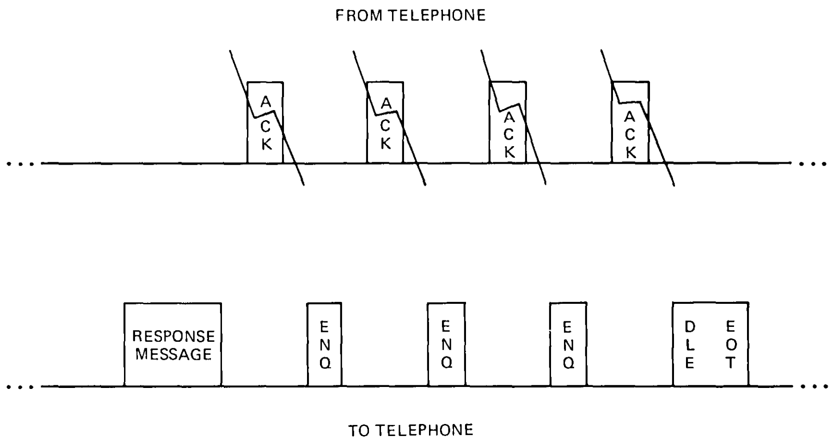

Fig. 9—Lost or garbled replies from telephone.

tone may be used to operate any one of a number of possible devices—for example, the green response lamp on the Transaction I telephone. The TN message switch expects the telephone to echo the "green" tone by transmitting a single *TOUCH-TONE a* character. If the TN does not receive this echo within two seconds after the end of the tone, a disconnect error message is transmitted to the telephone followed by an equipment disconnect.

3.4.2 "Yellow" Tone

A "yellow" tone consists of a three-second, 2025-Hz burst transmitted by the TN to the telephone as specified by the appearance of an ASCII 03 character sequence in the station identifier subfield. This tone alerts the user to pick up the handset and listen to the voice message which will follow. The text field of the response message, like other voice messages, will contain the triplets of ASCII characters specifying the phrases which will be voiced by the ARU. The TN expects the telephone to echo the "yellow" tone by transmitting a single *TOUCH-TONE b* character within two seconds after the end of the tone. The telephone then must also transmit an "off hook" indication consisting of a *TOUCH-TONE* # # character sequence within 10 seconds after the echo. This control sequence indicates that the user has picked up the handset. Failure to meet either of these two time constraints will result in the transmission of a disconnect error message followed by an equipment disconnect. Again, this tone may be used to operate any one of a number of devices for getting the user's attention—for example, the yellow lamp on the Transaction I telephone.

IV. SUMMARY

This paper has described the dial-in interface which provides access to the Transaction Network over the existing Switched Telecommunications Network. One of the three Dial-In protocols permits communications via *TOUCH-TONE* telephones; the other protocols interface with more sophisticated telephones.

ACKNOWLEDGMENTS

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Transaction Network, Telephones, and Terminals:

Customer Service Center Interface

By H. A. BODNER, D. R. JOHNSON, and W. E. OMOHUNDRO

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The Customer Service Center (CSC) interface to the Transaction Network System (TNS) is designed primarily for flexibility and efficiency so as to be able to interconnect with the majority of present customer computer installations. In addition, since these host computers have a large potential capability under program control, TNS features are made available, but are not generally mandated, to provide CSC control over and thereby optimize usage of this interface. This paper describes the design philosophy and the features of this interface.

I. DESIGN CRITERIA

The Transaction Network Service (TNS) is a new Bell System data offering to handle short data messages between Customer Service Centers (CSCs), e.g., host computers, and remote stations such as telephones, terminals, and other CSCs. An accompanying paper[1] describes the overall system design as depicted in Fig. 1; in this paper, the CSC interface is covered in detail. The CSC interface consists of a synchronous data link using the binary synchronous protocol.

1.1 Anticipated customer configuration

Figure 2 shows a block diagram of a typical software and hardware configuration at the CSC. The actual configuration is dependent on the supplier of hardware or software. The basic features however, are always present and may be relocated (e.g., if a front-end processor is installed, then some access method functions take place in the front end) to other segments of hardware and/or software.

The host computer software is generally operating under an operating system with several application programs resident for processing the

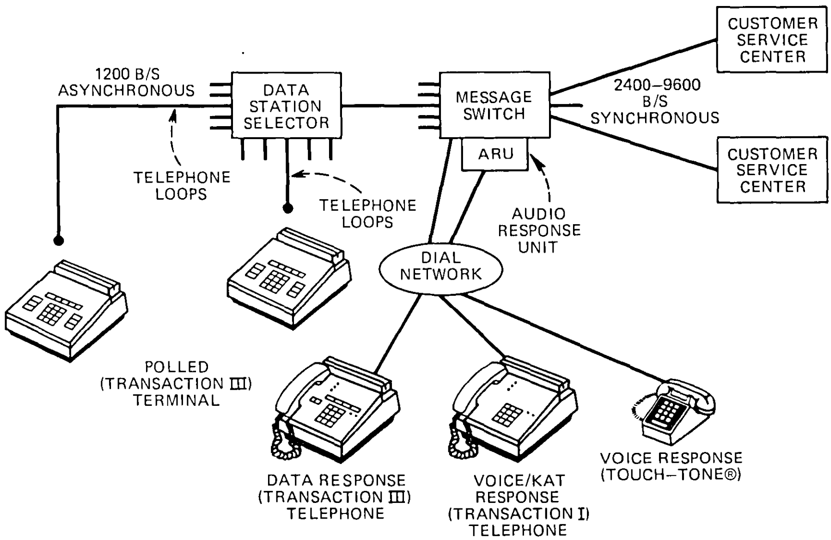


Fig. 1—Transaction Network.

messages. These programs are written by the CSC's staff. To interface between these application programs and the data links (which are connected to the remote TNS), a telecommunication monitor is often used.

Telecommunication monitors provide three basic functions:

(*i*) A data base interface.

(*ii*) Multi-threading (the capability of processing multiple messages in parallel) of application programs.

(*iii*) A data link interface (drives the telecommunications access method) and the device-dependent characteristics of the far-end station.

The first function depends solely on the processing programs, whereas the last two functions directly affect the CSC interconnection with TNS.

1.2 Design statement

The hardware for the data links has been specified according to standard industry practices to consist of four-wire, point-to-point, synchronous facilities operating at 2.4, 4.8, or 9.6 kb/s.

The system design challenge then is not the physical connection of stations but instead is the passing of intelligence between two entities, namely, the TNS message switch and the CSC's application program. To accomplish this, protocols are specified which properly pass the intelligence over the data link and through the software and hardware to the application programs.

These protocols are essentially *a priori* agreements between stations

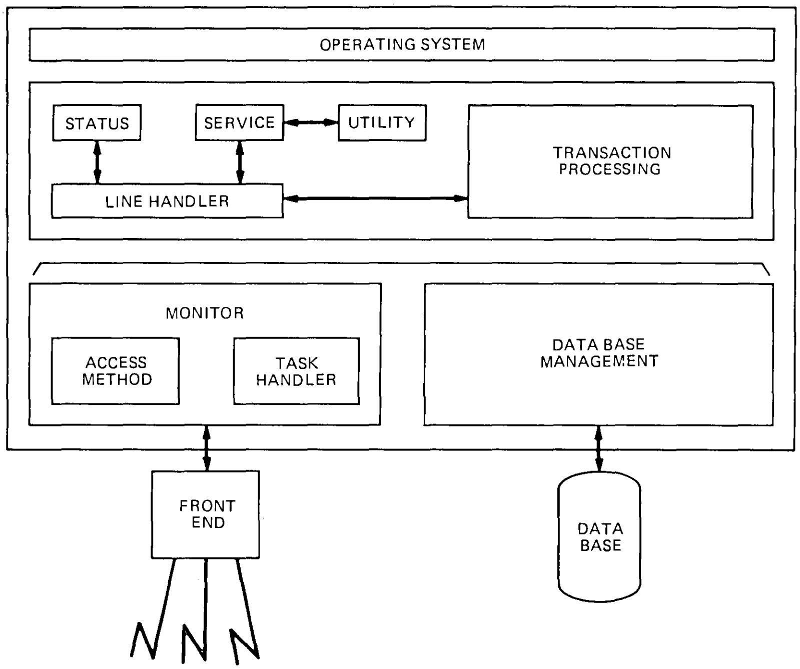


Fig. 2—Sample software configuration.

which provide for communication procedures under normal conditions and correction of any errors or anomalies that may arise.

1.3 Design criteria

In providing the TNS protocol specification for CSCs, the basic assumption is that the major hardware and software elements are available and that all the CSC should be required to do is provide interface programs (which can be written in a high-level language such as Cobol) between the CSC telecommunications monitor and the CSC's data base. Therefore, in selecting the features to be offered to CSCs, the following criteria are followed:

(*i*) A single, universal interface to be compatible with all expected types of CSC installations.

(*ii*) Minimum hardware/software impact on existing CSC installations.

(*iii*) Simplicity of installation with extension to full capabilities.

(*iv*) Efficient use of facilities and processing of messages.

(*v*) Reliable, flexible, and maintainable service.

The next sections describe briefly the features offered by TNS to achieve the above; complete descriptions are given in Refs. 2 and 3. Section II describes the overall network features; Section III, the data link protocol (DLP) and message format specification; Section IV, the options to provide flexibility; Section V, status reports and service messages; and Section VI, a description of a system implemented to test the interface.

II. NETWORK FEATURES

TNS provides a set of features so that each individual CSC can establish a network to fit its individual requirements. These features consist of a group concept which provides one single logical address for several physical links, alternate delivery which provides for automatic rerouting of messages, and screening which allows the CSC to predetermine the stations with which it desires to communicate.

2.1 Line group

Complete control of the CSC network by TNS ends at the local TNS port. To provide redundancy on the interface, one-for-N (N is the number of links utilizing identical data sets on a single message switch) sparing of message switch ports is provided. This spare port will be automatically switched in to replace any failing port by the message switch.

To further provide redundancy of both the data links and the CSC ports as well as greater traffic capacity, multiple data links may be incorporated into a line group. The line group contains multiple physical paths under a single, logical TNS directory number.

TNS will then distribute the message load that is transmitted to the CSC among all active lines in the line group and will accept messages from the CSC on any active line in the group.

In addition to the single line group directory number used for call routing, each line in the line group is assigned a unique address for service message and maintenance purposes as discussed in Section V.

2.2 Alternate delivery

The line group concept provides increased traffic capabilities as well as hardware redundancy for a single CSC entity. If the primary CSC itself becomes unavailable due to exceeding its traffic capacity or due to outage of the entire CSC, an alternate delivery feature to a secondary CSC is available. This forwarding mechanism, if optioned, is automatically triggered when either the primary line group is not active or when the message queue to the CSC overflows.

Forwarding a message consists of a single attempt to deliver to a secondary line group with the message returned to the originator if both primary and secondary line groups are not available. A line group may provide alternate delivery for up to nine other line groups.

Thus, alternate delivery provides an automatic alternate CSC for both scheduled or nonscheduled outages of an entire line group, and, as such, complements the line group concept.

2.3 Class of service

TNS provides an automatic screening function based on the originator of a message: polled terminals, dial-in telephones, or other CSCs. This allows the CSC to receive messages from any station or only from predetermined stations, e.g., the establishment of a private network within TNS.

2.3.1 Telephone and terminal classes of service

A CSC may elect to communicate with any combination of the following:

(*i*) Dial-in telephones.
(*ii*) Unrestricted polled terminals.
(*iii*) Restricted polled terminals.
(*iv*) Other CSCs (affiliated or unaffiliated).

Essentially, dial-in telephones consist of all stations originating calls over the Switched Telephone Network to the TNS dial-in interfaces.[2] If this class of service is chosen, TNS will allow the CSC to both transmit to and receive from stations such as *TOUCH-TONE*® calling stations and Transaction I and Transaction II telephones. No further screening is available for dial-in stations, since TNS does not have control over originations on the Switched Telephone Network.

For polled terminals,[2] completely dedicated TNS facilities are used to provide service and, consequently, the terminal's physical location is known: given this definite physical connectivity, it is useful that a terminal may be identified by TNS as being unrestricted and capable of communicating with any CSC specifying unrestricted class of service, or as being restricted and capable of communicating only with those CSCs (up to 10 for a shared private network) whose identity is stored in a TNS restricted service list.

For CSC-to-CSC transfers, affiliated CSCs provide the logical equivalent of a private network for members of the affiliation. TNS verifies that the calling and called CSCs are members of the affiliation identified in the message, as provided by an affiliation list stored in TNS. A CSC identified as unaffiliated can receive messages from any other CSC provided the message is identified as unaffiliated.

A Class of Service Character (CSCH) is used to accomplish these screening functions and is inserted by TNS for messages from a telephone or terminal or is provided by the CSC for messages between CSCs. Essentially, the range of the Class of Service Character identifies the station class and the value within the range identifies specific routing characteristics.

All screening for the CSC uses the service classes elected by the primary, *not* the alternate, delivery CSC, even when the message is delivered to the alternate CSC.

2.4 *Example of network features*

Figure 3 depicts a group of three lines ordered by CSC A and a group of one line ordered by CSC B. The groups have group identification numbers for message routing of 5550012 for group A and 5550018 for group B, as identified by the dotted loops. Note that, for routing purposes, the three lines in CSC A's group are indistinguishable. If any one or more of the links become inoperative, all traffic is automatically routed to the remaining active lines in the group. Of course, no such protection exists for group B since it is a group of size one.

In addition, each line within a group is assigned an identification number which for group A consists of the numbers 5550997, 5550998, and 5550986 and for group B is 5550990. These numbers are used for service messages and for line maintenance purposes.

Also shown is an alternate delivery point for automatic forwarding from CSC A to CSC B, which will be used whenever either CSC A's group is not active or its queue temporarily overflows.

III. INTERFACE SPECIFICATIONS

The basic interface specifications are based on the referenced ANSI standards:

(*i*) Data transfer its half-duplex under Binary Synchronous Communication (BCS) procedures.[4]

(*ii*) Data link hardware is full duplex, including data set operation and 4-wire facilities.

(*iii*) Seven-bit ASCII[5] is used for all data link control characters and all Bell System specified message heading entries which, with odd parity,[6] produces 8-bit (or one byte) characters.

(*iv*) The least significant bit is transmitted first.[7]

(*v*) Message heading is based on proposed ANSI standard.[8]

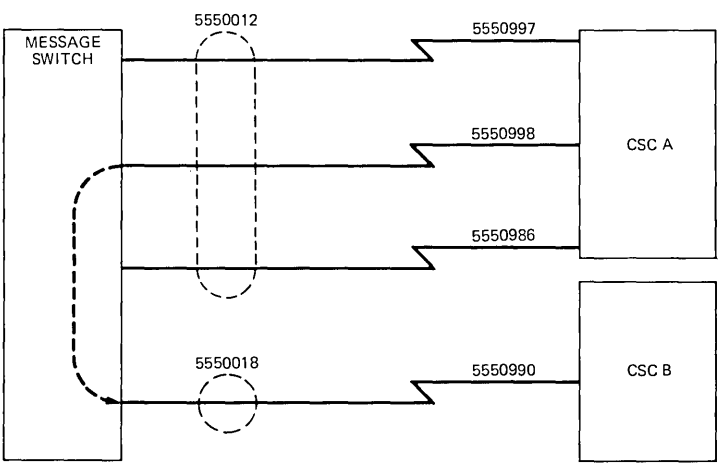


Fig. 3—Line group and alternate delivery.

3.1 Data link protocol (DLP) description

In Fig. 4, data link protocol procedures are broken into three parts: connection, data transfer with acknowledgments, and termination.

Under a contention protocol, either party may bid for the link when it has messages to send. A bid consists of issuing an enquiry (ENQ) sequence. In cases of simultaneous bids, one party is permanently designated the primary and will rebid in 1 second, while the other is the secondary and will rebid in 3 seconds. Upon successfully bidding for a line, as determined by receiving a positive acknowledgment (ACK 0), that station becomes the master station and the station which sent the positive acknowledgment becomes the slave. The master station then starts sending blocks of messages which are acknowledged by alternating acknowledgments, ACK 0 and ACK 1, from the slave station. This master/slave status designation is dynamic and is reestablished upon each successful bid for the line.

Upon completion, the master station relinquishes control of the line by sending the termination sequence (end of transmission sequence, EOT) and may not bid anew for the line for a post EOT delay of 1 or 3 seconds. Within this post-EOT delay, the former slave station may bid for the line without any contention from the former master and can thereby become the master station without contention.

After the post-EOT delay, either party may bid for the line and contention may occur.

If a block becomes garbled, the slave station sends a negative acknowledgment (NAK) and the master retransmits the block up to a predetermined maximum number of retries.

One of the features of the data link protocol consists of the optional inclusion of the transmission of the WACK and RVI sequences as replies, where both are positive acknowledgments. The WACK sequence requests the master to temporarily halt transmitting the next block until informed

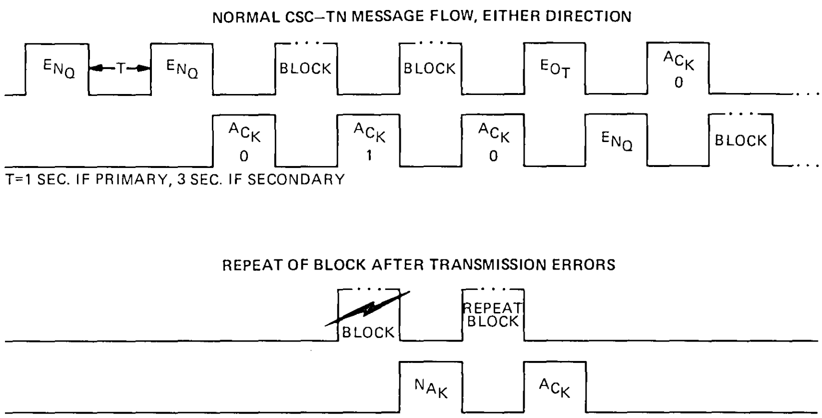


Fig. 4—Data link protocol.

to do so by receipt of the correct acknowledgment from the slave in response to an ENQ (also used to obtain retransmission of garbled replies), whereas the RVI sequence requests that the master relinquish control of the line by sending the EOT sequence so that the slave may in turn transmit.

3.2 Message, record, block, transmission definitions

A message is defined as one heading and one text as supplied by any station in the network. In general, each stream of characters that contain messages terminates with an end-of-message (EOM) character which is immediately followed by a Longitudinal Redundancy Check (LRC) character.

A record is defined as an entity ending with ITB as the EOM character or with ETB or ETX when it is the last record in the block. A message is normally one record but may span multiple records dependent on CSC-selected message-flow options.

A block is one or more records to which an acknowledgment must be sent. Each block ends in either ETB or ETX followed immediately by an LRC character. Put another way, a block is the entity to which an acknowledgment is sent and a record is a member of a block.

A transmission consists of a single connection procedure, is followed by the transmission of one or more blocks, and is then concluded by a single termination procedure. The last block, as sent by TNS, uses ETX as the EOM character, whereas all previous blocks end in the ETB character. Thus, receipt of ITB, ETB, or ETX can be used by the CSC to define the position of a record within the transmission as well as to delimit the record.

3.3 Data link protocol specification

This section gives a specification of the data link protocol procedures that were described in general in Section 3.1. These procedures are in accordance with ANSI standard, X3.28-1971,[4] subcategories 2.3 and B.2 with enhancements and capabilities that make them compatible with Binary Synchronous Communication (BSC) procedures as used by the majority of computer systems today.

The data link protocol consists of a point-to-point contention procedure for nontransparent data in a nonconversational mode. Two protocols are offered: Class I and Class II. Both recognize the WACK sequence and also the RVI sequence as positive acknowledgments, but neither transmits RVI. The RVI sequence is a request from the slave station for the master station to stop transmitting. This allows the slave station to interrupt the master station and transmit a high priority message. The WACK sequence is a request from the slave station for the master to delay transmitting a new block. This is normally used when the slave station has no more buffer space for new blocks. The WACK sequence is only transmitted by TNS in Class II.

The Class I protocol is a basic BSC procedure widely supported within the computer industry. The Class II protocol has been enhanced to support a fuller feature data link protocol procedure. The resultant choice between protocols increases the compatibility with existing teleprocessing monitors. Both protocols yield performance which is dependent on the choice of options, as described later in this paper.

3.4 Message format specification

A message is defined independently of records or blocks and is defined to consist of one of each of the following parts, as shown at the top of Fig. 5. The first part is a prefix of up to eight characters which may be included in every message from or to TNS and immediately follows the SOH character. Following the prefix, a Bell System specified heading must be provided by the originating station, as discussed below.

Immediately following the heading and preceded by STX is a text field provided entirely by the originating station and transparent to the transaction network within the following constraints:

(*i*) No data link control characters may be included.

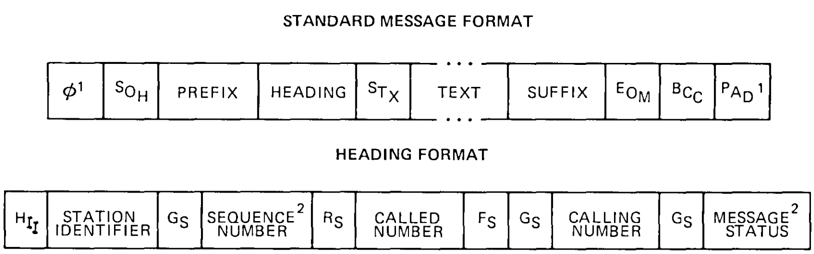
(*ii*) The text length is 128 characters or less.

Preceding the EOM character, a suffix field consisting of one character may be combined with the EOM character in every message from and to TNS. Immediately following the EOM character, an LRC character must be included for error detection.

All blocks are preceded by a synchronization pattern (shown as ∅ in Fig. 5) that consists of a leading pad character of alternating ones and zeros followed by at least two SYN characters. Also, all blocks end with a trailing pad character consisting of eight binary ones.

