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Transaction Network, Telephones, and Terminals:

Polled Access Interface

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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

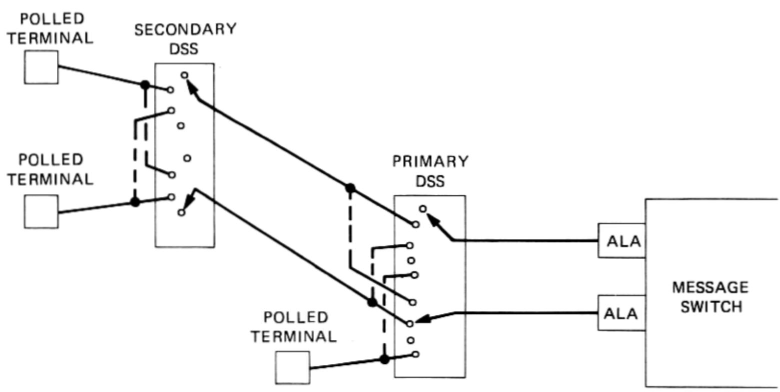

Fig. 1—Polled Access Circuit.

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

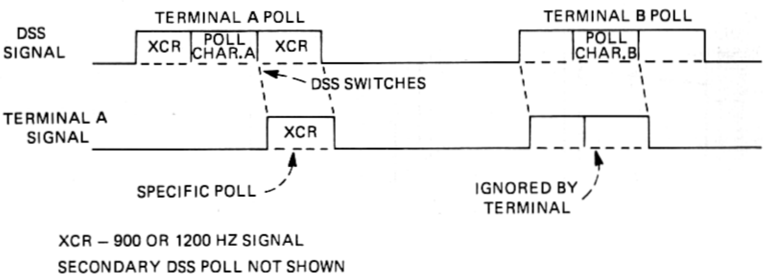

Fig. 2—Polling sequence.

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

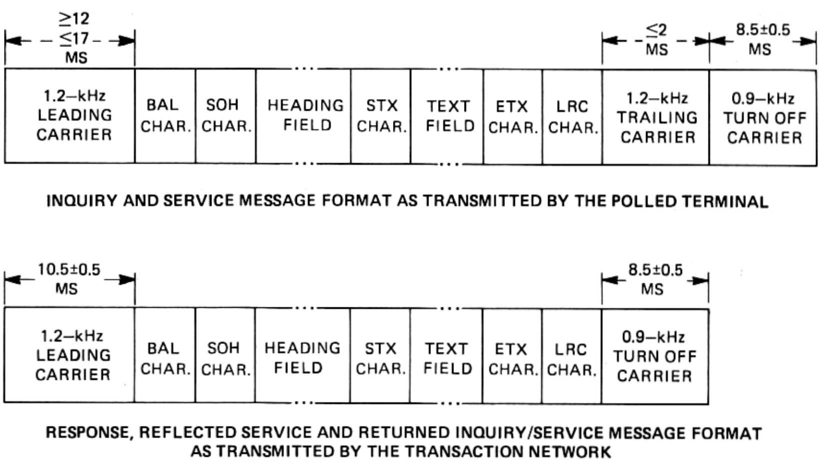

Fig. 3—Polled access data messages transferred across the interface.

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.