While the text is composed solely by the originating station, the heading is specified by TNS.

The heading format follows the proposed ANSI standard for heading formats. The two-character Heading Item Indicator[8] (HII) identifies



NOTES: 1. APPEARS ONLY AT BEGINNING AND END OF EACH BLOCK.
2. OPTIONAL FROM CSC TO TN.

Fig. 5—Message format specification.

which of the allowable fields are present. The one-byte sequence number subfield of the heading consists of an entry which is incremented by one on each successive message transmitted per data link by TNS. For a message transmitted from the CSC to TNS, this field may be omitted with the appropriate alteration of HII or may be stuffed with a space character if the field is not to be used. If a sequence number is included in messages sent to TNS, TNS will check to make sure that, on a given line, no two successive messages begin with the same sequence number. If they do, the second one will be returned with a message status report.

The message status subfield consists of two characters and contains information *only* from TNS to the CSC, as will be seen in Section V. Thus the subfield must either be omitted on messages from the CSC, or stuffed with ASCII spaces or the normal status, all ASCII zeros.

The calling and called number subfields are seven characters in length and contain the routing information.

The station identifier subfield is used by TNS for screening as discussed in Section 2.3 and may also be used by the CSCs to identify the type of station or calling party.

IV. SPECIFICATION OPTIONS

Options are available within these specifications to accommodate the varying degrees of capabilities and requirements of each CSC to do the following:

(*i*) *Control* what TNS may send to the CSC.
(*ii*) *Specify* what the CSC will send to TNS.

The major options consists of:

(*i*) Data link protocol options to provide additional line efficiency and teleprocessing monitor compatibilities.
(*ii*) Message format options which allow the replacement of all Bell System-specified control characters in the heading by an optional set of characters which lie outside the ASCII control character set; and also prefixes and suffixes which are intended to aid in deblocking and transaction handling.
(*iii*) Message flow options to comply with teleprocessing monitor characteristics which in turn specify maximum characters per record, maximum characters per block, maximum records per block, and maximum number of blocks per transmission.

In addition to the above, the previously mentioned options determine the classes of service to be supported by the CSCs and also the network configurations such as line group specifications and alternate delivery points.

4.1 Data link protocol options

Several options are available to enhance the data link protocol (DLP). The first is a one- or three-second post-EOT delay for TNS which should not be confused with the primary/secondary designation. This post-EOT delay only applies immediately after relinquishing the line and before bidding anew. Choosing 1 second allows TNS to speed message transfers in the absence of messages from the CSC. The choice of 3 seconds gives the CSC a larger window in which to bid for the line *uncontested,* after the transmission of EOT by TNS.

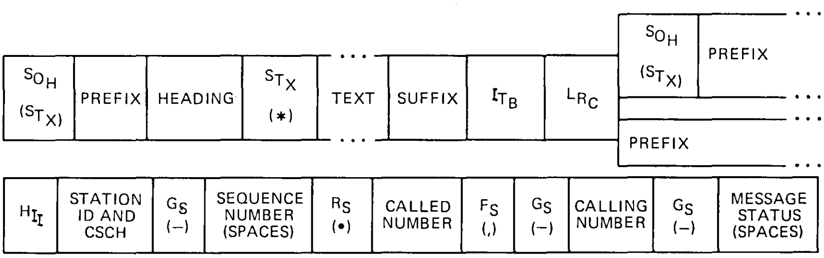
The second option is the choice of Class I or Class II protocols. The CSC chooses this option to best fit its existing software configuration.

The last data link protocol option is the primary/secondary designation in the case of simultaneous line bids. This option applies only to Class II protocols, since Class I protocols mandate that TNS be the primary.

4.2 Message format options

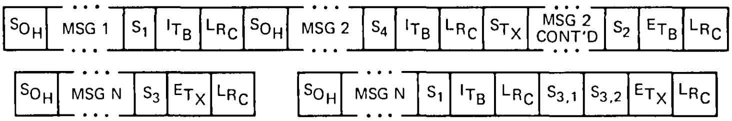
The message format options provide considerable flexibility in accommodating existing CSC procedures. Referring to Figs. 6 and 7, these include:

(*i*) Use of optional, noncontrol character heading subfield separators.
(*ii*) SOH deleted on the second and successive records in a block (a BSC option).
(*iii*) CSC use of optional sequence number and message status subfields to TNS.
(*iv*) Prefixes for transaction identification and device codes.
(*v*) Suffixes to aid in deblocking.
(*vi*) Transmission end record to provide end-of-job indication.



1. SOH, STX, FS, GS AND RS MAY BE REPLACED BY STX, "*", ",", "–", AND "•" RESPECTIVELY.
2. SOH WILL BE OPTIONALLY DELETED ON INTERMEDIATE RECORDS.
3. TO THE TN, THE OPTIONAL SEQUENCE NUMBER AND MESSAGE STATUS SUBFIELDS MAY CONTAIN "SPACE" CHARACTERS OR BE DELETED.
4. PREFIX MAY BE CSC SPECIFIED UP TO EIGHT CHARACTERS TO INCLUDE TRANSACTION IDs, DEVICE DEPENDENT CODES, ETC.

Fig. 6—Message format options.



5. CSC MAY CHOOSE A SUFFIX (S_1, S_2, S_3) TO EXTEND THE THREE EOM CHARACTERS BY SELECTING A SINGLE (DIFFERENT IF DESIRED) CHARACTER TO PRECEDE ITB, ETB, AND ETX TO AID IN DEBLOCKING MESSAGES AND IN TURNING THE LINE AROUND.

6. MULTIPLE RECORDS PER MESSAGE (MESSAGE FLOW OPTION) MANDATES A FOURTH CONTINUATION CHARACTER SUFFIX TO BE INSERTED BEFORE ITB WHICH MUST BE DIFFERENT FROM THE CHARACTERS CHOSEN ABOVE ($S_4 \neq S_1, S_2, S_3$).

7. IN ADDITION, THE SUFFIX BEFORE ETX MAY BE CSC CHOSEN TO CONSIST OF TWO CHARACTERS ($S_{3,1}$, $S_{3,2}$) TO BE TRANSMITTED AS A SEPARATE RECORD.

Fig. 7—Message format options (cont'd).

4.3 Message flow options

A set of options are offered to alter message flow which range from simplified message transfers to very efficient data link usage.

The basic requirements are: the messages must be confined within a single block, no record should contain characters for more than one message, and the records should be inherently of variable length up to a maximum.

The options are:

(*i*) Maximum number of characters per record (F_1) to and/or from TNS. If less than the maximum message length is selected, the message suffix must also be included to identify continuation records.

(*ii*) Maximum number of characters per block (F_2) from TNS.

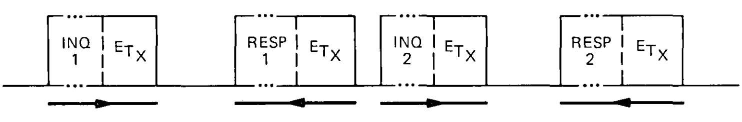
(*iii*) Maximum number of records per block (F_3) from TNS.

(*iv*) Maximum number of blocks per transmission (F_4) from TNS.

4.4 Examples of option choice

The two examples in Figs. 8 and 9 show the range of effect of the various messages flow options.

In Fig. 8, F_1 has been chosen to be the maximum and F_3 and F_4 to be

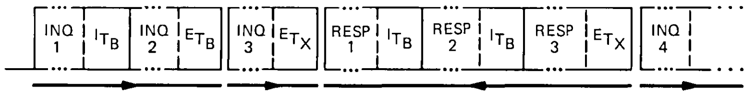


SINGLE MESSAGE PER TRANSMISSION

OPTIONS:

1. CHARACTERS PER RECORD F_1 = MAXIMUM
2. RECORDS PER BLOCK $F_3 = 1$
3. BLOCKS PER TRANSMISSION $F_4 = 1$
4. NO SUFFIX REQUIRED

Fig. 8—Message flow—example 1.



MOST EFFICIENT MESSAGE FLOW

OPTIONS:

1. CHARACTERS PER RECORD F_1 = MAXIMUM
2. CHARACTERS PER BLOCK F_2 = MAXIMUM
3. RECORDS PER BLOCK F_3 = MAXIMUM
4. BLOCKS PER TRANSMISSION F_4 = MAXIMUM
5. NO SUFFIX (OR PREFIX)

Fig. 9—Message flow—example 2.

1. Note that specifying the characters per record to be the maximum and records per block to be 1 makes F_2, the characters per block, automatically redundant and equal to M, the maximum characters per message.

The effect of these choices is that TNS will send only one message at a time. Thus if the return message is ready for transmission before the post-EOT delay of 3 seconds (or 1 second) elapsed, one then gets a relatively straightforward but inefficient inquiry/response-type flow on the line.

Since there is only one block per transmission, no suffix is required. This choice may in fact be appropriate when traffic requirements are very low or when the teleprocessing monitor can handle only one inquiry and response pair at a time.

By contrast, Fig. 9 shows the most efficient line utilization where F_1 through F_4 are set to the maximum, reducing the number of acknowledgments and line turnarounds.

Notice that the prefix and suffix have also been eliminated by the CSC, reducing the character overhead on the line.

V. MESSAGE STATUS AND SERVICE FACILITIES

The remaining major features of TNS are the message status reports and the service facilities alluded to previously. These features provide the CSC with considerable control over the data links and error conditions. The implementation of these features is designed so that a CSC need do little (e.g., not take advantage of all these extra features) or, as conditions warrant, may take full advantage of these capabilities.

5.1 Message status reports

Any message that encounters telephone company or customer equipment irregularities not covered by the data link protocols will be delivered to the called station, as is possible, or returned to the originating station. A report of the irregularity encountered is always inserted in the message status subfield of the heading as previously defined. The report is of the form X and Y, where X and Y are ASCII digits from 0 to 9.

A class structure has been set up in the same order in which errors would be detected by TNS. The first class, Class I, consists of reception errors, or errors upon receipt of the message from the station not covered by the data link protocol. The second class, Class II, consists of routing errors as detected by TNS in attempting to route the message to the called party. Class III consists of forward path errors which prohibit the delivery of the message. For Classes I, II, and III, the message will always be sent back to the originator.

Class IV also consists of forwarding irregularities, where in this case the error does not prevent the message from being sent forward. And finally, in the great majority of the cases, Class 0 applies to normal message transfers.

The message status reports which will be seen in messages delivered to the CSC are shown in Fig. 10. Since most of the message status reports are self-explanatory, this paper will briefly highlight a few of the irregularities that will be reported. For example, "heading format error," or $XY = 1{,}0$, means that a required heading entry is missing in the heading field. One point to note, however, is that, if no heading can be found, the message will be dropped as an extraneous data stream not intended for message transfers.

CLASS I – IRREGULARITIES ENCOUNTERED UPON TRANSMISSION TO THE TN.

(X, Y)	
(1, 0)	HEADING FORMAT ERROR
(1, 1)	MAXIMUM TEXT LENGTH EXCEEDED
(1, 2)	IMPROPER USE OF CHARACTERS
(1, 4)	PROTOCOL ERROR
(1, 5)	INVALID CALLING STATION

CLASS II – IRREGULARITIES ENCOUNTERED UPON TN ROUTING.

(X, Y)	
(3, 0)	NO SUCH NUMBER
(3, 1)	NUMBER CHANGED
(3, 2)	IMPROPER CLASS OF SERVICE CHARACTER
(3, 3)	INVALID CALLED NUMBER
(3, 4)	INVALID CALLING STATION TYPE

CLASS III – IRREGULARITIES WHICH PREVENT MESSAGE FORWARDING FROM TN.

(X, Y)	
(5, 0)	CALLED STATION UNAVAILABLE
(5, 1)	CALLED STATION QUEUE OVERFLOW
(5, 2)	UNANTICIPATED RESPONSE
(5, 3)	TN NETWORK TROUBLE
(5, 4)	INVALID CALLED STATION TYPE
(5, 5)	NO SUCH VOICE PHRASE
(5, 6)	SERVICE MESSAGE CANNOT BE PROCESSED
(5, 7)	INCOMPLETE TRANSMISSION

CLASS IV – IRREGULARITIES ENCOUNTERED UPON FORWARDING MESSAGE

(X, Y)	
(7, 0)	POSSIBLE DUPLICATE MESSAGE

Fig. 10—Synchronous message status reports.

Another example, "called station unavailable" with $XY = 5,0$, is necessarily a broad category encompassing *all* accidental or intentional failures of the called station to respond correctly to the delivery of messages.

Only one status in Class IV applies, namely, possible duplicate message. This will be appended whenever TNS is unsure whether the message was previously delivered.

5.2 Service facility—service messages

Service facilities consist of instructions passed between TNS and any user station. As contrasted to a data message passed between terminals, telephones, and CSCs, a service message is a message either originated by or addressed to TNS and therefore includes the TNS station identification number in the heading of the form NXX-0999.

There are two types of service messages. A request service message contains one or more requests for service actions and an acknowledgment service message contains one or more acknowledgments which are reports, affirmations, or denials of the requests.

Service messages may initiate actions only for the line group on which they are received and therefore, for appropriate coordination, all the lines within the line group must be handled by a single entity or CSC.

TNS will accept service messages over any line in the group, but the CSC may specify one line as the Service Administration Facility (SAF) over which TNS will send all service messages. This is done by specifying a priority scheme for each line in the line group which TNS will follow, as any line or lines in the line group become unavailable for use. This priority applies to both request and acknowledgment service messages, but not to reflection service messages, as will be seen.

5.2.1 Line and line group states

A major usage of service messages arises from the fact that a line or line group can be in any one of several states, as shown in Fig. 11, each of which defines its capability. Service messages are used to set or report these states. While TNS will change states only upon the discovery or correction of failures, CSCs may implement state changes, if desired, to accommodate their own operational procedures.

State 1, the active state, may only be set by the CSC and allows all message transfers. This is the normal state for a line or a line group.

State 2, the active/CSC data only (ADO) state, can be set by either TNS or the CSC allowing data messages only from the CSC and service messages in both directions. This may be considered as a standby state and, upon recovery from failures, TNS will always set state 2 and *never* state 1.

State 3, the out-of-service far-end removed (OFER) state, may be set

TYPE FIELD	SERVICE MESSAGE SEQUENCE NUMBER	TYPE CODE	STATE	LINE NUMBER	FIELD SEPATATOR	
t	s	TC	K	$X_1X_2X_3 0 X_4X_5X_6$	+	...

- TYPE FIELD ($0 \leq t \leq 9$) IDENTIFIES THE BASIC TYPE OF THE SERVICE MESSAGE.
- SERVICE MESSAGE SEQUENCE NUMBER ($0 \leq t \leq 9$) COORDINATES REQUESTS AND ACKNOWLEDGEMENTS.
- INDIVIDUAL REQUESTS AND ACKNOWLEDGEMENTS MAY CONTAIN THE FOLLOWING TEXT FIELDS;
  - THE TYPE CODE ($00 \leq TC \leq 99$) IDENTIFIES THE TYPE OF REQUEST OR ACKNOWLEDGEMENT.
  - THE STATE ($1 \leq K \leq 6$) IDENTIFIES THE STATE REQUESTED OR REPORTED.
  - THE LINE NUMBER, IN LINE RELATED SERVICE MESSAGES, IDENTIFIES THE LINE, WITHIN THE LINE GROUP, ON WHICH ACTION IS TAKEN.
  - THE FIELD SEPARATOR, "+", DELIMITS INDIVIDUAL REQUESTS OR ACKNOWLEDGEMENTS.
  - ALTERNATIVELY, TEXT OF REFLECTION SERVICE MESSAGES APPEARS AFTER TC.

Fig. 11—Service message request and acknowledgment format.

only by the CSC which then prevents all message transfers except for request service messages from the CSC and their accompanying acknowledgment service messages from TNS.

State 4, the out-of-service far-end test (OFET) state, may only be set by the CSC and requests that TNS test its synchronous port hardware. No message transfers are possible and, upon successful completion of the test, TNS will set either state 2 or, upon failure, state 5.

State 5 is the out-of-service other (00) state, which means that the TNS synchronous port hardware has failed.

State 6 is the unavailable state for a line that has not yet been put into service.

The relationship between the group state and the line states is as follows: Ordinarily, the group state will follow the highest line state within the group, where state 1 is considered to be the highest of the states. The group may *never* assume a state greater than the highest line state. For example, if there are three lines in a group and two lines are in state 1 and one line is in state 4, the group will normally be in state 1.

The CSC, however, may purposely put the group state to a lower state, thus not requiring the setting of each of the individual line states to accomplish a service objective of its own. Therefore, if a line has a state higher than the group state, the group state in effect determines the operational status of that line. For example, if there are three lines in the group and the lines have states of 1, 2, and 3 and the group has a state of 3, each line will effectively be in state 3. However, when the group state is changed back again, the lines will return to their original states.

The TNS and the CSC must both keep a state table for each line and the line group, with the TNS defined to have the master state table.

5.2.2 Service message protocol

To accomplish the transfer of service messages, a simple end-to-end service message protocol must be obeyed.

For each request put out by either station, there must be an acknowledgment. Only one request service message may be outstanding on a group at any given time from either TNS or the CSC, although, as will be seen in ertain cases, a request or acknowledgment service message may contain multiple requests or acknowledgments.

Because of this, in the case of simultaneous requests, TNS is always considered to be the master since it will only originate service requests due to detected failures (or their correction), and therefore its request must be processed. In this case, the CSC request will be rejected and returned with a message status report.

In case this service message protocol becomes violated, a halt/wait request will reset the protocol from either station by ordering all service message processing canceled; when received by the CSC, the CSC may not originate any new requests until it receives at least one additional request from TNS. This is required for the case where TNS is attempting to report a service failure and, because of a violation of this protocol, it cannot get a service request into the CSC. Therefore, it will halt all service message processing so that it will be able to send at least that *one* service request to the CSC.

Finally, since multiple requests or acknowledgments may be contained in a single service message, in order to facilitate the CSC programming, an option exists to limit TNS to the transmission of only one request per request service message.

TNS will always send acknowledgments in the form the requests were received. For example, N acknowledgments per service message will be sent back when N requests per service message were received. Therefore, if one request per service message was received, one acknowledgment per service message will be transmitted.

5.2.3 Service message format

Figure 11 shows the format of a service message excluding the heading which is identical to a data message. The first two characters in the text of a service message consist of a type field, t, and a sequence number, s, followed by the individual requests or acknowledgments.

The type field, t, identifies the basic type of the service message. When grouped together, individual requests or acknowledgments must be of the same type.

The next character is the service message sequence number (not to be confused with the heading sequence number) which coordinates the requests and acknowledgments. The sequence number, s, must be exactly echoed in the acknowledgment to make sure that each request and acknowledgment may be paired by the request originating party. It is in the range from ASCII 0 to 9 and is incremented by two modulo 10. It is even for TNS requests and odd for CSC requests.

Each individual request or acknowledgment is identified by a type code (TC) which uniquely identifies the function to be performed. The remaining entries may consist first of a state K (between 1 and 6 as previously defined under the state definitions) which contains the state requested or reported. The second entry that may be present is a line number identifying the line on which the function is to be performed. Alternatively, for reflection requests the text to be reflected appears after TC.

Finally, when multiple requests or acknowledgments are present within the same service message, the field separator ASCII "+" is used as a delimiter immediately following each individual request or acknowledgment.

5.2.4 Service messages

This section defines the individual service message requests and acknowledgments. The set state service messages consist of set group state or set line state requests, which are commands to put the group or line into a specified state. The accompanying acknowledgments report whether the requested action was taken and the resulting state.

Similarly, the report state service messages consist of report group or report line requests seeking information as to what state the other station perceives to be true. The requests contain the state that the inquiring station assumes to be true. Thus, the acknowledgment contains the receiving station's perception of state.

The Halt/Wait request/acknowledgment service messages carry out the actions described in Section 5.2.2.

While the above service messages follow the priority scheme of the SAF, the reflection request service messages may be transmitted over any line. The associated acknowledgments must be returned on the same line over which the request was received. The reflection service messages are requests to provide a predetermined echo of the original transmission. They are intended to provide a testing capability both for new installation testing of software and hardware by the CSC and also as an operational test by both TNS and the CSC.

The simplest reflection request is for the return of the accompanying text. Other reflection requests produce single or multiple messages in one or two blocks as the echo subject to the constraints of Sections 4.2 and 4.3. Also, reflection requests are defined to allow the testing of input/output buffer sizes and to allow the acknowledgment to appear as an inquiry from a customer station.

5.2.5 Summary of service message capabilities

The service messages provide the CSC with the capability of exercising considerable control over the interface. This includes, in addition to the normal failure recovery procedures, the capability to fully test and reconfigure the local network due to operational requirements.

5.3 Service facility—station identifier subfield

The remaining service facility feature is the station identifier subfield in the message *heading* of messages from the CSC to terminals; that is to say, response messages. Whereas service messages do not relate to a specific data message, the station identifier service facility is used to choose operational procedures to be followed by TNS for a particular message.

This service facility is generally used for dial-in telephones, for the following actions:

(*i*) Voice only response.
(*ii*) Key answer tone response for 1.5 seconds with no accompanying voice message.
(*iii*) Keyed answer tone for 3 seconds followed by a voice message.
(*iv*) FSK response for dial-in telephones.
(*v*) CSC specified disconnect of the telephone from the dial-in port.
(*vi*) Finally, if no instructions are required, as for example, if the message is destined to a polled terminal, the CSC inserts the null field entries of ASCII "space space."

VI. TEST INSTALLATION

To verify the procedures of the interface specifications, a test configuration was installed on the Bell Laboratories' IBM 370/168 at Holmdel, N.J. The software configuration is shown in Fig. 2. The task consisted of writing Cobol programs to transfer messages with the TNS message switch.

The approach taken was to write processing programs which were independent of the originating station and had a preprocessor and postprocessor to handle any station dependencies of the message text. It required less than 150 lines of Cobol code to enqueue and dequeue the inquiry and response messages.

A service message routine was written to handle normal service message processing (e.g., acknowledge TNS requests and activate lines) and consisted of some 200 Cobol statements. Message status reports were simply logged and used as a debugging tool for the test system.

VII. ACKNOWLEDGMENTS

We would like to acknowledge the work of G. S. Hoffman in writing Cobol application programs, T. Tammaru for hardware design of the synchronous interface, and K. W. Sussman for interface design contributions.

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Transaction Network, Telephones, and Terminals:

The Switched Network Transaction Telephone System

By F. E. FROEHLICH, C. B. Mc DOWELL, F. P. SANSONE, and G. D. ZALLY

(Manuscript received June 6, 1978)

In June of 1972, an AT&T/BTL project team was formed to determine the evolving communication needs of the financial and retail industries as they moved to implement electronic funds transfer systems. The Bell System response occurred in three phases. The first phase introduced the Transaction I telephone, 407B data sets, and the Transaction Telephone Test Line Station in order to provide a simple means of evolving from the widespread manual-entry/audio-response systems into automatic-entry/audio-response systems. The second phase expanded our system offering to include Transaction II telephone, 407C data sets, and an upgraded Transaction Telephone Test Line Station. The third phase introduced the Transaction printer, which provided a simple means of generating receipts at the terminal location under control of the data center computer. This paper describes the resulting Switched Network Transaction Telephone System and the individual products of which it is built.

I. INTRODUCTION

During the past few years, the Bell System has been actively engaged in developing new offerings to satisfy the unique communication needs of financial and retail establishments. Clerks and tellers who deal directly with customers need access to information in remote data bases to authorize credit, cash checks, or handle account transactions. As our society moves toward the implementation of electronic funds transfer systems, many new communication offerings are required. In June of 1972, an

AT&T/BTL project team was formed to determine these growing needs. After visiting a large number of financial customers throughout the country and conducting an extensive market survey, the project team developed a proposal for a Transaction telephone system which used the public switched telecommunications network and which could evolve simultaneously with the increasing communication needs of the financial and retail industries.

A technical trial of the first stage in the project team's proposal was conducted with the regional data center for Master Charge transactions in Cleveland, Ohio, from October 1973 to February 1974. During this trial, 33 trial Transaction telephones were installed in 13 retail outlets in the Cleveland-Akron area, eight modified 407A data sets were interfaced to the regional Master Charge computer, and a custom-designed automatic call distributor (ACD) referral system was interfaced to the existing Master Charge ACD facility. Retail clerks were able to automatically dial the computer center and enter transaction data directly into the computer. The computer in turn generated a voice response to the clerk indicating approval or disapproval of the transaction.

This trial of Transaction telephones for credit authorization was a success from both technical and operational standpoints. However, the trial indicated the need for several design changes in the terminals, system configuration, and maintenance procedures. Some of these modifications were strictly technical, such as the replacement of discrete digital logic by a microprocessor and the change to a calculator type of keyboard. Others made the system more robust, such as the generation and testing of check characters and provision for customer testing of the Transaction I telephone. The redesign of the data set as the 407B added new capabilities, such as the ability of a clerk at a Transaction telephone to automatically refer the call to an attendant. A pilot installation of the modified first-phase system was conducted with a commercial bank in Cincinnati, Ohio, in early October 1974 to confirm the effectiveness of these design changes before gearing up for manufacture. This pilot installation started with Transaction telephones used as lobby inquiry terminals which were used by bank customers to obtain current account balances. It was later expanded to include check authorization/guarantee.

The Western Electric Company delivered the first production Transaction I telephones, 407B data sets, and Transaction Telephone Test Line Stations before mid-1975 to facilitate implementation of the first phase of the AT&T/BTL project team proposal. This system allowed automatic entry of data with computer-activated voice response. The Transaction II telephones, 407C data stations, and an upgraded Transaction Telephone Test Line Station were introduced about one year later to facilitate implementation of the second phase. The inclusion of an alphanumeric display on the Transaction telephone allowed the computer to send a data response and permitted the clerk to operate in a hands-free mode. A third phase, which incorporated adjunct Transaction printers and an upgraded Transaction Telephone Line Test Station, was implemented during 1977. Receipts and authorizations were printed directly, further simplifying the clerk's task and reducing inconvenience to the customer. These various developmental phases were specified to mesh with the increasing communication needs of financial and retail establishments. Each of these three phases is described in detail in the following sections.

II. THE FIRST PHASE

The first phase in the AT&T/BTL project team plan was intended to provide a simple means of progressing from the manual-entry/audio-response systems which are in use by numerous financial and retail establishments into automatic-entry/audio-response systems. In the typical manual-entry system, either the clerk specifies the inquiry data by voice to an attendant who manually enters the data into a computer system, or the clerk manually enters the data directly into a computer system via a direct data link. The computer system may then either respond via a CRT terminal to the attendant who relays the response to the clerk by voice, or the computer may directly respond to the clerk with computerized audio. In all such cases, the inquiry data are manually entered into the computer and an audible response is given to the clerk.

The overall system requirements for our first offering were that it:

(*i*) Be compatible with the subscriber's existing telephone service needs.
(*ii*) Automate the manual data entry procedures.
(*iii*) Be easily maintainable.
(*iv*) Be compatible with existing computerized voice systems.
(*v*) Allow expandable system features to meet the changing communication needs of our customers.

The system that resulted is shown in Fig. 1. Transaction I telephones call the computer center over the public switched network. An optional Automatic Call Distributor (ACD) routes incoming calls to 407B data sets, which are connected to customer-provided equipment. In the typical configuration shown, an Audio Response Unit (ARU) serves as a telecommunications front end for the host computer. CRT terminals are provided for referral clerks, who handle exceptional transactions. The Transaction Telephone Test Line Station is provided to exercise and test the Transaction telephone from the field.

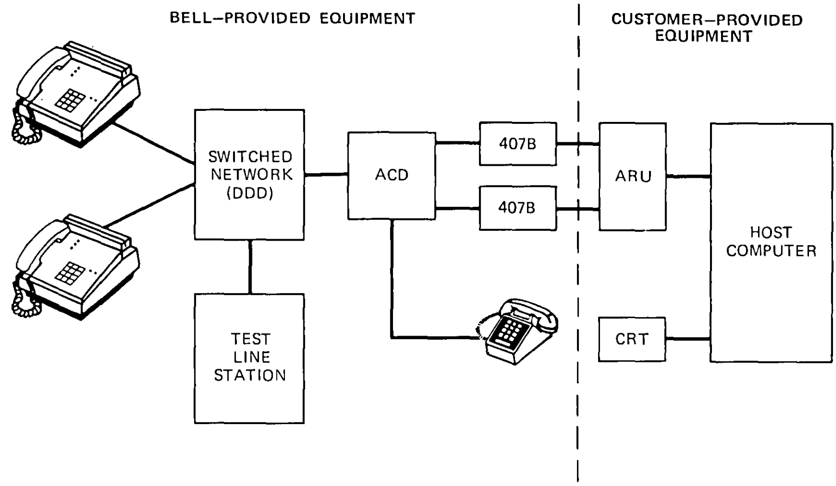

Fig. 1—Switched Network Transaction Telephone System, first phase.

2.1 Transaction I telephone

The Transaction I telephone[1] includes the following features:

(*i*) Automatic dialing of the telephone number of the computer center.
(*ii*) Fully buffering input data.
(*iii*) Reading input data from magnetic stripe cards.
(*iv*) Providing sequenced instruction lamps to aid the user in data entry.
(*v*) Providing a manual entry key pad for entry of additional numeric data.
(*vi*) Transmitting information and responding to answer tones.

The Transaction I telephone can dial into *TOUCH-TONE** or rotary offices and can dial from behind PBXs or key systems. Thus it is capable of being used virtually wherever a conventional telephone can be installed. In addition, it can dial automatically from information contained on the magnetic stripe of specially encoded plastic dialing cards. To automate the data entry, the Transaction I telephone has instruction lamps to guide the clerk through the data entry procedure, a buffer for temporarily storing data until they are needed, and a magnetic stripe card reader. The buffer allows data to be entered before or after connection with the computer center is made and then to be transmitted when the computer center is ready. The card reader accepts data encoded on magnetic cards formatted according to the financial industry standard American Banking Association Track 2.

The Transaction I telephone's design incorporates several features which facilitate use with existing computerized voice systems and which allow expansion of the product line to meet evolving communication

* Registered service mark of AT&T Co.

needs. To ease the integration of Transaction I telephones into existing voice response systems, the Transaction I telephone transmits the inquiry data as *TOUCH-TONE* signals. It uses a magnetic-stripe character-to-*TOUCH-TONE*-signal conversion table which was selected for compatibility with all commercially available voice response systems. The *TOUCH-TONE* inquiry also includes error check and status characters in anticipation of increased needs to automatically detect transmission errors and limit certain types of potential fraud exposure. The automatic generation of check characters and the use of all 16 *TOUCH-TONE* signals make it impossible for a conventional telephone to be used to place a fraudulent Transaction telephone call. To facilitate the expansion of system capabilities, all data inquiries begin with a unique sequence of terminal identification characters which identify the calling set as a Transaction I telephone. Other sequences of characters identify different members of the Transaction telephone family. The Transaction I telephone is designed to receive simple tone responses from nonaudio systems as well as to receive the usual voice response from systems with computerized audio capability. Tone responses of specified durations will activate the green or yellow response lamps, which can be used to signal such action as the approval or disapproval of a transaction.

During the introduction of the first phase offerings, the need for remote entry of a secret Personal Identification Number (PIN) by the customer was evidenced. This provided a greater measure of security for the customer and gave the customer a greater sense of control over a transaction. In response to this need, an optional auxiliary manual entry pad, called a PIN pad, was added to the first phase offerings. PIN entries are used to minimize unauthorized use of customer cards, since only the customer is supposed to know the PIN.

2.2 407B data set

The 407B data set has all the features of the 407A data set[2] plus several features that enable it to satsify the special needs for transaction processing in the financial and retail industries. Like the 407A data set, it was designed to interface Bell System terminals and the network with existing computerized voice response systems. It receives and decodes incoming *TOUCH-TONE* signals, presenting them in a 2-out-of-8 parallel format to the computer system. In addition, it provides a means for sending back voice signals generated by the computer or for sending answer tones to the Transaction telephone. The 407B data set includes extensive self and remote test capabilities to facilitate system maintenance.

The 407B data set can initiate referrals to an attendant at the request of either the computer system or the clerk using the Transaction telephone. The 407B detects a special sequence of *TOUCH-TONE* signals from the Transaction telephone which the clerk can initiate. This referral capability can be implemented with adjunct *CALL DIRECTOR** telephones or through certain ACD arrangements. This clerk is connected directly to the referral attendant and can receive verbal assistance in handling the transaction. The 407B data set can also detect a "computer down" condition and proceed in a limited fashion to handle inquiries from Transaction telephones. This eliminates "ring-no answer" or busy signals during computer outages and allows transactions to be consummated. The 407B sends a special answer tone to the Transaction telephone, indicating the "computer down" condition. If the dollar amount of the transaction is below a "floor limit" encoded on the dialing card, the "Follow Special Instructions" lamp is lighted. If the floor limit is exceeded, a different response lamp lights, and an automatic referral is initiated by the Transaction telephone.

One feature could only be implemented in the second phase, when the Transaction II telephone became available. This feature, an automatic disconnect, shortens computer port holding time and improves efficiency. The Transaction II telephone can send a special *TOUCH-TONE* sequence just before it disconnects from the line. This sequence is interpreted by the 407B, which then drops its end of the line.

2.3 Transaction Telephone Test Line Station

The 1973 to 1974 Master Charge technical trial indicated the need for improved terminal maintenance procedures. As a result, the 1A Transaction Telephone Test Line Station was developed and deployed. The Test Line Station is located on telephone company premises, typically in a Data Test Center. One unit can serve a large number (up to 1200) of Transaction telephones. The Test Line Station is comprised of a 407A data set and an 806E data auxiliary set. The data set answers test calls, sends back answer tones, and receives and converts *TOUCH-TONE* signals. The 806E DAS is a microprocessor-controlled unit which verifies that the Transaction telephone is transmitting the proper data and generates control signals to the Transaction telephone at appropriate times during a test.

Each Transaction telephone is shipped with a universal magnetic stripe test card which the installer uses to test proper operation. The installer calls the Test Line Station with the handset on the Transaction telephone and uses the test card to enter both dialing and customer data. The installer presses each button in the prescribed sequence and observes the proper operation of the response lamps on the Transaction telephone. Every functional element of the Transaction telephone is exercised and verified during the test. Unique tone responses on the handset indicate success or failure of the test. The test card and Test Line

* Registered trademark of AT&T Co.

Station telephone number are left at the installation site so that the subscriber can also verify proper operation of the telephone. Subscribers are encouraged to test any Transaction telephone that seems to be functioning improperly. This helps to isolate problems either to the telephone or to some other element of the entire Transaction telephone system.

III. THE SECOND PHASE

The second phase of the AT&T/BTL project team plan was intended to satisfy the needs of the financial and retail establishments that did not find it efficacious to support computerized voice response systems. At the same time, it was desired not to exclude the use of the new Phase II equipment by concerns which did support computerized audio systems. This second phase provides a simple means of evolving from the labor-intensive, manual-entry/attendant-response systems which are in wide use in the financial and retail industries into automatic-entry/visual-response systems.

The overall system requirements for the second offering include all those of the first phase system. In addition, it was required that it:

(*i*) Be compatible with computer front-end telecommunications controllers.

(*ii*) Be capable of supporting Transaction I telephones in a limited fashion.

The full second-phase system is shown in Fig. 2. Both Transaction I and II telephones can call the computer center over the public switched network. Calls are routed to 407B data sets, which are connected to customer-provided Audio Response Units, or to 407C data sets, which are connected to digital front-end telecommunications controllers. A new Test Line Station is provided to test both Transaction I and II telephones.

3.1 Transaction II telephone

The Transaction II telephone[1] is similar to the Transaction I telephone with the addition of an eight-character visual display, a data receiver, a monitoring loudspeaker, and ON/OFF buttons. The Transaction II telephone includes all the dialing capabilities of the Transaction I telephone plus a visual display of the dialed number for manually entered telephone numbers. It provides two data entry features beyond those of the Transaction I telephone:

(*i*) Hands-free operation, so that the clerk does not need to raise the handset.

(*ii*) Visual display for verifying all manually entered data and for displaying the data center responses.

Transaction II telephones can be supported by existing computerized

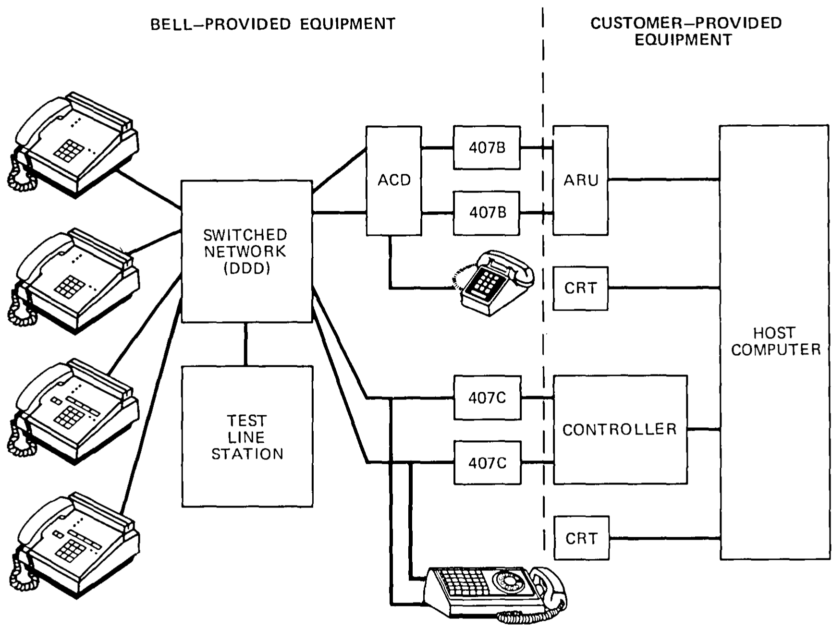

Fig. 2—Switched Network Transaction Telephone System, second phase.

voice response systems in two modes. First, the Transaction II telephone can perform in the same way as a Transaction I telephone, where the new capabilities are not used. The user is instructed to raise the handset and listen for the usual computerized voice response. Second, the data vocabulary can be recorded in the computerized voice response system in its audio version, using the frequency-shift keying (FSK) equivalent for each ASCII character. These audio FSK signals can be sent through the 407B data set's voice channel to activate the Transaction II telephones' visual display. In fact, a special 14-character subset of the full 128 ASCII character code can be used to activate most the Transaction II telephone features. This special subset was specified because of the limited storage vocabulary capability of most existing computerized voice systems.

The Transaction II telephone incorporates features which facilitate working into digital front-end controllers and at the same time retain a compatibility which permits simultaneous limited support of Transaction I telephones. The Transaction II telephone transmits the inquiry data as *TOUCH-TONE* characters using the same transmission format as the Transaction I telephone except for the leading terminal-type identification characters. All data inquiries begin with terminal identification characters that specify the Transaction II telephone's mode of operation. If the Transaction II telephone is being used in a voice response mode, that is, like a Transaction I telephone, the terminal-type identification characters are the same as for a Transaction I telephone.

If, on the other hand, the Transaction II telephone is being used in its usual data response mode, the terminal-type identification characters specify that a data response is expected. Each data center specifies the modes of operation it will support by encoding certain characters on the dialing cards which it provides to the subscriber. The Transaction II telephone's internal data receiver can be set for either 110 or 150 b/s FSK-modulated responses. The data responses can contain up to 120 characters, which are buffered by the telephone until they are needed. After verifying the validity of the data response by checking parity and error control characters, the Transaction II telephone divides the response into three fields of data.

The first field, the action field, is executed to control the switchhook, response lamps, and other terminal control features. The second field is the display field. After executing the action field, the first eight characters of the display field are presented. The clerk may page through the display, eight characters at a time, by pressing the ERASE button. The third field, the print field, is reserved for use in the third-phase offering.

3.2 407C data set

The 407C data set is a completely new unit whose design is based on microprocessor technology. It offers all the features of the 407B data set plus an array of significant expanded capabilities. In addition to receiving and decoding *TOUCH-TONE* signals and presenting them to the customer's equipment in a parallel 2-out-of-8 format, the 407C can translate them into the parallel binary-coded matrix form used by certain commercial voice response units. Not only does the 407C interface Transaction telephones to computer systems with voice response systems, it also presents an interface to digital front-end telecommunications controllers. The data processing system need support only low-speed serial interfaces of the kind used by Teletype-like terminals, and the 407C will make the connection to the Transaction telephone system.

In its serial mode of operation, the 407C translates the incoming *TOUCH-TONE* inquiry into a serial ASCII data stream. Each *TOUCH-TONE* signal is converted into an 8-bit ASCII character. The 407C also verifies the validity of the inquiry by checking the error control characters which are generated in the Transaction I and II telephones.

The data set performs a number of specialized interfacing functions for various digital front-end controller configurations. The 407C provides 18 options which are selectable by the customer. Data transmission can occur at rates of 110, 150, or 300 b/s. Automatic disconnect and "computer down" features can be enabled, as can initiation of referrals from the terminal.

End-of-message sequences can be selected to match a particular computer system. Other options allow buffering messages, inserting the punctuation characters expected by the Transaction II telephone, and implementing the error control protocol of the Transaction II telephone. The expanded error control and specialized interfacing functions of the 407C data set simplify interfacing to existing data base facilities. Thus, through the customer's selection of the options provided by the 407C, the interface format and protocol can be tailored to suit the customer's telecommunications hardware and software installation.

In the serial mode, the 407C converts the ASCII response from the computer to a Transaction II telephone into the FSK form that can be transmitted through the network. At the same time, the 407C permits simultaneous limited support of Transaction I telephones by sending answer tones to light response lamps. The 407C data set includes extensive self and remote test capabilities to facilitate system maintenance.

3.3 Transaction Telephone Test Line Station

To facilitate Transaction II telephone maintenance, a modified Transaction Telephone Test Line Station was introduced to support it. This new test line station was designed to test all the new features of the Transaction II telephone as well as perform the Phase I tests on the Transaction I telephones. Due to the microprocessor-based design of the 806E data auxiliary set, no hardware modification was needed to provide the new testing capabilities. Instead, additional programming was done to accomplish the changes. The programming was done in a modular fashion so that all the initial program was retained intact and a new program was added. Since the program is stored in integrated circuits, it was possible to update existing units to become an 806E2 DAS in the field.

All Transaction II telephones are shipped with a magnetic striped test card which the installer and subscriber can use to verify proper operation of the Transaction II telephones in a manner similar to that for Transaction I telephones. The magnetic stripes on the Transaction I and II test cards are the same, but the testing instructions on the cards are different. Thus, a knowledgeable installer needs to have only one test card. The detailed test procedures for Transaction II telephones are quite different, however, in that they exercise the data receiver, the display, and the hands-free mode of operation.

IV. THE THIRD PHASE

The third phase of the AT&T/BTL project team plan was intended to augment the Phase II offering by providing a simple means of generating receipts at the terminal location under control of the data center computer. Starting in 1977, the production of Transaction II telephones included a jack for connection to the Transaction printer. These Transaction II telephones and a preproduction printer design were given a technical evaluation from late 1976 through early 1977. Western Electric Company is now delivering standard production Transaction printers.

The Transaction printer provides the means for printing on forms or slips of paper. ASCII-coded, FSK-modulated, response messages contain transaction data transmitted to the local Transaction II telephone from a remotely located data center. The content and format of the printer message is under full control of the data center. The third (print) field of the FSK response message to the Transaction II telephone is executed after the clerk has finished paging through the display field and has inserted paper in the Transaction printer. The print field contains the text to be printed and control characters to activate special printer features.

The top of the printer is designed to support the Transaction II telephone so that the units can be stacked to conserve counter space. When top mounting is undesirable, the Transaction II telephone may be located on the same surface as the printer (on either side) with a connecting cord which is provided. A detailed description of the Transaction printer is contained in a companion paper[3] in this issue.

To facilitate maintenance of the Transaction II telephone with printer, a third version of the Transaction Telephone Test Line Station was introduced. This new test line station was designed to test Transaction II telephones with printers, as well as to perform the Phase I and II tests. Kits of parts were distributed to upgrade test line stations to this third version.

V. SUMMARY

As the financial and retail establishments of our society move toward the implementation of electronic funds transfer systems, the Bell System has been actively developing and offering an expanding variety of terminals and systems to coincide with their ever-increasing communication needs. In the process of responding to these needs, three phases of new offerings have been trialed and subsequently introduced. The first phase introduced the Transaction I telephones, 407B data sets, and the Transaction Telephone Test Line Station to provide a simple means of evolving from manual-entry/audio-response systems into automatic-entry/audio-response systems. The second phase expanded our system offering to include Transaction II telephones, 407C data sets, and an upgraded Transaction Telephone Test Line Station to satisfy the communication needs of establishments that did not choose to support computerized audio systems. The third phase provided a simple means of generating receipts at the terminal location under control of the data center computer.

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Transaction Network, Telephones, and Terminals:

Transaction Stations

By W. E. BAKER, R. M. DUDONIS, and J. H. KEE

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The Transaction station family includes the Transaction I and II telephones and the Transaction III terminal. This paper describes these sets. They are designed to provide access to data base systems via the switched network or, for Transaction III, the dedicated Transaction Network. The items discussed are overall telephone/terminal operation, hardware and software design, and data center interaction and protocol.

I. INTRODUCTION

The Transaction I and II telephones are designed to serve as user main station telephones and to automate the procedures of short message, inquiry/response systems when connected to a customer's computer center via the switched telecommunications network. These telephones have been employed in a broad range of financial applications including credit checking, check authorization, account inquiry, teller inquiry, and electronic funds transfer. Other industry applications include inventory control, process control, and personal identification systems.

The Transaction telephone transmits short computer inquiries as *TOUCH-TONE*® signals and receives responses returned as voice or data messages. It provides a means of reading information from plastic cards encoded with a magnetic stripe and a means of manual data entry. Instruction lamps guide the user through the transaction.

In general, information needed by the computer in these inquiries includes merchant identification, customer identification, and the nature and amount of the transaction. The merchant and dialing information is generally obtained from a dialing card, while the customer information is obtained from a customer card. The dialing card also contains control information for the Transaction telephone. Where cards are not available, these data can be entered manually. Discretionary data, such as a dollar amount or a transaction code, are always entered manually on the keyboard. For added security, an auxiliary manual entry pad may be added for entry of customer Personal Identification Numbers (PIN).

The Transaction II supports voice responses, keyed answer tone (KAT) responses, and frequency-shift keyed (FSK) responses. The Transaction I supports only voice and KAT responses.

The Transaction telephones also provide basic telephone service. Manual dialing is provided via a *TRIMLINE*® handset or the manual entry pad. The telephones can be used as automatic dialers by using appropriately encoded magnetic striped cards.

The Transaction III is also an inquiry/response terminal differing from its two predecessors in that it operates on dedicated exchange facilities on a polled basis. It was designed to interface to a customer's computer center via the data-only polled access facilities of the Transaction Network Service (TNS).

The operation of the Transaction III terminal by the user is basically the same as that of the dial sets. Information needed by the computer is normally entered via two magnetically encoded cards and a manual entry keyboard. Instead of a dialing card, the terminal employs an identification (ID) card which contains the Transaction Network (TN) address of the Customer Service Center (CSC). Other data on this card are option control information and merchant identification.

The Transaction III terminal communicates with the Transaction Network on an ordinary unconditioned 2-wire line at 1200 b/s rate. The terminal's FSK responses are visually displayed on its 8-digit display and/or printed via the optionally available Transaction printer.

II. TELEPHONES I AND II

The Transaction I telephone is intended primarily to expedite and facilitate inquiries and transactions in a switched-network, digital-inquiry/voice-answer (DIVA) system. It can automatically dial the telephone number of the data center and fully buffer input data for transmission after contact with a data center. The telephone number and/or the input data may be keyed in manually or entered into the telephone via magnetic encoded cards. An ERASE button on the set corrects errors in manual entries and an ATTN button signals the data center for assistance. The ATTN button can also be used to redial the last number dialed. An END button is used to delineate the data fields and transmit an end of text (ETX) sequence at the conclusion of data entry. Four sequenced instruction lamps guide the user through the data input. Voice answerback or yellow and green response lamps activated upon receipt of a KAT signal can communicate approval or disapproval of a transaction.

The Transaction II telephone provides for *TOUCH-TONE* inquiry/FSK data response applications. It has all the features of the Transaction I telephone: in addition, it has an FSK data receiver and a 120-character buffer for accepting and storing data sent from a data center. An eight-position visual display is provided to display responses from the data center and data entered from the set's manual entry pad. The seven-segment LED display can display the numeric and limited alphanumeric characters shown in Fig. 1. Messages up to 119 characters can be displayed eight characters at a time by paging the data via the ERASE button. The Transaction II telephone has ON and OFF buttons for hands-free operation and a call progress monitoring loudspeaker for audible feedback to the user. The Transaction II telephone also has a printer interface for connection to the Transaction printer. Messages from the data center computer, up to 118 characters in length, may be stored by the telephone and delivered to the printer. In normal usage, FSK messages contain control data, display data, and print data. Several FSK messages can be sent in one session, thereby permitting longer messages to be printed.

There is also a volatile last-number-dialed feature. It can be programmed and protected from alteration by manual entries.

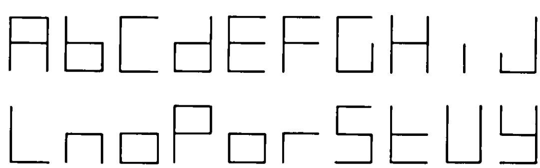
III. TRANSACTION TELEPHONE-DATA CENTER INTERACTION

To begin a transaction, the merchant lifts the handset of the Transaction I telephone or presses the ON button of the Transaction II telephone, waits for the dial tone, and inserts first the dialing card and then the customer card. The telephone automatically dials the telephone number of the data center while buffering the merchant and customer data.

At the data center, the ACD (Automatic Call Distributor) queues the call, if necessary, and directs it to the first available computer port. The 407-type data set associated with the port answers the call and sends the 1.5-second answer tone.

While the call is being dialed, set up, and/or answered, the merchant can manually enter data such as the transaction amount or a PIN (Per-

LETTERS



SPECIAL CHARACTERS
- • (DECIMAL POINT)
- – (DISPLAYED FOR (/) KEY OR FOR TRANSMITTED (–)

Fig. 1—Displayable characters—Transaction II.

sonal Identification Number). When the additional data have been entered, the merchant presses the END button. When the answer tone ends, the Transaction telephone begins to transmit the buffered data. If all the data in the buffer go out before the merchant has finished manual entry, the remaining keyed data are transmitted as they are entered.

The data center computer processes the incoming data and decides whether or not to approve credit. It then sends the appropriate response to the Transaction telephone. If credit is approved, an appropriate audible response and/or a 1.5-second answer tone for green light activation is transmitted. If not, an appropriate audible response and/or a 3-second answer tone for yellow lamp activation is transmitted.

The Transaction telephone acknowledges receipt of the answer tone by sending a *TOUCH-TONE* signal *a* (green lamp) or *TOUCH-TONE* signals *b* (yellow lamp) to indicate the set is ready to receive a detailed voice message associated with a referral or some other appropriate action. If no audio followup is necessary, the merchant hangs up and the computer disconnects the call. If the merchant doesn't hang up, the computer times out to allow the call to disconnect.

The Transaction II operation is identical to that described for I except that the call progress sounder is generally muted as data transmission begins and the response selected by a dialing card character can consist of FSK signals to light or blink the green and yellow lamps and activate the display and/or printer. If the response is in FSK, the message begins with the ASCII STX character as shown in Fig. 2a. The response message from the data base consists of three fields. The first field is the action field which contains all the terminal control information as shown in Fig. 2b. The second and third fields are the display and the print fields. If a print field is present, a test is made for the presence of a printer and paper. If there is no printer, then the print field is ignored. If the printer is there but there is no paper, then the word "PAPER" is displayed. When paper is inserted, "PUSH END" is displayed. After the END key is operated, the display field is paged by operating the ERASE key. When the last page* is on the display, the print field is printed.

A positive or negative acknowledgment of FSK messages is returned to the data center. A negative acknowledgment is a request for retransmission of the ESK message. When the telephone receives and executes an error-free message, it returns a positive acknowledgment. The telephone will hang up automatically if instructed to do so in the FSK message, or it may be hung up via the OFF button. If the telephone does not receive a hang-up command, it will disconnect 20 seconds after a positive acknowledgment of the message. A hang-up code is sent just prior to disconnecting from the telephone line.

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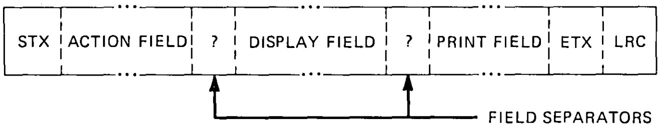
* A page consists of 8 characters or is terminated by a "/". The / is not displayed.



(a) RESPONSE MESSAGE FORMAT

0 – SET AUTOMATIC DISCONNECT TIMER TO 3 MINUTES

1 – "NAK" – RETRANSMIT LAST MESSAGE

2 – UNMUTE CALL PROGRESS TONE SOUNDER

3 – DO NOT CHECK MESSAGE LRC (MUST APPEAR IMMEDIATELY AFTER STX)

4 – RESERVED FOR FUTURE USE

5 – ACKNOWLEDGES END OF DISPLAY/ACKNOWLEDGES SUCCESSFUL OR UNSUCCESSFUL PRINTING

6 – LIGHT GREEN RESPONSE LAMP

7 – LIGHT YELLOW RESPONSE LAMP

8 – BLINK LAMP

9 – DISCONNECT, SEND * # *

(b) ACTION FIELD CHARACTERS

Fig. 2—Response format/action field.

IV. DESIGN OF TRANSACTION TELEPHONES

The Transaction telephones are designed around the Rockwell MOS/LSI PPS4 microprocessor system. This is a five-chip system consisting of a Central Processor Unit (CPU), Random Access Memory (RAM), Read Only Memory (ROM), general-purpose input/output device (GP I/O), and a clock chip. A block diagram of the Transaction II telephone is shown in Fig. 3. Since Transaction I is a subset of Transaction II, the following discussion will be limited to Transaction II. Input/output ports interface with medium-scale integrated circuits to implement the Transaction II features described above. Besides controlling the interfacing circuits, the microprocessor does message decoding, error checking, and printer control and tabbing. The design intent is to simplify the peripheral circuitry by utilizing the power of the microprocessor.

The network signaling and line supervision are controlled via a manual or hands-free line circuit as shown in Fig. 4. The manual operation is implemented with a *TRIMLINE*® handset and a mechanical switchhook (SWHK), whereas the hands-free line circuit consists of a microprocessor controlled mute relay (M), line relay (L), dial relay (D), dial tone sounder, and terminating network. The mute relay enables the transmit and receive circuits and eliminates handset interference.

Direct-current dial-pulse network signaling is accomplished via the

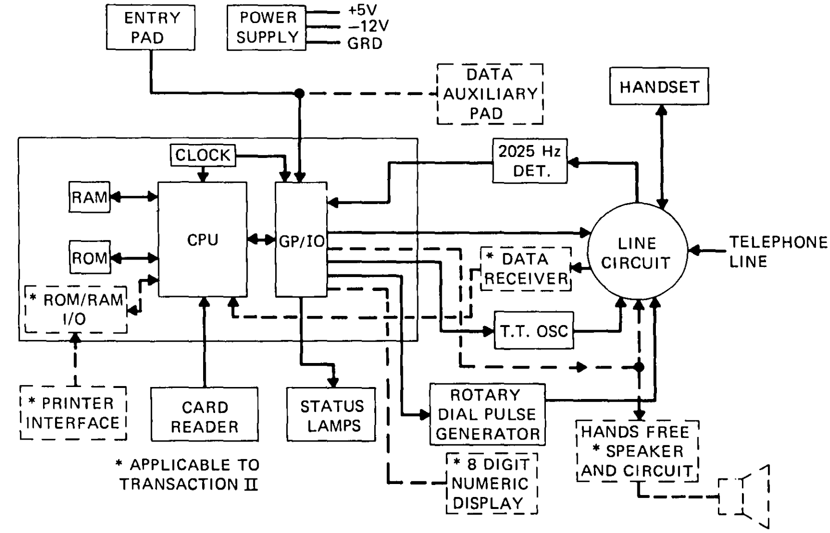


Fig. 3—Transaction telephone.

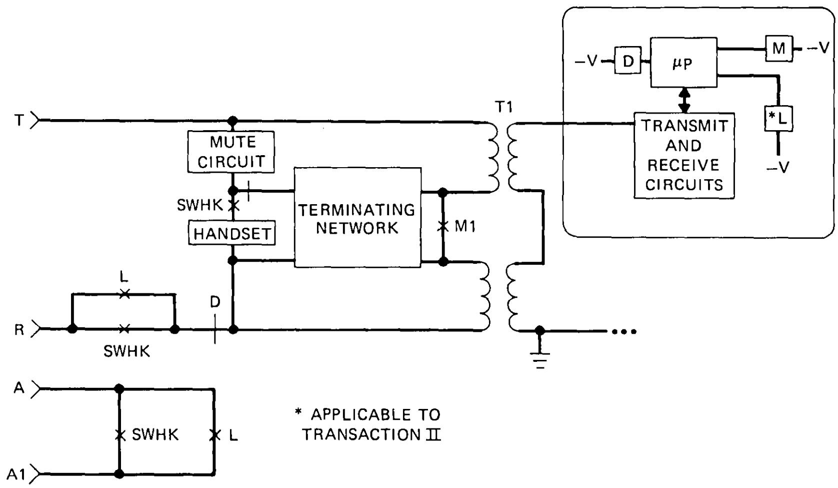


Fig. 4—Line control.

microprocessor-controlled relay (D) or a 220 *TRIMLINE*-type handset. *TOUCH-TONE* signals are generated by a 2220 *TRIMLINE* type handset or a line transformer-isolated transmit circuit under control of the microprocessor's keyboard and card reader inputs. Sixteen keyboard entry pad inputs are multiplexed via a two-phase clock using eight inputs of the microprocessor system. The microprocessor reads the keyboard, card reader input, or auxiliary entry pad and activates the correct 2-out-of-8 *TOUCH-TONE* signaling oscillator (559G hybrid integrated circuit) inputs for network signaling and/or end-to-end data transmission. In normal operation, FSK response messages rather than KAT messages are expected in answer to an inquiry. Response messages are decoded via a keyed answer tone (2025 Hz) detector or a low speed (110 or 150 b/s) frequency-shift keyed (FSK) data receiver. The FSK receiver consists of an input filter, a limiter, a product demodulator, and a dual integrator carrier detector. The KAT receiver is a resistive, tuned, phase-lock loop.

Messages are decoded by the microprocessor and conveyed via the response lamps, the numeric display, and/or printer to the user of the Transaction telephone.

The response and instruction lamps are light-emitting diodes (LEDs). The display is an eight-digit (seven segments per digit plus decimal point), serial mode static display. Each display is driven by an 8-bit serial-input, parallel-output, low power TTL shift register.

Transaction II is designed to work with an optional Transaction printer. The printer is interfaced to the Transaction II telephone microprocessor system via a memory/input-output device of the PPS-4 family. This is a parallel data interface with data-strobe and data-ready signals. Information to be printed and control characters to format the printing are received in the FSK message to the Transaction II telephone.

The Transaction telephone design permits certain features to be optioned in or out to accommodate particular customer requirements. The set's dialing mode is controlled by an option strap to be either *TOUCH-TONE* or dial-pulse. An option strap also inhibits dialing via the manual entry pad. This option is referred to as "keyboard lockout" and is used to restrict dialing except by a dialing card. Another dialing option is the "one number option," which restricts dialing to a single data base. When this option is activated, the set must be used as a repertory dialer. Once the repertory has been loaded, the set does not accept dialing cards and requires only a customer card to initiate operation of the Transaction telephone features. Following a power failure, the repertory contents are lost and must be reloaded.

The design also incorporates an interface for an optional data auxiliary PIN pad (5000A DIAL) to accommodate the use of PIN numbers. The PIN pad is activated via a pushbutton switch on the face of the Transaction telephone. LED lamps light on the pushbutton and the PIN pad to indicate that the PIN pad is active. The Transaction telephone obscures all manual entries when the PIN pad is active by placing the letter P on the visual display for each entry.

The Transaction telephone provides A-lead control and may be used in key systems by the installation of a key strip.

The Transaction telephone has options (Table I) that are controlled by the dialing card. These optional features are designed into the Transaction telephone without the expense of circuit hardware, and are enabled by programming the telephone via the dialing card.

Table I — Transaction telephone dialing card controlled options

1. Green-yellow response lamps enable.
2. FSK receiver enable and data rate selection.
3. Dialing mode change—dial pulse to *TOUCH-TONE*® or *TOUCH-TONE* to dial pulse for split mode dialing.
4. Two-part dialing enable.
5. Response mode in computer down—controlled by floor limit.
6. Repertory dialer disable.
7. Customer card LRC check inhibit.
8. Predialing enable.

The card reader is designed to read magnetic stripe cards encoded on track 2 according to the American National Standards Institute, Inc. (ANSI) standards for credit cards. The reader is hand-powered and has no moving parts. It can read cards driven as slow as 4 inches per second and as fast as 30 inches per second.

The encoding technique on the magnetic stripe is known as two-frequency, coherent phase encoding. This scheme combines serial data and clock information on one recording channel. A flux transition occurring between clocking transitions defines a 1, and the absence of an intermediate flux transition defines a 0. The data are a synchronous sequence of characters without intervening gaps. A block diagram of the card reader is shown in Fig. 5. This circuit dynamically tracks changes in the card velocity by using the previous clock interval to generate the data sampling point. A magnetic head reads the biphase encoded signal. The signal is amplified, integrated, and shaped to produce a bipolar non-return-to-zero signal. This signal is applied to an edge detector which produces a unipolar pulse for each flux transition read from the magnetically encoded card. The time between these pulses varies as the speed

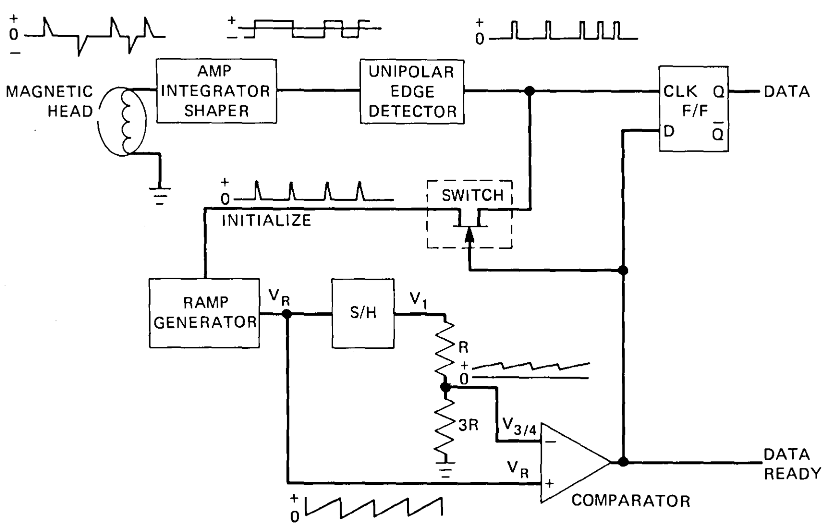


Fig. 5—Card reader.

at which the card is driven through the reader; hence, the clock and data bit periods vary.

The circuit assumes that a 1 bit edge pulse comes before three-fourths of the time required for two successive clock pulses has elapsed. Any pulse occurring before the three-fourths point is assumed to be a bit center pulse and corresponds to a 1. This assumption is based on the fact that a flux transition occurring between clocking transitions defines a 1 and the absence of an intermediate flux transition defines a 0.

A ramp generator, a sample and hold (S/H) circuit, a switch, and a comparator are used to derive the clock and data from the unipolar encoded pulses. The switch is controlled to pass successive clock pulses (i.e., only if the present time period is at least three-fourths of the previous time period). Pulses that occur earlier than three-fourths of the time between the previous two pulses are not used to reset the ramp generator. Hence the ramp generator's output (V_R) is a function of the bit length. The S/H circuit output V_1 is proportional to the period of the preceding bit. Three-fourths of V_1 ($V_{3/4}$) is compared with V_R. Hence, the comparator's output always changes to a high state three-fourths of the way into a bit and remains in a high state until the ramp generator is reset. The output of the comparator directs the clock pulses through the switch and acts as the data input to the flip-flop (f/f). If no pulse is applied to the f/f between clocking pulses, the data out is a high state or a zero data bit. If a data pulse is applied to the f/f between the clocking pulses, the comparator output is a LOW state and the data out changes to a low state or one data bit. The next clock pulse then resets the ramp generator, references the S/H circuit, and resets the data flip-flop.

The magnetic stripe cards are encoded with a string of leading zeros to establish an initial bit period. A card sense switch is synchronized with the leading zeros, which indicates the data are valid.

The sets operate on ac power. The power supply design incorporates a linear transformer and integrated circuit regulators to provide 5-percent regulated dc voltages. The power supply responds to overloading via foldback current limiting and thermal shutdown. Also, transformer protection is provided by a primary thermal cutout and secondary fusing.

V. DESIGN OF TRANSACTION TERMINAL

A simplified block diagram of the electronics used in the Transaction III terminal is shown in Fig. 6. The set must be plugged into locally available power, 117V ac ± 10 percent, 60 Hz. An integral power supply is capable of producing 1.1 A at +5V and 0.2 A at −12 V. The supply utilizes a linear power transformer with dual secondaries and monolithic integrated circuit voltage regulators.

The heart of the electronics and the control for all functions performed by the terminal is a microprocessor. The one used in the Transaction III

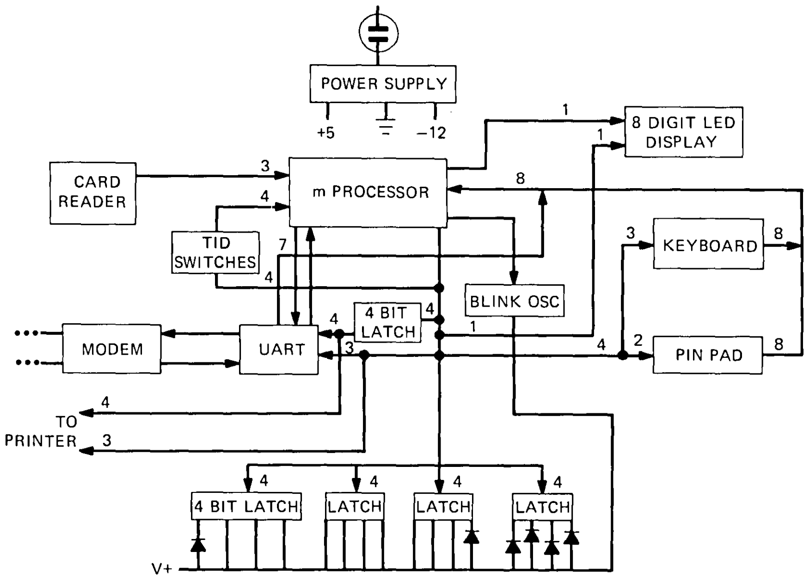


Fig. 6—Transaction III block diagram.

terminal is the same as that used in the Transaction I and II, the Rockwell PPS-4. This is a 4-bit microcomputer system which executes most instructions in 5 μs.

The microcomputer system used in the Transaction III terminal is made up of six integrated circuits. The central processing unit performs the instruction decodes and contains the arithmetic logic unit, program counter, stack, memory address register, etc. A clock driver uses a common 3.57954-MHz color TV crystal and produces the two clock signals required by the rest of the system. Two 16-kb read-only memories provide the program storage. A 2-kb random access memory is sufficient for buffering both the transmit and receive messages as well as the pointers, flags, and scratch pad memory required.

The microprocessor's peripheral circuitry primarily interfaces to it via a 4-bit output bus and an 8-bit input bus. Four 4-bit TTL latches are used to both drive and store the state of the instruction, call progress, and response LEDs that appear on the face of the unit. Five of the LEDs, which are sometimes required to blink and at other times be continuously on, have their anodes returned to the output of the blinking oscillator. This is then controlled by an output from the microprocessor.

5.1 Terminal Identification (TID)

Each terminal contains switches for setting a four-digit terminal identification number. The terminal identification switches consist of an array of 16 switches, physically realized in two DIP packages. The switches are organized as a 4 × 4 array, using the 4-bit output bus to strobe the rows, and four processor inputs to read the columns. Two DIPs containing eight diodes each are used to isolate the switch cross-points.

5.2 Keyboard

The main and PIN pad keyboards are read in a similar manner. Together, they may be thought of as a 4 × 8 array with 19 buttons on the main keyboard and 12 on the PIN pad. Again, the 4-bit output bus provides the strobe signals. However, input is provided on the 8-bit bus. Isolation diodes are again used to prevent one keyboard from interfering with the other. Button decoding and debouncing are provided by the software. This keeps keyboard hardware to an absolute minimum.

5.3 Modem

The processor's interface to the modem is primarily via a universal asynchronous receiver transmitter (UART) device. The 7-bit-wide transmit data are supplied by an LPTTL 4-bit latch and the processor's output data bus. The 7-bit-wide receive data are multiplexed onto the processor's input bus between strobes to the keyboards. At other times, the bus remains in its high-impedance state. Control signals to and from the UART go directly to the GPI/O device.

The modem contained in the Transaction III is a 1200-b/s, two-wire, half-duplex, frequency-shift keyed type, compatible with and using the same technology as the *DATAPHONE*® 202S and 202T data sets. This includes the use of hybrid integrated circuit active filters and large-scale integrated circuit modulator and demodulator. The modem includes a self-test feature. The System Ready lamp on the face of the terminal is normally on and will blink off whenever carrier is detected. However, when the reset button is depressed and held, the modem loops the transmit signal back to the receiver and verifies a quasi-random data pattern. If successful, the System Ready lamp will remain off until the reset button is released.

5.4 Card Reader

The card reader used in the Transaction III is a new type employing the magneto-resistive effect. The head contains a ceramic chip patterned with permalloy (a magneto-resistive material), conductor patterns, and an acrylic coating. The total package has much the same shape and size as a conventional magnetic head. See Ref. 1 for further information on the physical design of the reader.

Two permalloy detectors, spaced one-half bit width apart, are patterned on the chip. This allows decoding of the biphase signaling pattern encoded on Track 2 of a credit card in a speed-insensitive manner. This is illustrated by the block diagram in Fig. 7a and the timing diagram in Fig. 7b. After the signals from each detector are amplified and squared up, clocking information is retrieved by simply ORing those signals and dividing by 2. The one-shot multivibrator is needed to satisfy timing constraints at the interface with the microprocessor. Data are recovered by ANDing the detector outputs with the toggle flip-flop output and using that to set another flip-flop. This flip-flop is then reset at the end of the clock cycle.

The speed-insensitive nature of the detection allows the use of a card reader consisting of a slot through which the card is passed by hand. The reader will accept card velocities from approximately 2 in./s to 40 in./s. The head in this reader is itself sprung, allowing it to better conform to irregularities on the card. The result is an inexpensive magnetic card reader that is very easy to use.

VI. SOFTWARE

The functional operation of the Transaction telephone is implemented via its microprocessor software. The software comprises approximately 3000 assembly language instructions and resides in 4000 8-bit bytes of ROM storage. Organization of the software is accomplished by dividing the set's operation into five major states. Each of the states controls the set's operation during a particular portion of its activity. These states are Idle, Merchant Data Input, Customer Data Input, FSK Data Receive, and Rekey.

The primary function of the various states are as follows:

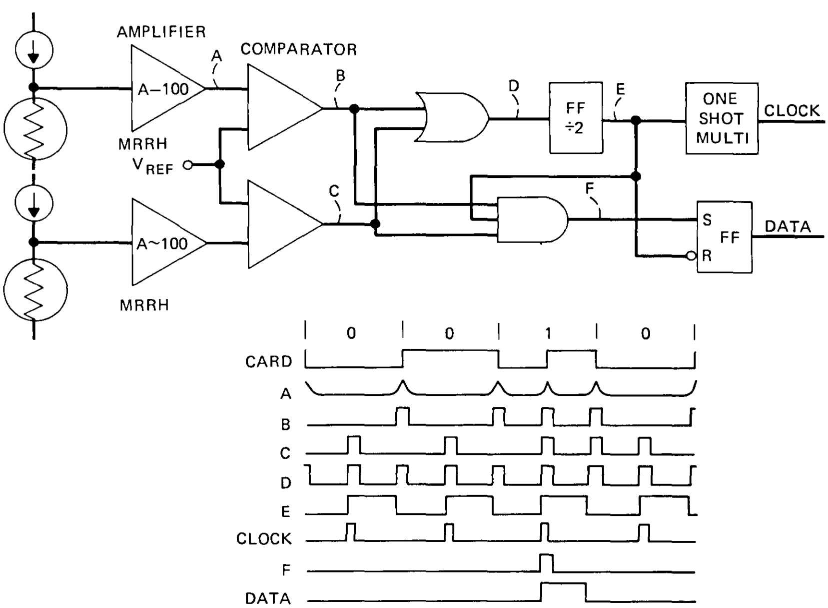


Fig. 7—Magneto-resistive card reader.

(*i*) Idle—Detect start of transaction (off-hook detection).
(*ii*) Merchant—Store telephone and merchant number. Enable option and response modes. Outpulse telephone number.
(*iii*) Customer—Store customer number and transaction data (e.g. dollar amount, PIN, etc). Outpulse inquiry message.
(*iv*) FSK Receive—Decode FSK response message. Execute response message. Execute data link protocol.
(*v*) Rekey—Decode KAT response message. Outpulse follow-up inquiry messages.

Control is passed between these states as appropriate in order to implement the over-all system requirements. Detailed operation internal to the states is accomplished by calling a set of subroutines in conjunction with testing various control flags stored in RAM. Some of the most interesting subroutines are described in the next section.

VII. SUBROUTINE FUNCTIONS

7.1 Key reading

When a key is operated on the manual data entry keyboard, it is the key reading subroutine (RDKEY) that detects the key, decodes it, covers contact bounce, and protects against multiple keys.

Keyboard data are given to the CPU through two 4-bit input ports. Each bit represents one of two keys, depending on the state of an output bit. The two ports are each read twice on each RDKEY cycle, thereby testing each key.

RDKEY takes approximately 800 μs to execute. This is the longest routine and accounts for the major portion of time used in each state except FSK. Because of this, RDKEY provides its own timing for bounce protection.

RDKEY scans the keyboard, testing for a key operation. If a key is found and no other key is operated, it is decoded and a counter set to inhibit further scanning for 40 ms,* thereby implementing bounce protection. RDKEY returns to the main program, indicating that a key was operated and which key it was. After the 40-ms passes, the keyboard is again scanned. As long as the same key is detected, the routine returns to the main program, indicating no key. As soon as no key or multiple keys are detected, the counter is set to inhibit scanning for 20 ms, and the routine continues returning an indication of no key. If a different key were detected after 40 ms, it would be handled the same as a new key operation.

* During this interval, each time RDKEY is entered, approximately 800 μs are wasted to maintain timing.

7.2 Card reading

The card reading subroutine (CDRD) receives the card data, stores it in a specified RAM location, tests character parity and card LRC, and signals the end of a card. CDRD is entered when the main program detects the presence of a card in the reader. There are three inputs to the CPU from the card reader: a data lead, a clock lead, and a switch lead indicating card in reader.

CDRD monitors the three leads, looking for a clock pulse. When the clock pulse is found, the data lead is sampled and the bit stored. One character consists of 5 bits, 4 data and 1 parity. Initial character framing is achieved by matching the incoming bit pattern with the hex character B, which is the first character on all cards. Each time a character is received, it is loaded in RAM, its parity checked, and then added to the previous characters to form the LRC. The end of card data is signaled by the hex character F. This is followed by the LRC character which is matched with the LRC generated by CDRD during the read. Since this character does not appear on all cards, this test is optional. The return to the main program indicates whether the card was read correctly (parity, LRC) or not. If at any time during the reading the card sense switch opens, control is immediately returned to the main program, indicating a bad read.

7.3 FSK receiver

The FSK receiver subroutine (RDFSK) monitors the data lead from the FSK receiver and detects the start of an FSK character. Once the start is detected, the subroutine maintains control of the set until the entire character is received. It then decodes the character, distinguishes between control and data characters, tests character parity, and updates the message LRC.

The FSK character consists of 10 bits. There is one start bit (0), 8 bits (7 ASCII, 1 parity), and one stop bit (1). Between characters, the data input lead stays at 1.

RDFSK monitors the data input lead looking for a "start edge," i.e., a 1-to-0 transition. If it does not find one, it returns control to the main program. Upon detecting a start edge, the routine times for 1/2-bit time, constantly monitoring the input lead. If the lead returns to 1 any time during the 1/2-bit time, RDFSK assumes it was a noise pulse and returns to the main program. If the lead remains at 0 the entire time, then RDFSK assumes it is a valid FSK character and proceeds to receive it.

RDFSK receives the FSK character by timing for 1-bit time, then sampling the data lead. Each time the lead is sampled, the bit is stored in a register and also added to the sum of the previous bits as a parity check. After 8 bits are received, the data lead is monitored until it becomes a 1, indicating the stop bit. The parity of the character is tested and the message LRC is then updated. The data are stored in RAM as they are received in a location reserved for the FSK message. If the character was a data character, then the pointer to the message location is updated to the next location. If the character was a control character, a control code is returned to the main program and the data discarded by not updating the pointer. In this way, only data characters are stored in RAM.

7.4 Outpulsing

Two subroutines are involved in outpulsing: RDEDGE, the routine that monitors the outpulsing clock and detects when it changes state, and OUTPL, the routine that actually does the outpulsing.

The number to be outpulsed is stored in a specific section of RAM. The specific digit is indicated by an outpulse pointer.

The timing for the outpulsing is provided by the outpulsing clock. The *TOUCH-TONE* oscillator is turned on at the leading (positive) edge and turned off at the trailing (negative) edge of the clock. The Dial Pulse (DP) circuit is both enabled and disabled at the trailing edge of the clock. The outpulsing clock is monitored by RDEDGE. When an edge is detected, OUTPL is called. OUTPL determines which edge has been detected and if the outpulse mode is TT or DP. If it is a leading edge and DP, no further action is taken. If it is a leading edge and TT, the TT oscillator is turned on to the frequencies representing the digit indicated by the outpulse pointer. The LRC and Character Count (CC) are also updated at this time. If it is a trailing edge and TT, the TT oscillator is turned off. The return to the main program in this case indicates that the outpulsing of the digit is complete. All the logic for DP outpulsing is done on the trailing edge of the clock. On the first edge of a new digit, that digit is stored in a temporary RAM location and the DP outpulsing circuit enabled. On following edges, the digit is counted down until it is zero, when the DP outpulsing circuit is disabled. At the same time, another counter is set to be counted down in the same manner to form the interdigit time. The return on the edge on which the DP controller was disabled indicates to the main program that the digit was outpulsed.

VII. CONCLUSION

The Transaction telephones and terminals provide efficient operation in short message inquiry/response systems. The user is provided with easy data entry modes (magnetic card reader and manual keyboard data entry) and sequenced instruction lamps. The responses (audio, visual, and printed) are clear and concise.

The Transaction telephone design utilizes a microprocessor to implement its numerous features. The employment of the PPS-4 microprocessor has permitted complicated hardware to be eliminated. The functions of the sets are written in software which interfaces with simplified peripheral circuitry. This is clearly evident in the interface of the Transaction II telephone with the Transaction printer. The Transaction telephone's software totally controls the operation of the printer.

The Transaction III terminal augments the dial Transaction telephones by providing service over dedicated exchange facilities. It is expected to find use in those applications that have high transaction volumes.

The use of a microprocessor makes the design features of the stations flexible and future feature offerings possible.

The development of stations with different features is possible with a software development and little or no hardware design. This permits a Transaction telephone to be updated with the demand for new features from the marketplace.

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Transaction Network, Telephones, and Terminals:

Physical Design

By D. D. BANKS, G. A. BHAT, and J. W. WESNER

(Manuscript received June 6, 1978)

Physical designs of Transaction I and II telephones and Transaction III terminal are described and illustrated. All three sets feature new card reader designs and a click-disk switch design. These designs are described in detail. Use of these designs in Transaction sets has helped to meet performance, reliability, and cost objectives.

I. INTRODUCTION

A field trial was conducted in the state of Ohio in late 1973 to establish the market potential for a Transaction telephone. Thirty-four sets were installed in 13 merchant locations in Cleveland and Akron for credit verification. The set used in the field trial is shown in Fig. 1. In addition to the parts associated with a telephone, the field trial set contained a motor-driven card reader and electronics required for the card reader and other functions. Instruction lamps, along with brief operating instructions and pockets for storing dialing cards, were located on the front of the set. Some sets also contained a numeric display of information entered from the *TOUCH-TONE*® dial. The field trial experience established the need for a more reliable card reader, a display of not only locally generated information but also an authorization code generated by the data center computer, and a button to permit correction of manually entered information. In addition, the trial established the usefulness of instruction lamps and instructions, and the importance of making the Transaction telephone set as small as possible, since the space where the sets are likely to be located is at a premium.

Utilizing field trial experience, the design of production Transaction telephones began in early 1974. Packaging the electronics of one of the most sophisticated telephone sets the Bell System has ever introduced was a challenge heightened by space and development time constraints.

Fig. 1—Transaction telephone used in field trial.

Transaction II, for example, contains a microprocessor, card reader, data receiver, power supply, numeric display, electronics for a hands-free feature, and a keyboard, all inside a low-profile housing with base dimensions of only 9 in. by 12 in. All three Transaction telephones were designed and introduced in the market in approximately 2½ years.

All Transaction telephones are in similar housings to maintain a family appearance and to minimize costs. The sets follow the current philosophy of offering business telephone sets in only one color and providing color accent with colored faceplates; the Transaction telephone faceplates are offered in eight different colors.

Transaction I and II also share the same card reader, some of the printed circuit boards, and some internal hardware. This has also resulted in reduced development time and in cost savings.

II. CONSTRUCTION

2.1 Transaction I, II, and III sets

The Transaction I, II, and III sets are shown in Figs. 2, 3, and 4. An important difference between Transaction I and II and Transaction III is that I and II function as telephones even in case of power failure, whereas III does not provide a telephone function at all. Transaction III

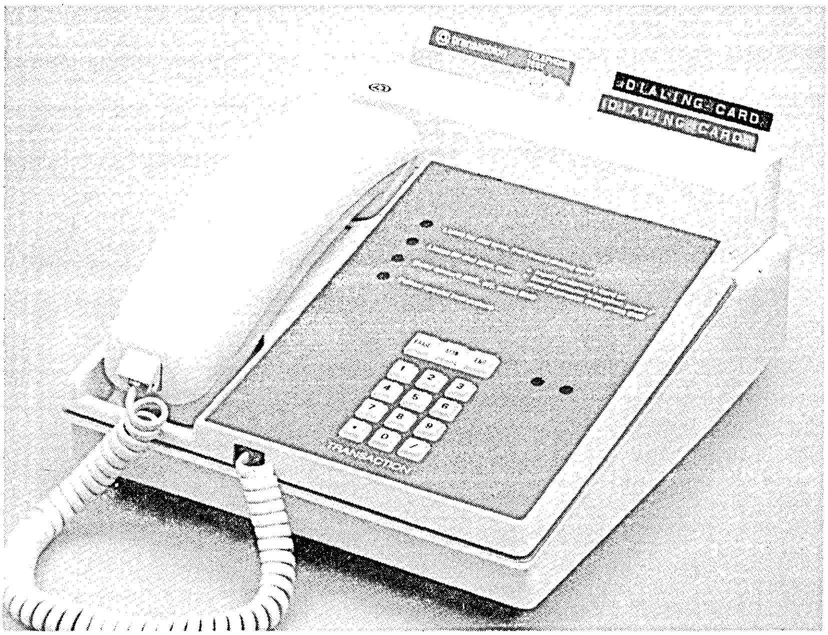


Fig. 2—Transaction I set.

is designed to be connected via private lines to TNS (Transaction Network Service). In Transaction I and II, the telephone function is provided by a *TRIMLINE*® handset that performs all the telephone functions except for ringing and line switching. The choice of the *TRIMLINE* handset has not only saved internal space, some of which otherwise would have been occupied by telephone components, but it also provides the option of rotary or *TOUCH-TONE* dialing without any space penalty.

The faceplate layouts of all three Transaction sets were based on human factors studies and are designed to assure easy operation of the sets and to minimize operator errors. The instruction lamps, response lamps, and call progress lamps located on the faceplates guide the operator through the transactions. Abbreviated operating instructions appear alongside the instruction lamps. It was assumed that the operator would be familiar with the operation of the set, and these instructions serve only to prompt the operator of the next step. A comprehensive operating procedure is described in a "How to Use" booklet supplied with every set.

A manual entry pad located in the lower half of the faceplate on all three sets consists of an array of click-disk switches similar to the ones used in some hand-held calculators. These switches were chosen because of their long life and low profile. A more detailed description of the pad is given in Section IV.

Fig. 3—Transaction II set.

The card reader located at the back of Transaction I and II consists of a "slot" in which a conventional magnetic head, a spring, and a switch are located. A card is read by passing it through the slot oriented so that the magnetic stripe passes along the face of the head. The card reader used in Transaction III uses a magnetoresistive read head instead of the conventional magnetic head. A detailed description of the two card readers is given in Section III.

There is sufficient similarity in the electrical design of Transaction I and II that several printed circuit boards (PCB) are common to both these sets. This commonality has helped reduce cost. Transaction I contains four printed circuit boards which provide a four-chip microprocessor with peripheral electronics, the power supply, the manual entry pad, and electronics associated with the card reader. Two voltage regulators and a transformer associated with the power supply are mounted on a heat sink located at the back of the set. Transaction II, which is more sophisticated than Transaction I, contains additional electronics, viz., a data receiver, an eight-digit, seven-segment numeric display, and electronics required for a hands-free feature. Incorporating the additional electronics in the same housing used for Transaction I presented a difficult problem. The additional electronics meant more power consumption, which presented a challenge in heat sink design. Under the worst-case conditions (i.e., line voltage of 129 volts and all 8's on the numeric display), the power to be dissipated in the heat sink is 15 watts

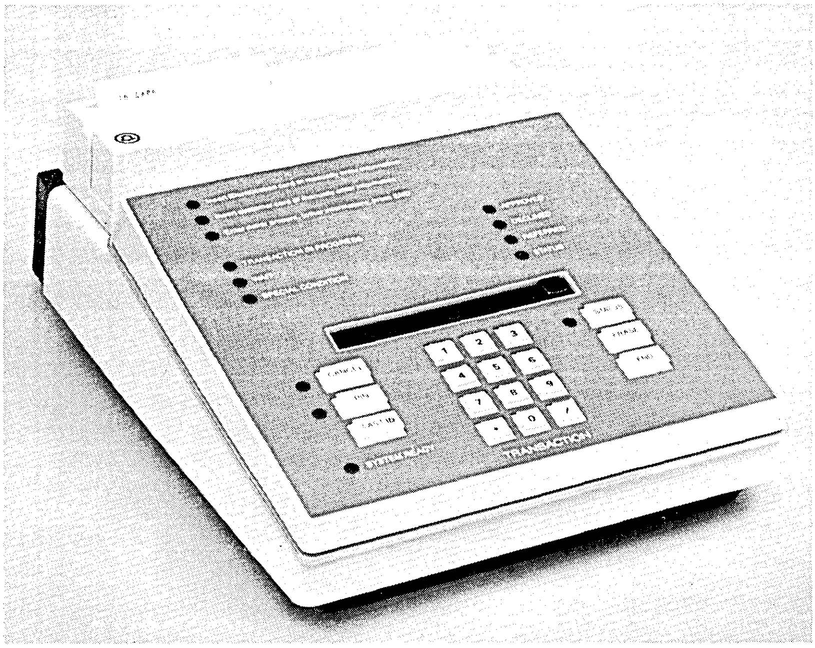


Fig. 4—Transaction III set.

while operating in the required maximum ambient temperature of 120°F. From a human engineering viewpoint, the temperature of the exposed heat sink should not exceed 140°F (a temperature considered too hot to touch). After the fin thickness and spacing were optimized, it would have been necessary for the heat sink fins to be approximately 2 in. long to achieve a fin temperature below 140°F; this would have violated size constraints and also have been aesthetically unacceptable. The selected compromise was to allow the heat sink to reach a temperature of 163°F (which could be achieved with fins only $\frac{3}{4}$ in. long) and to enclose the entire heat sink in a vented plastic cover to prevent direct user contact with the too-hot surface.

Electronics in Transaction III are packaged on six printed circuit boards which contain a five-chip microprocessor and peripheral electronics, a modem, a numeric display, a manual entry pad, and a power supply. Since the power consumption of Transaction III is approximately the same as Transaction II, it uses the same heat sink and cover arrangement.

2.2 PIN pad

A PIN pad, shown in Fig. 5, provides a means for entering a personal identification number (PIN) during a transaction. Since the PIN pad is a field-installable adjunct to all three Transaction sets, it is available in

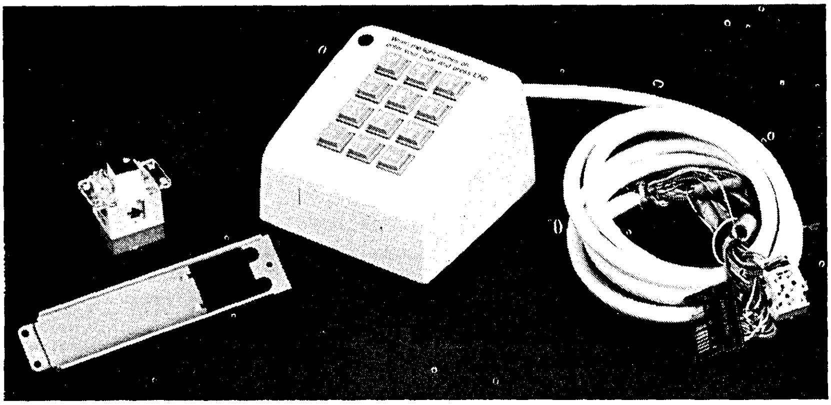


Fig. 5—PIN pad.

the form of a kit. The kit consists of a click-disk dial assembly, a cord, and a push-on/push-off key. (The added push-on/push-off key is not required in Transaction III because this function is performed by a switch integrated with the manual entry pad.) The push-on/push-off key, which mounts in the Transaction set, allows the operator to enable the PIN pad at the appropriate time during a transaction.

III. CARD READER

The card reader used in the field trial set was an electromechanical reader purchased commercially which contained a motor-driven rubber roller that pulled the card into the reader and moved the card past a fixed magnetic head at constant speed. A microswitch located at the back of the reader reversed the motor to return the card. The reader was expensive and did not meet reliability objectives; occasionally a card, especially one which had become dirty or wet, would not be returned to the user.

To avoid the problems of a motor-driven reader, an electronic technique was developed that permitted reading of cards over a wide range of speeds and speed variations. This technique simplified the physical design of the card reader considerably. A reader was designed that consists simply of a slot containing a magnetic head, a spring to maintain the proximity of the card to the head, and a switch; a card is read by manually passing it through the slot. The switch initiates the electronics when the card reaches the proper position with respect to the head. The reader has no moving parts (other than the switch actuator) and is quite insensitive to bent cards. The cost of the reader is also considerably less than any known alternatives. The "slot" reader was introduced in an early design of Transaction telephone; the set with this first slot reader is shown in Fig. 6. Human factor evaluations of this reader showed an error rate of only 2.4 percent on the first try.

Fig. 6—Transaction set with first slot reader.

3.1 *Transaction I and II card reader*

The slot reader as redesigned for the production sets is shown in Fig. 7. In this reader, the card moves in a vertical plane—a better position from a human factors standpoint than the first, sloping configuration. The reader housing also contains pockets for storing dialing and test cards.

3.2 *Transaction III card reader*

3.2.1 *Construction*

The card reader used in Transaction III employs a new technology: a magnetoresistive read head instead of the conventional magnetic split-ring read head. Pictures of the reader and the read head are shown in Figs. 8 and 9. Another improvement accommodates the printed circuit board containing the reader electronics in the reader housing rather than within the main part of the set. This feature has faciliated testing at manufacture, and troubleshooting and repair in the Western Electric repair centers.

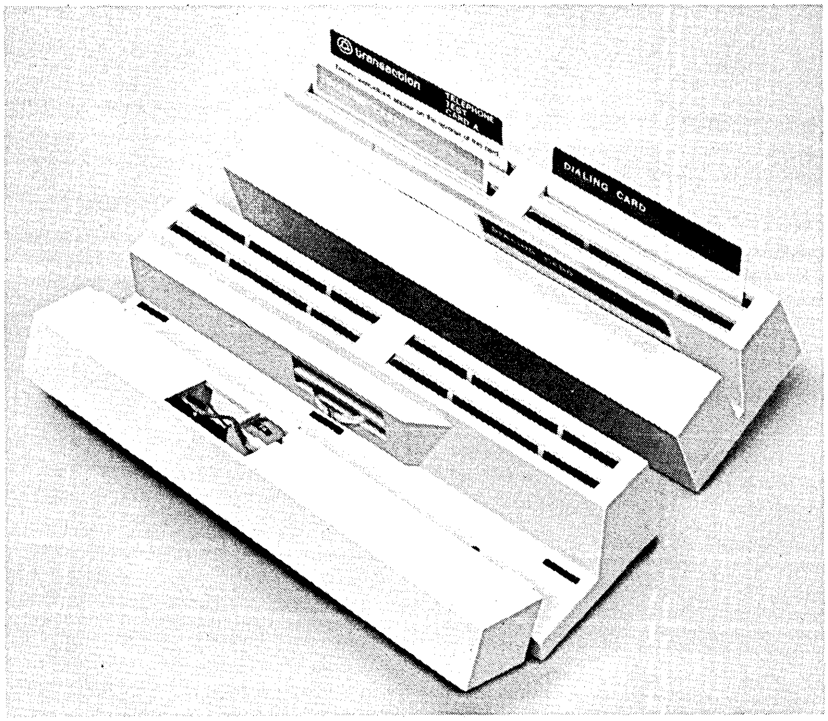


Fig. 7—Slot reader designed for production.

3.2.2 Read head

The magnetoresistive read head consists of a plastic holder and a ceramic chip (see Fig. 10) which contains two stripes of permalloy magnetoresistive material. Connections to the stripes are brought to the back side of the chip via feed-through holes, and leads are bonded to lands connected to the feed-through holes. The "stripe" side is coated with an acrylic material to protect the permalloy from wear.

Assembly of the chip in the holder is critical in that the exposed chip surface must be flush with the front surface of the holder. This has been accomplished by coordinated design of the holder and a special assembly fixture.

IV. MANUAL ENTRY PAD

4.1 Construction

The manual entry pad in all Transaction telephones consists of an array of click-disk switches. Construction of a typical click-disk switch is shown in Fig. 11. The two outer "staples" and the center "staple" form the contacts of the switch, and the dome-shaped disk acts like a switch arm. In the free position, the disk makes contact only with the outer

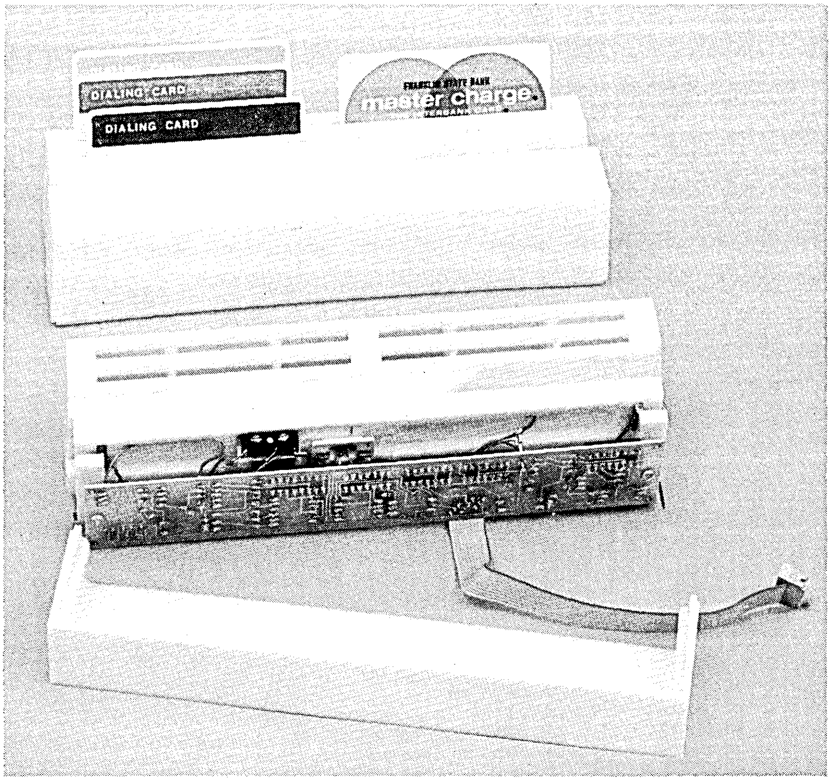


Fig. 8—Transaction III card reader.

staples. When sufficient force is applied to the disk, it buckles and makes contact with the center staple. The buckling action of the disk provides a tactile feedback to the switch. Nominal operate force of the switch is about 180 grams.

The click-disk switches were selected for the Transaction telephones for the following reasons:

(*i*) Long life—greater than 2 million operations.
(*ii*) Low profile.
(*iii*) Printed circuit board construction permits integration of the keyboard with other electronics. While it somewhat complicated the keyboard assembly, this approach (which was unique at the time of its introduction) eliminated the need for, and cost of, a separate terminal board.
(*iv*) Tactile feedback.
(*v*) Low incremental cost for additional switches. This has proved to be advantageous in Transaction II and III; costs of the additional control keys in these sets were small.

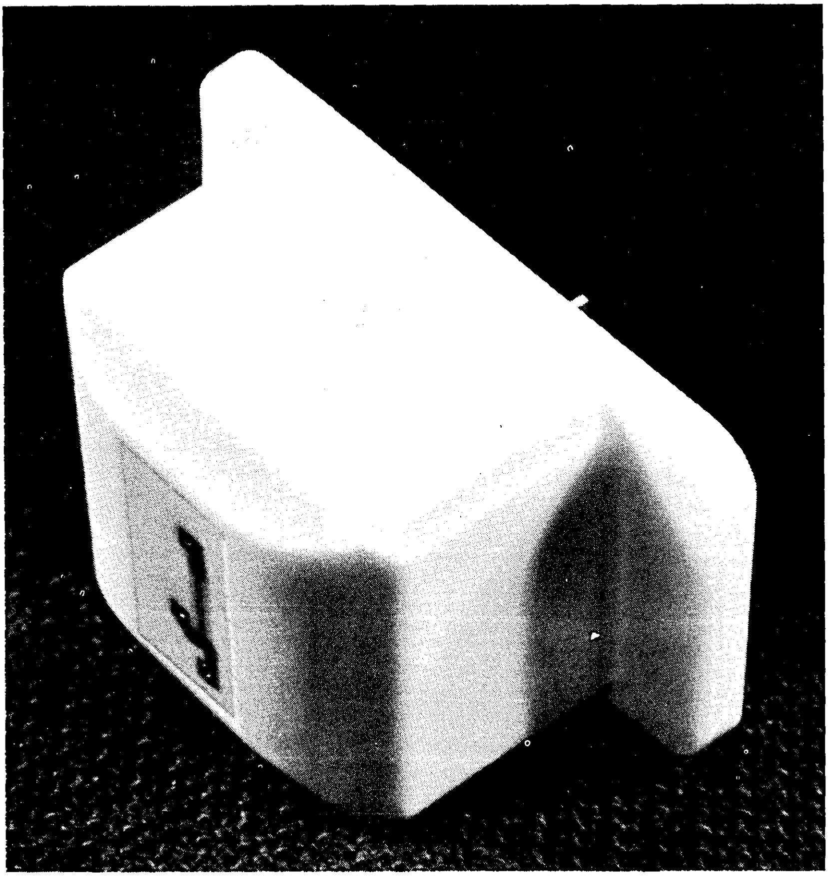


Fig. 9—Transaction III read head.

4.2 Human factors

Dials using click-disk switches were tested for dialing speed and accuracy. Click-disk dials with various button travels were tested, along with a regular *TOUCH-TONE* dial. The study concluded that, even though the *TOUCH-TONE* dial was preferred over all others (especially by subjects familiar with *TOUCH-TONE* dialing), the speed and error rates associated with use of the click-disk dials were not significantly different from those of the *TOUCH-TONE* dials.

4.3 Bounce

Even though the click-disk switches exhibit almost no detectable "bounce" when firmly depressed, they do exhibit a "bounce" problem if the buttons operating them are "tapped" or "teased." This bounce could cause double digits, unless it is compensated for by the electronics reading the keyboard.

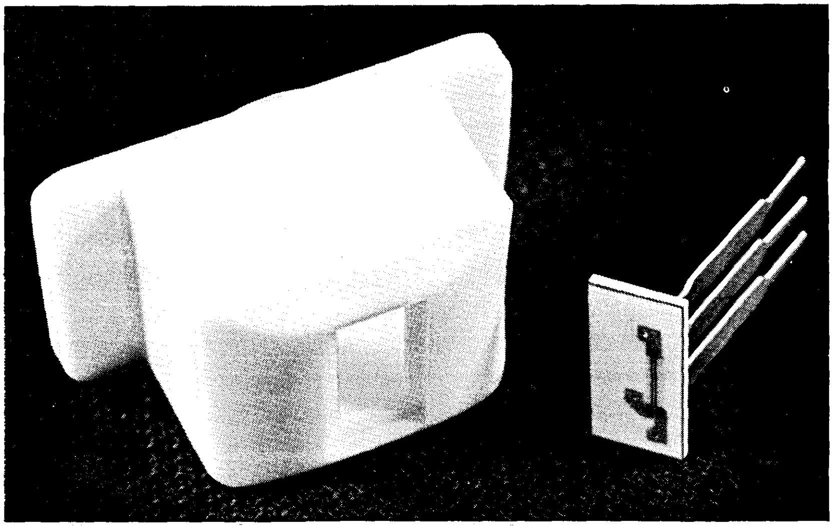


Fig. 10—Components of read head.

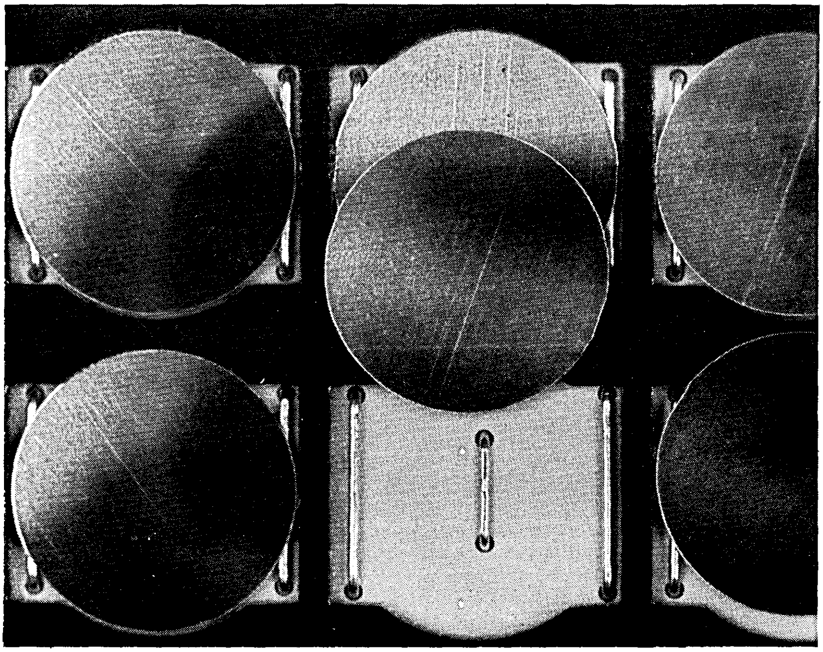
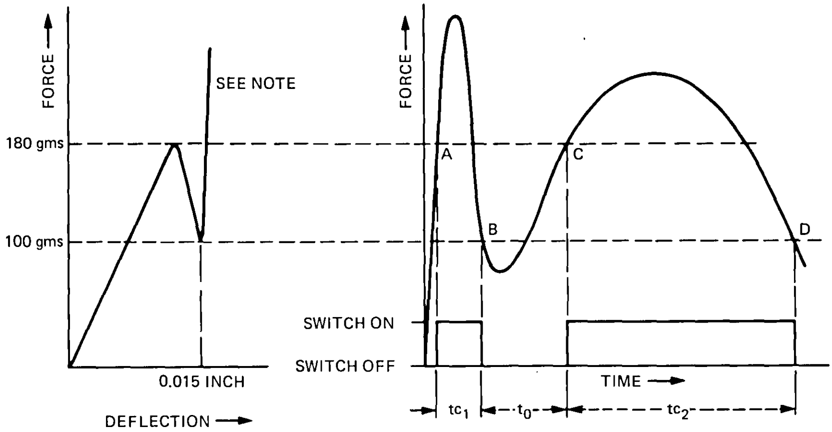


Fig. 11—Click-disk switch.

The bounce occurs because of the characteristics of the force applied by the finger, especially when the force is applied perpendicular to, rather than along, the axis of the finger (Fig. 12). The force-deflection curve for the disk is also shown in Fig. 12. When the applied force exceeds the



NOTE: AFTER THE DISK BOTTOMS ON THE CENTER STAPLE, THE SLOPE DEPENDS ON THE MANUAL ENTRY PAD SUPPORT.

Fig. 12—Click-disk switch force deflection characteristics.

"operate" force (point A), the disk buckles and the switch closes; when the applied force drops below the "release" force (point B), the disk begins to restore and the switch opens. Complete recovery of the disk depends upon how far the applied force drops below point B and how fast it builds up again. In any case, the switch definitely closes again when the applied force again exceeds the operate force (point C). The switch opens once again when the finger is lifted (point D). The first closure (tc_1) is typically 5 to 10 ms long, and the open period (t_o) is typically 2 to 30 ms long. The second closure (tc_2) is typically greater than 5 ms. Programming the microprocessor not to look for a switch closure for slightly more than 30 ms after a valid closure is detected eliminated the possibility of identifying the bounce as a second valid switch closure.

V. SUMMARY

The key to successful introduction of three Transaction sets in approximately 2½ years was in maintaining commonality of several components among the three sets. This commonality of parts helped to expedite the designs and minimize costs.

A new card reader which is simple to use, reliable, and inexpensive was introduced in these sets. Application of a new Bell System-developed magetoresistive read head technology has helped to further reduce the cost of the card reader. Click-disk switches, which are of non-Bell System design, were introduced in telephone sets for the first time in the Transaction sets. Their use has facilitated design while maintaining high reliability. Both the card reader and the click-disk switches have been well received in the field. The Transaction sets, which were originally intended for credit verification, are finding other applications in the financial industry—including use as a check-cashing terminal and a lobby terminal in banks where customers can determine their bank balances without seeking teller assistance. The sets have generally performed very well in all these applications.

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***Transaction Network, Telephones, and Terminals*:**

Transaction Printer

By H. G. MATTES and B. A. WRIGHT

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An inexpensive, reliable, impact pin printer adjunct has been designed to increase the range of applications for the Transaction II telephone and Transaction III terminal. The printer will accommodate a wide variety of forms due to its slip printer format and its ribbon inking mechanism. The character set includes the upper and lower case alphabets, numerics, and 25 punctuation marks. These can be printed at densities of 30, 40, or 50 characters per four-inch line at a rate of approximately 1.0 line per second.

I. INTRODUCTION

User experience throughout the Transaction telephone program has indicated the versatile nature of the terminals. Units that were installed for field trials in late 1973 and 1974 were used for credit authorization from retail locations, as bank lobby terminals for account information inquiry, and for check validation in grocery stores. Transaction I telephones, first installed in April 1975, have been used for remote banking, for entry of orders into a computerized purchasing system, and as bank teller terminals. Prospective uses of Transaction terminals include inventory and payroll control, data entry for insurance claims, and the countless credit, debit, and transfer operations of an electronic funds transfer system.

Many of these applications would be enhanced by a hard-copy delivery mechanism at the terminal location. For this reason, it was decided, in the summer of 1975, to provide a printer adjunct for the then-to-be-released Transaction II telephone and Transaction III terminal.

II. DESIGN GOALS

The design goals for the Transaction printer were strongly influenced by the wide range of existing and projected applications for Transaction terminals. The requirements can be considered in three categories: those relating directly to the printing operation, those relating to the physical configuration of the printer, and those relating to the provision of printers by operating telephone companies.

2.1 Printing requirements

Virtually all projected printer applications required the printing of numerals; most also required the printing of alphabetic and punctuation data. A printer with full alphanumeric print capability was therefore required. A character set consisting of the upper and lower case alphabet, numerals, and 25 punctuation and symbol characters was chosen (Fig. 1). Capabilities of printing multiple lines and of accommodating at least 40 characters on a single print line were also felt necessary. To enhance the printer versatility, print densities of either 30, 40, or 50 characters per line were provided (Fig. 1). A requirement for optical character recognizable font (OCR) was considered but was not implemented for several reasons. Since only information transmitted to a Transaction

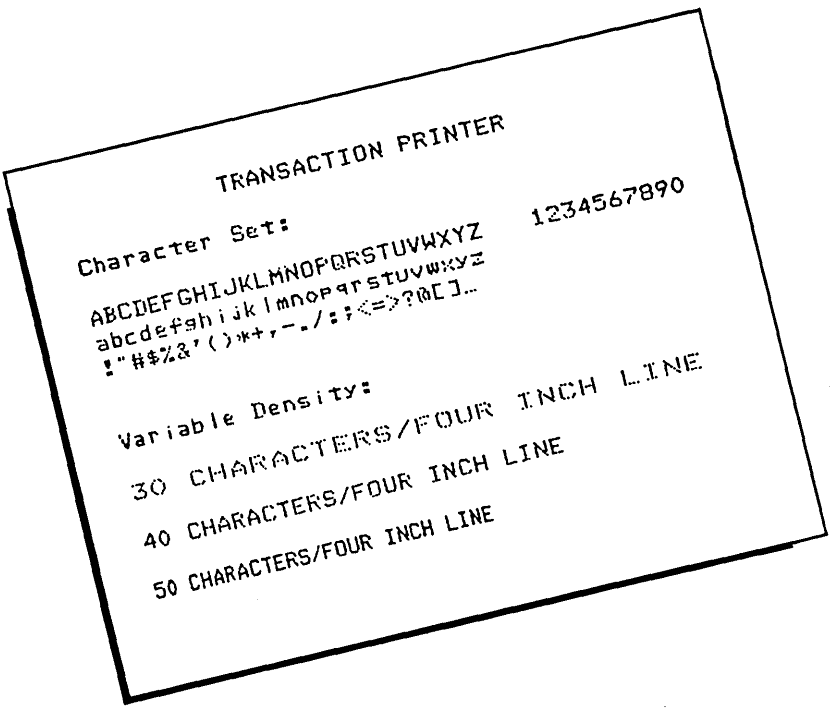

Fig. 1—Character set of printer.

terminal was to be printed, it was assumed that the data would already be stored in electronic form and that rereading the data from printed paper would be unnecessary.

Many printer applications would require printing on existing documents. In check authorization, for example, it would be desirable to print on the back of presently utilized bank checks. This required printing on plain paper. Impact printing using an inking medium, and not thermal printing or electric discharge printing, was thus mandated. Impact printing also satisfied another requirement, that of multiple copies. In credit validation, for example, multiple copies can be made by impact printing using conventional carbon or pressure-sensitive forms. Nonimpact techniques require reprinting the message for multicopies, and this would have entailed new forms.

The need to accommodate a wide variety of special forms, many already in existence, required a printer which handled paper in a "slip" format; that is, a printer with physical access to the printing region from three sides in the plane of printing. Although paper handling is greatly simplified by roll printing (as in cash registers) or ticket printing configurations (as in credit slip imprinters), the slip printer allows printing anywhere within the rightmost X inches of an indefinitely long or wide piece of paper. The dimension X is determined by the physical configuration of the mechanism; four inches was considered an acceptable compromise between maximizing print area and tolerable mechanical constraints. The slip printer which resulted can accommodate paper ranging from check size up to ledgers or invoices. Fanfold bank deposit books have been proposed and could be accommodated by a slip printer.

The variety of forms and paper stock to be printed, and the need for multiple copies, suggested that a range of paper thicknesses (stack height) must be accommodated. The design specification ranged from 0.003 inch (a single check or bond paper) to 0.015 inch (an original and three copies with tissue carbons).

Print speed was not firmly specified, but it was felt that a 100-character message, including line feeds and carriage returns, should be printable in three seconds or less after receipt by the Transaction terminal.

2.2 Physical requirements

In addition to the normal environmental requirements for Bell System business terminals, e.g., temperature and humidity range, shock and vibration, etc., the Transaction printer was required to provide an appearance and configuration suitable to its range of applications. Small size was a fundamental requirement, yet the printer would always be offered in conjunction with a Transaction II telephone or Transaction

III terminal. The demands on space, both footprint and vertical space, of the terminal-printer combination had to be minimized and made as flexible as possible. A configuration had to be offered wherein the combination appeared to the customer as a single unit. One corollary requirement was thus that the printer must provide a concealed ac power outlet and concealed cord stowage for the Transaction terminal.

2.3 Service requirements

Two nontechnical requirements affected the design process as dramatically as any other requirements: price and availability date. The pricing target indicated that a completed printer would cost no more than the Transaction terminal to which it would be attached. Additionally, prototype models for field evaluation were to be available 12 months after inception of the project.

These requirements mandated the use of commercially available printing and paper-handling mechanisms. One advantage of using existing mechanisms was the availability of reliability data for proven print mechanisms. Reliability is often a parameter that can be readily traded for lower cost in an electromechanical design process. Yet product reliability and maintenance requirements were specified to avoid service impairment.

Marketing data suggested a typical location life of 2.5 years for a Transaction terminal. Ideally, the printer should not require maintenance or repair within this interval. The most critical element thus became the inking mechanism. Assuming 50 printed characters per transaction, 10 transactions per hour, for a 12-hour day, operating 360 days per year, the 2.5-year life translated into a requirement of 5.4 million characters before ribbon replacement. The printing mechanism life objective is 50 million characters and 5 million line feeds before failure.

III. PRINTER DESCRIPTION

The Transaction printer was designed to allow the Transaction terminal to be mounted on top of the printer so as to give the appearance of an integral printing terminal, as shown in Fig. 2. Alternatively, the units may be mounted separately, up to 10 feet apart for flexibility of installation or to allow several terminals to share one printer. The printer alone measures approximately 13 in. deep, 10 in. wide, and 7 in. high, and weighs approximately 15 pounds. Forms are inserted into the printer from the front or right side, aligned with registration marks on the print table and housing, and fed from right to left during printing. The open print table design with access from three sides allows easy removal of a wide variety of forms. To help ensure proper form insertion, feedback is given to the user via a rear paper stop and by a paper prompt display in the terminal, as discussed below.

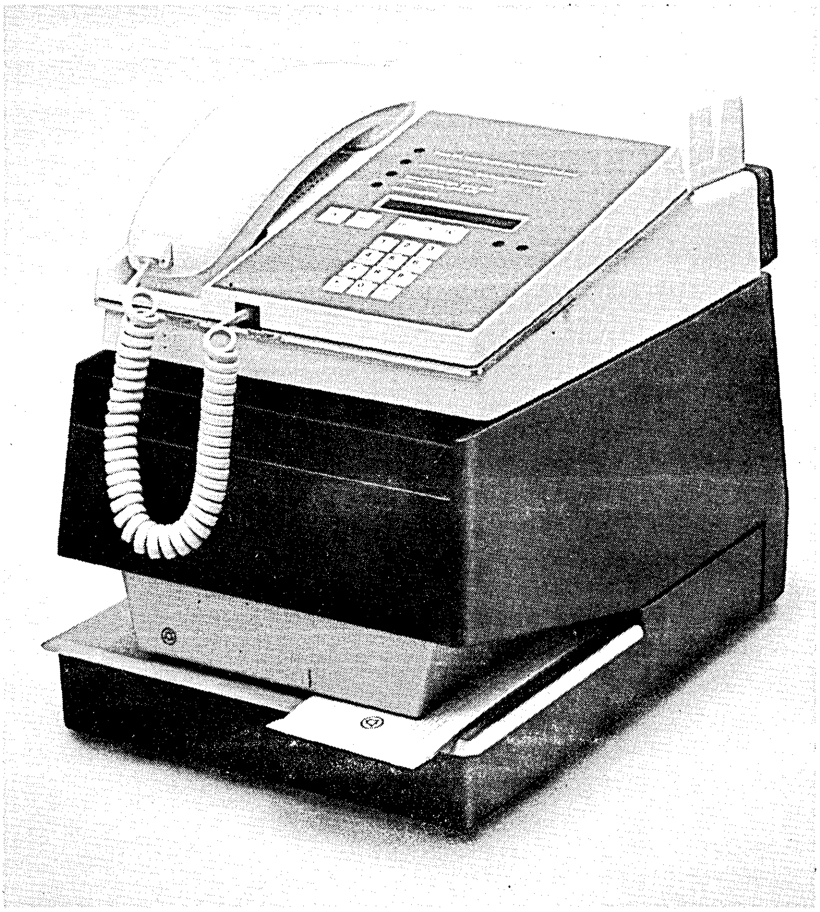

Fig. 2—Transaction printer and telephone.

As can be seen in Fig. 3, the printer is made up of four parts—the housing, a power transformer mounted in the housing, a printed circuit board, and a printing mechanism.

3.1 Printing mechanism

This mechanism (Fig. 4) was developed to Bell System requirements by Practical Automation, Inc., of Shelton, Conn., working in conjunction with Bell Laboratories. It consists of a 7-pin impact printing head driven at a constant velocity on two guide rods by a reversible, synchronous ac motor and cable drive system. Head position detection is provided for the control circuitry by optical sensors located near the left- and right-hand extremes of head travel. A 25-yard long, ½-in. wide fabric inking ribbon is fed from open reels and between the printing pins and a hardened steel platen by an automatically reversing ribbon advance

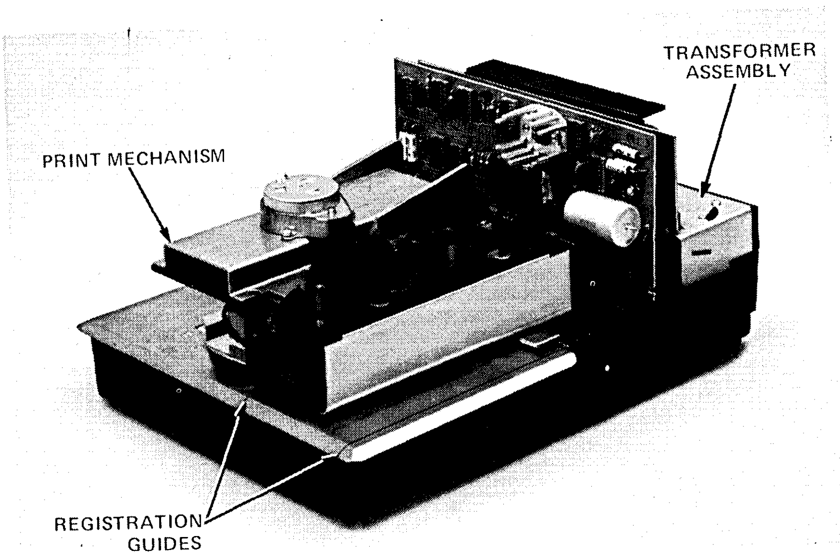

Fig. 3—Transaction printer, cover removed.

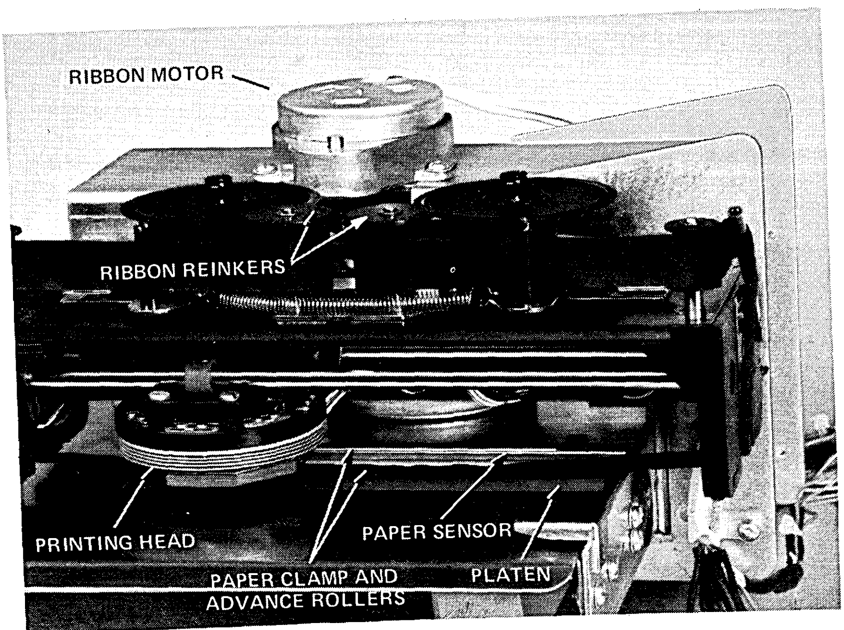

Fig. 4—Printing mechanism.

mechanism. This ratchet type mechanism is cam-operated from a unidirectional synchronous motor separate from the head drive motor. To improve ribbon life, the ribbon is fed in a skewed path across the print line and re-inked with a black oil-based ink by two porous inkers located on the ribbon feed mechanism. Ink selection is critical for impact pin printers. A conventional, pigment-based ink will cause premature head wear by abrasion of the pins. An oil-based ink must be used, which will lubricate the pins, provide adequate printing opacity, dry rapidly enough on glossy paper to prevent smearing, and yet not dry excessively on the ribbon or re-inking rollers. To ensure proper paper feed and minimize paper skewing, paper is inserted over a solid 4-in. wide paper advance roller. A solenoid-actuated top idler roller can clamp the paper on command by the Transaction terminal. Paper feed is accomplished with a solenoid-actuated ratchet drive mechanism. A mechanical paper-sensing switch protrudes through the print table to signal the control circuitry that paper is properly located between the rollers and against the rear paper stop.

The housing and print mechanism designs were configured to maximize the print area within the constraints of limited modifications to the commercially available mechanism. An unlimited number of 4-in. lines, starting 4.5 in. and ending 0.5 in. from the right-hand edge of the form may be printed subject only to the limitation of the 120-character buffer size when the printer is used with the Transaction terminals. Lines may start $\frac{7}{8}$-in. from the top of the form and, on most forms, continue to the bottom of the form. Forms smaller than $4\frac{1}{2}$ in. long by $6\frac{3}{4}$ in. wide can only be printed to within $1\frac{11}{16}$ in. of the bottom of the form; otherwise, these small forms disappear under the housing. This $1\frac{11}{16}$-in. restriction severely limits the useful printable area on petroleum industry and some credit-slip-sized forms, and studies are presently under way to consider adding a paper ejection means. With form ejection allowed, such forms could be printed to the bottom of the form, thus enhancing the versatility of the printer.

3.2 Circuit board

The printer circuitry, contained on the printed wiring board of Fig. 2, must interpret control and print character data from the Transaction terminal to properly operate the various paper sensing, clamp, feed, and printing functions provided by the print mechanism. An unregulated 50-V power source is generated on the circuit board to drive the paper clamp solenoid, paper feed solenoid, and the pins of the print head. Considerable savings in power supply cost and size are realized by using an unregulated 50-V supply. This is made possible by a novel head drive compensation circuit that will be discussed later. The remainder of the circuitry as well as the paper sense switch and head position sensors in the print mechanism are powered from a 5-V regulated supply. Twenty-seven volts ac is routed through the circuit board for control of the head and ribbon drive motors.

Care was taken in the power supply circuit design to protect the print head against overheating and subsequent failure in the event of circuit component failures. Both the circuit drive and voltage supply to the head solenoids are enabled only during the time the head is being activated to impact a print column. The low print-to-idle duty cycle ensures that the head does not have time to overheat to the point where it could sustain damage.

The majority of the hardwired control logic is implemented by CMOS gates because of the ease in providing the various time delays needed for proper printer operation. Control of the various print mechanism motors, solenoids, and print head solenoids are provided by triacs, discrete power transistors, and Darlington power drivers, respectively. A 1024 × 8-bit MOS ROM is used for character generation, control character decoding, and print density decoding (as discussed below). The eighth bit of each character word is coded to differentiate control characters and printable characters, thereby simplifying the logic design. To achieve circuit protection and proper printing operation in the presence of electrostatic discharges, the circuitry is packaged on a multilayer circuit board with a middle layer ground plane.

3.3 Printer-terminal interface

The printer connects to the Transaction terminal via a 10-lead interface containing 7 data leads, a data strobe (DS) lead, a data response (DR) lead, and a ground lead. The DS-DR protocol is designed to control the data transfer between the terminal and printer and to inform the terminal when a printer is attached, when paper is present, and when a printing error has occurred.

The printer-terminal interaction is best explained by proceeding through a typical printing sequence. Initially, the printer is in the idle mode, which corresponds to deactivation of all the printer motors, solenoids, and sensors. A high (logical 1) voltage is on the DR lead to indicate to the terminal that a printer is attached. Before printing a message, the terminal ensures that the printer is in its correct (idle) stage by setting up an ASCII-encoded ETX on the data leads and loading it into the printer data register during the positive transition of the DS lead. The terminal then interrogates the printer to determine if paper is present by loading a "∧" into the printer. If paper is present, DR momentarily drops in response to DS and the terminal proceeds to the printing sequence. If paper is not present, the word "PAPER" appears on the Transaction terminal display to prompt the user. When paper is inserted, the display prompts the user to push the END button on the keyboard by displaying "PUSH END." After the END button depression, the terminal transfers the data associated with a normal printing sequence.

A typical printing sequence starts with an STX loaded into the printer, which clamps paper, starts the ribbon moving, and turns on the optical head sensors. The first print character activates the printing cycle. DR is held low as the character is being printed and is raised after each character is printed to signal the terminal to load a new character. DR is also held low during line feeds (which cause a line feed, then carriage return) and carriage returns to inhibit further character loading until the head returns home and is ready to start a new line. Should the print message be improperly formatted or contain errors such that these control characters are not received, the optical sensor in the print mechanism senses the line overrun and maintains the DR lead low. When the terminal obtains no response on the DR lead in an appropriate time interval, it displays an error code indicating a printing error. Should paper be pulled out during printing or be misfed so as to deactivate the paper sensor, the DR lead is latched high and fails to respond to the next character. This produces the same error message in the terminal. Horizontal tabbing from any print location to the 11th, 21st, 31st, or 41st character is implemented in the terminal software and achieved by sending the printer an appropriate number of print spaces. The printing sequence is normally terminated by an ETX which returns the printer to the idle state.

3.4 Character printing

Before the first printable character is loaded into the printer, paper has been clamped and the ribbon set into motion by the STX character. The Transaction terminal then sets up the first print character on the 7 data leads and sends the printer a 400-μs DS pulse. After a 15-μs integration period to eliminate short duration noise transients, the terminal interface circuit generates a 385-μs strobe pulse. The leading edge of this pulse latches the data, and the trailing edge starts the head moving to the right and enables a voltage-controlled oscillator (VCO) and 4-bit counter. The VCO is nominally arranged to run at 1000 Hz to print a 40-character line in 400 ms. If a "BEL" or "/" is received prior to the first print character of the line, the oscillator frequency is scaled appropriately to achieve a 50- or 30-character line, respectively. The counter counts to eight and temporarily halts. After the head reaches a uniform velocity, it exits the start-of-line optical sensor and the count is reinstituted, continuing from 9 through 16. The 9th count corresponds to a one-column space on the left of the first character, and the 10th through 16th counts make up the seven vertical column strokes in the 7×7 character font. On subsequent characters, the counter is arranged to cycle from a 7th through 16th count. The 7th through 9th counts make up the three-column intercharacter space, and the 10th through 16th counts correspond again to the seven column strokes of the printed character. The three least significant counter bits control the ROM address for the proper character generation, and the most significant bit is used in the print head drive circuit to allow the ROM outputs to activate the print solenoids.

3.5 Printer circuitry

Three aspects of the printer circuitry may be considered as novel:

(*i*) The use of a single ROM for character generation and control functions.

(*ii*) The use of variable print density under remote software control.

(*iii*) The use of variable solenoid drive timing to compensate for power supply fluctuations.

These features are illustrated in the schematic drawing of Fig. 5.

The ROM has 10 input leads and 8 output leads. Seven of the input leads receive an address in the form of an ASCII code which may indicate a printing character or may indicate a control character. The other three ROM inputs come from the counter discussed above. Seven of the ROM output leads are connected, through gates, to high current drivers which control print head solenoids. The eighth ROM output indicates whether the ASCII address indicated a printable character. If it did indicate a printable character, output lead 8 will go high, enabling the data on output leads 1 through 7 to be fed through gates to the print head solenoids. If output lead 8 goes low, in response to an ASCII input for a non-printing character such as line feed, carriage return, etc., the signals from output leads 1 through 7 will not be communicated to the high current drivers and instead can be used for other control functions.

Let us consider Fig. 5 in the case of a printing character present on ROM input leads 1 through 7. Output lead 8 will be high, and the two AND gates on the left side will be disabled by the action of the inverter. The high on output 8 will enable timer A, and timer A will generate a series of pulses whose frequency will be determined by capacitor C_1, resistors R_1 and R_2, and any current fed from resistors R_3 and R_4. The duration of each pulse from timer A is determined by resistor R_2 and capacitor C_1, and is of no consequence in the operation of this circuit. The rising output to each pulse of timer A will trigger timer B to respond with a single pulse whose duration is determined by the value of capacitor C_2 and the current fed into C_2 through resistors R_5 and R_6. This output from timer B will act on the seven AND gates, allowing the high current drivers to respond to the signals on output leads 1 through 7 of the ROM.

The rate of pulses out of timer A determines the rate at which the character font is formed. Since the print head moves across the paper at a constant velocity, fixed by a constant speed motor and gears, the rate at which characters are formed can be adjusted by varying the rate at which the solenoids are activated. The Transaction printer can vary this rate so that 30, 40, or 50 characters may be spread evenly over a 4-in. printing line. It varies the rate in the following way. To print 30 char-

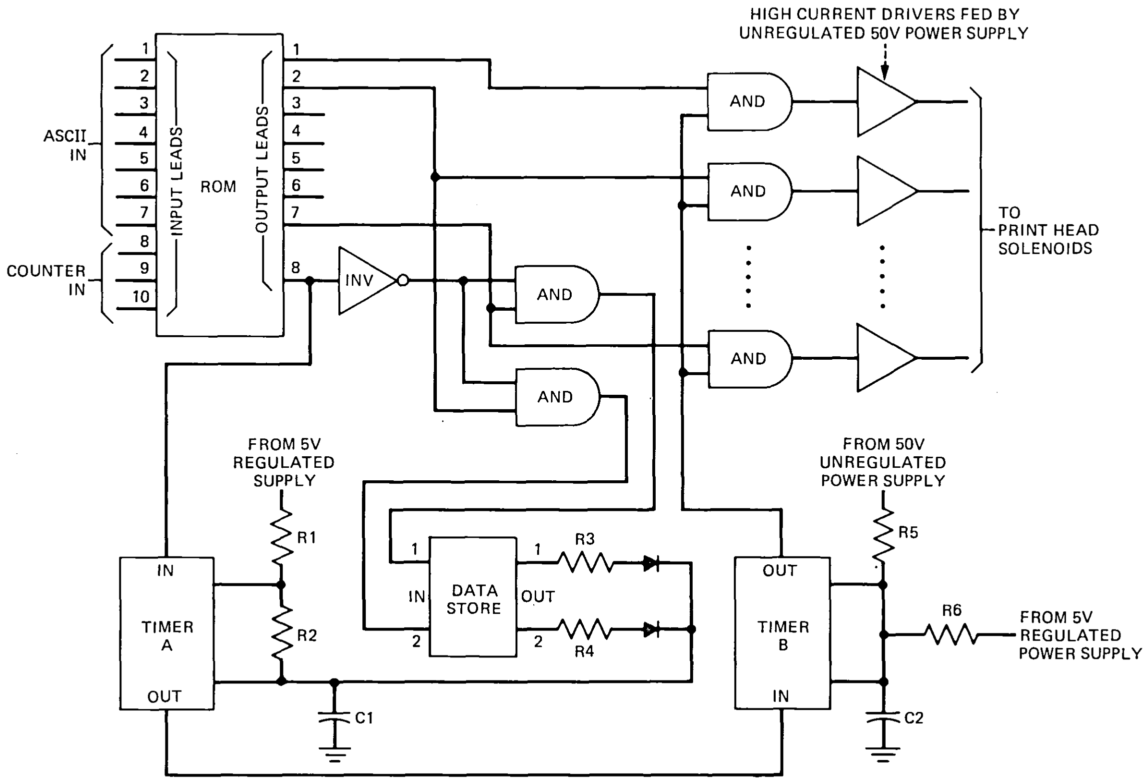

Fig. 5—Printer circuitry.

acters per line, the slowest rate out of timer A, current is fed into C_1 through resistor R_1 and R_2. To increase the rate of pulses out of timer A to the 40-character-per-line rate, current is also fed through R_3 by raising output 1 of the data store. To further increase the rate of pulses out of timer A, so as to obtain 50 characters per line, current is fed through both R_3 and R_4 by raising both data store outputs. The data store outputs are changed by the data store inputs which are sensitive to certain of the ROM output leads 1 through 7. This only occurs when ROM output lead 8 is low, indicating a nonprinting character. By this means, a special ASCII word can change the printing density.

Timer B controls the length of time when the high current driver feeds power from the unrelated 50-V power supply to the print head solenoids. Timer B produces a single output pulse in response to each input pulse from timer A. If the 50-V power supply were unvarying in its voltage, timer B could produce a pulse of uniform length and yield acceptable print. Unfortunately, the print head may draw currents as high as 10 A

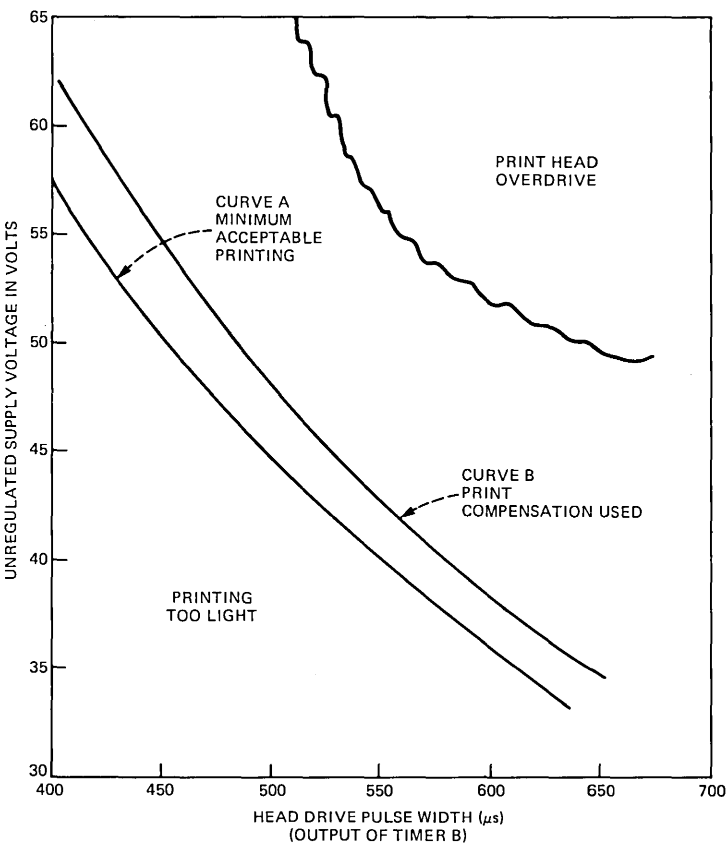

Fig. 6—Power supply voltage and pulse width for acceptable printing.

when printing a vertical column. It is economically unattractive to construct a power supply that can yield such high current pulses while not varying its voltage output more than a small amount. A more economical power supply design would vary its output voltage over a wide range, say, plus 10 percent, minus 50 percent, when large currents are drawn and/or the ac line voltage is varied. If timer B produced constant length pulses, this inexpensive power supply would yield unacceptable printing.

Curve A in Fig. 6 shows the range of power supply voltages and pulse widths which yield acceptable print quality. Too low a voltage and/or too short a pulse width will result in printing which is unacceptably light. Too high a voltage and/or too long a pulse width will waste power, will overheat the print head, and may cause blurred printing. The combination of resistor R_5, feeding from the unregulated 50 V supply, and R_6, feeding from a regulated 5 V power supply into capacitor C_2, causes timer B to exhibit the pulse width versus supply voltage variation shown by curve B in Fig. 6. This yields satisfactory print over the entire operating range of the low cost, unregulated 50-V power supply used in Transaction printer.

IV. CONCLUSION

First Bell Laboratories prototype models of the Transaction printer were available in the summer of 1976. Further prototypes were provided for a field trial starting in the fourth quarter of that year. After incorporation of certain design improvements, design information was released to Western Electric for the production of the 5000A Transaction printer in the second quarter of 1977.

Contributors to This Issue

William E. Baker, B.S.E.E., 1956, Saint Louis University; M.S. (Mathematics), 1964, Rutgers University; Bell Laboratories, 1956—. Since joining Bell Laboratories, Mr. Baker has worked in the data transmission area and on electronic PBXs. He was involved in the design of test equipment for the different transaction sets. He is licensed as a Professional Engineer in the State of New Jersey and is a member of Pi Mu Epsilon.

Donald D. Banks, B.S. (mechanical engineering), 1941, Newark College of Engineering; Marine Engineering, 1942, U. S. Naval Academy; N. J. Bell Telephone Co., 1941–1960; Bell Laboratories, 1960—. Mr. Banks began his telephone career as an installer in the N. J. Bell Telephone Company and rotated through various assignments as a supervisor in the plant and engineering departments. In 1960, he joined Bell Laboratories' Common Systems laboratory where he supervised the physical development of the Stored Program Control for the Traffic Service Position System. He joined the Station Systems Laboratory in 1973 where he supervises the physical design of station apparatus.

Leland R. Beaumont, B.S.E.E., 1972, Lehigh University; M.S.E.E., 1974, Purdue University, Bell Laboratories, 1973—. Since joining Bell Laboratories, Mr. Beaumont has worked on software development projects including planning tools for *DATAPHONE*® Digital Service and Maintenance Software for Transaction Network. Currently he is a supervisor of the Maintenance Operations Software Group, working on the Advanced Communications Service.

G. A. Bhat, B.E., 1967, University of Poona, India; M.S.M.E., 1968, University of California; M.S.E.E., 1975, Brooklyn Polytechnic Institute; Bell Laboratories, 1973–1978. Before he came to Bell Laboratories, Mr. Bhat developed experience designing dynamic devices such as accelerometers and gyroscopes; at Bell Laboratories he was associated with the Transaction telephones. Member, ASME.

Howard A. Bodner, B.E.E. (Electrical Engineering), 1963, M.S., 1965, Ph.D., 1968, Cornell University; Bell Laboratories, 1968—. At Bell Laboratories, Mr. Bodner first worked on theoretical problems in data communications. He was then involved in the design and implementation of the Transaction Network Service with particular emphasis on the host procedures. He presently supervises a group responsible for the systems engineering aspects of the host computer interfaces for the Advanced Communications Service. Member, Phi Kappa Phi, Tau Beta Pi, Eta Kappa Nu, IEEE.

C. A. Buzzard, B.S.E.E., 1964, M.S.E.E., 1965, Cornell University; Bell Laboratories, 1964—. Mr. Buzzard has worked on the development of data sets and data networks. He is presently supervisor of the circuit design group, Advanced Business Telephone Systems Department.

Karen L. Cohen, B.S., 1970, Ohio State University; M.S. (Computer Science), 1974, Ohio State University; Bell Laboratories, 1976—. Since joining Bell Laboratories, Ms. Cohen has been working on call processing, maintenance, and audit programs for Transaction Network.

John A. Drager, B.S.M.E., 1964, University of Maryland, 1964; S.M. (M.E.), 1965, Massachusetts Institute of Technology; Bell Laboratories 1964–1978; AT&T, 1978—. Mr. Drager has been involved in physical design of data sets and data systems, including an acoustically coupled data set for low-speed data transmission, data line concentrator, the switched digital data system, and the Transaction Network. From 1976 to 1978, he supervised groups involved in design of 407 data sets and Transaction Network peripherals. He is currently an Assistant Manager for Teletype products at AT&T. Member, Phi Kappa Phi, Tau Beta Pi, Pi Tau Sigma.

Ronald M. Dudonis, Polytechnic Institute of Brooklyn, 1954, 1956–1958; University of Maine, 1960–1962; Bell Laboratories, 1956—. Mr. Dudonis has worked on the AMA circuit in both No. 1 ESS and TSPS No. 1. He designed and built the exploratory version of the Automated Coin Toll service equipment in TSPS and helped develop the software for Transaction I and II telephones.

J. W. Fitzwilliam, B.S., Physics, Case Western Univ., 1940; Ph.D., Physics, M.I.T., 1947; Bell Laboratories, 1953—. Mr. Fitzwilliam's early work concerned the development of magnetrons. In 1955 he was appointed Department Head responsible for work on TJ microwave radio, and later for development of the TH system. In 1958 he became Director of the Electron Device Laboratory, where he was responsible for the design of various microwave tubes used in the Telstar project. In 1962, Mr. Fitzwilliam was named Director of the Array Radar Laboratory; and in 1968 Executive Director of the Station Systems Division, where he was responsible for providing the concept, systems engineering, design, and development of customer premises telephone system equipment. In 1977 he was appointed Executive Director of the Systems Studies Division. Member, American Physical Society, American Crystallographic Association, Tau Beta Pi and Sigma Xi.

Fritz E. Froehlich, B.S. (Physics), 1950, M.S. (Physics), 1952, Ph.D. (Physics), 1955, Syracuse University; Bell Laboratories, 1954—. Mr. Froehlich conducted high-altitude cosmic ray research before he joined Bell Laboratories. At Bell Laboratories, he first worked in electronic switching. Following this, he worked in data transmission on voiceband and wideband modems, error control techniques, automatic equalizers and in data theory. In the station area, he was responsible for electronic telephones and the Transaction telephone family. He is currently head of the Business Terminal Department. Fellow and member, IEEE; member, Phi Beta Kappa, Sigma Xi, Sigma Pi Sigma, Pi Mu Epsilon, N.Y. Academy of Sciences, and the American Association for the Advancement of Science.

Travis H. Gordon, B.E.E., 1960, M.S.E., 1962, Ph.D., 1964, University of Florida; Bell Laboratories, 1965—. Mr. Gordon's work has included data set design and analysis, data multiplexing and switching analysis, and, most recently, system planning for Transaction Network Service. Member, IEEE, Phi Kappa Phi.

W. Gordon Heffron, Jr., B.E.E.E., 1947, Tulane University; M.S.E.E., 1950, Purdue University; D.Sc., 1969, The George Washington University; General Electric Co., 1949–1955; General Dynamics Corp. (Convair), 1955–1956; Melpar, Inc., 1956–1964; Bellcomm, Inc., 1964–1972; Bell Laboratories, 1972—. At Bellcomm, Mr. Heffron was Head of the Guidance and Navigation Department, concerned with the Apollo Lunar Landing program. Since transferring to Bell Laboratories, he has been Department Head for systems engineering of the Digital Data System, the Switched Digital Data System, and the Transaction

Network System (for which he was also responsible for software development). He is now involved in engineering and economic studies of advanced communications systems. Registered professional engineer; member, Eta Kappa Nu, Sigma Xi; senior member, IEEE.

David R. Johnson, B.S.E.E., 1962, Newark College of Engineering; M.S.E.E., 1966, University of Pennsylvania; Bell Laboratories, 1964—. Mr. Johnson has performed circuit design for portable test equipment, circuit and software design for the Automatic Data Test System, and software design for the Transaction Network. He is currently working on the Advanced Communications Service.

John H. Kee, A.A.S., 1963, Staten Island Community College; B.S.E.E., 1972, Newark College of Engineering; M.S.E.E., 1974, Columbia University; Bell Laboratories, 1963—. Mr. Kee has been involved in the design of various data products and the Transaction telephones. He is presently responsible for all Transaction station work. Member, Tau Beta Pi, Eta Kappa Nu.

Hans G. Mattes, B.S. (engineering), 1964, California Institute of Technology; M.S., 1966, Ph.D. (electrical engineering), 1968, University of Southern California; Bell Laboratories, 1968–1970, National Taiwan University, 1970–1971, Bell Laboratories, 1972—. Mr. Mattes has been involved in the design of various specialized input and output modules for use with communications terminals. He is presently supervisor of the New Services Group in the Station Systems and Business Terminal Laboratory.

C. B. Mc Dowell, B.S.E.E., 1965, M.S.E.E., 1967, Ph.D., 1969, Duke University; Bell Laboratories, 1969–1977; AT&T, 1977—. At Bell Laboratories, Mr. Mc Dowell supervised the development of the Switched Network Transaction Telephone System and worked on an exploratory development of telewriting systems. He is currently the Assistant Engineering Manager for Customer Equipment Systems at American Telephone and Telegraph Co. Member, IEEE, Tau Beta Pi, Eta Kappa Nu, Sigma Xi.

W. E. Omohundro, B.S. (E.E.), 1970, M.S. (E.E.), 1971, and Ph.D. (E.E.), 1973, University of Missouri at Rolla; Bell Laboratories, 1973—.

Mr. Omohundro has worked on communication protocols, diagnostics, and maintenance on the Transaction Network. He currently supervises a group that has responsibility for the Transaction Network and also for operations support on the Advanced Communications Service.

Robert E. Reid, B.E.E., 1970, Georgia Institute of Technology; M.E.E., 1971, Stanford University; South Central Bell (part-time), 1965–1970; Bell Laboratories, 1970–1977; AT&T, 1977—. Mr. Reid was in the Data Communications Planning Center while at Bell Laboratories and has worked on the Digital Data System implementation strategy and time-shared programs to aid the operating telephone companies in the deployment of DDS. His work on the Transaction Network System began in 1974 and concentrated in polled terminal call processing, system integrity, and initialization. Mr. Reid is currently Supervisor in the Data & Special Services section at AT&T and has engineering responsibilities for voice band data sets. Member, Tau Beta Pi, Eta Kappa Nu.

Robert F. Ricca, B.S.E.E., 1950, New York University; Western Electric Company, 1941–1960; Bell Laboratories, 1960—. Mr. Ricca was involved in various phases of ABM system work until 1975. Since then, he has been a member of the Transaction Network Planning Group.

Ernesto J. Rodriguez, B.S. (Math.), 1967, Michigan Technological University; M.S.O.R., 1970, New York University; Bell Laboratories, 1967—. Mr. Rodriguez initially worked on various aspects of computer-access planning for *PICTUREPHONE*® service. He supervised a group responsible for developing software aids to help telephone companies in planning for the *DATAPHONE*® Digital Service. He was also involved in the software development and design of the Transaction Network. Mr. Rodriguez is currently head of a department responsible for data message switching software development.

Burton R. Saltzberg, B.E.E., 1954, New York University; M.S. (E.E.), 1955, University of Wisconsin; Sc.D., 1964, New York University; Bell Laboratories, 1954—. Since joining Bell Laboratories, Mr. Saltzberg has been engaged in development and theoretical analysis of data communications. Since 1968, he has been supervisor of a group involved in designing data communications systems. Member, Eta Kappa Nu, Tau Beta Pi, Sigma Xi. Fellow, IEEE.

Frank P. Sansone, B.S.E.E., 1966, Manhattan College; M.S.E.E., 1967, Columbia University; Bell Laboratories, 1966—. Mr Sansone has worked in the area of data communications since joining Bell Laboratories. He has been involved in the development of a variety of data systems and is presently head of the Voiceband Data Communications Department. Member, IEEE, Eta Kappa Nu.

Norman E. Snow, B.S.E.E., 1952, University of Arkansas; Southwestern Bell, 1952–1957; Bell Laboratories, 1957—. Mr. Snow initially worked in the Arkansas area of Southwestern Bell where he engineered toll terminal, local switching, and central office power installations. At Bell Laboratories, he has worked in both systems engineering and development of voiceband and wideband data sets and systems for a variety of standard and special-purpose Bell System data services. He is presently Bell Laboratories Field Representative in Chicago. Registered professional engineer; member, Tau Beta Pi, Theta Tau, Phi Eta Sigma, Pi Mu Epsilon.

Kenneth W. Sussman, B.E.E., 1963, City College of New York; M.E.E., 1964, New York University; Bell Laboratories, 1964–1969; AT&T, 1969–1971; Bell Laboratories, 1971—. At Bell Laboratories, Mr. Sussman worked on computer-aided design and simulation techniques until 1969. From 1969 to 1971, he was an Assistant Engineering Manager at AT&T responsible for the planning of the Switched Digital Data System. From 1971 to 1974, he supervised a group at Bell Laboratories responsible for studies of the effects of unusual usage traffic on the Message Telephone Network. In 1974, he assumed his present position, supervising a group responsible for system engineering of the Transaction Network. Member, IEEE, Tau Beta Pi, Eta Kappa Nu.

Robert L. Wagner, B.S., 1949, and M.S., 1952, Electrical Engineering, Rutgers University; Bell Laboratories, 1954–1962, 1972—. Mr Wagner was initially concerned with the development of techniques for underwater detection of submarines. In 1962 he joined Bellcomm, Inc. and in 1967 became Executive Director of Bellcomm's Systems Engineering Center; simultaneously he served as NASA's Director of Systems Engineering for Apollo. His work included systems studies and analysis, systems engineering, planning, and technical support for NASA on the Apollo Project to land men on the moon and return them to earth. In 1972 Mr. Wagner rejoined Bell Laboratories as Executive Director on Special Assignment in the Network Planning and Customer Services

Area, and later in the same year became Executive Director of the Data and Mobile Communications Division. Member, Phi Beta Kappa and Tau Beta Pi.

John W. Wesner, P.E., B.S.M.E., 1958, Carnegie Institute of Technology; M.S.M.E., 1959, California Institute of Technology; Ph.D. (mechanical engineering), 1968, Carnegie-Mellon University; Bell Laboratories, 1968—. Mr. Wesner is a Supervisor in the Station Physical Design Department. He was the original physical designer for the Transaction telephones, beginning with the field trial, and remained on the project through field introduction. His first supervisory task was to bring the Transaction printer into production and then into the field. More recently, he has been responsible for exploratory physical design work related to office communications. Member, ASME, NSPE, Sigma Xi, Pi Tau Sigma, Tau Beta Pi.

Bernard A. Wright, B.S.E.E., 1960, University of Michigan; M.S.E.E., 1963, New York University; Bell Laboratories, 1960—. Mr. Wright has been involved in the design of *PICTUREPHONE*® station sets and Transaction terminals. He is presently a supervisor in the Station Circuits Department and responsible for special telephone activities. Member, IEEE, Tau Beta Pi, Eta Kappa Nu, Phi Kappa Phi.

G. Daniel Zally, B.A. (Physics), 1961, University of Utah; M.S., 1966, and Ph.D. (Physics), 1970, University of Illinois, Urbana; Bell Laboratories, 1970—. Since joining Bell Laboratories, Mr. Zally has done research on the perception of reverberant speech and on processing speech for speakerphone applications. He has worked on the development of speakerphones and other station equipment, including Transaction telephones. He is currently involved in designing office communications systems. Member Phi Beta Kappa, Sigma Pi Sigma, Phi Kappa Phi, APS.

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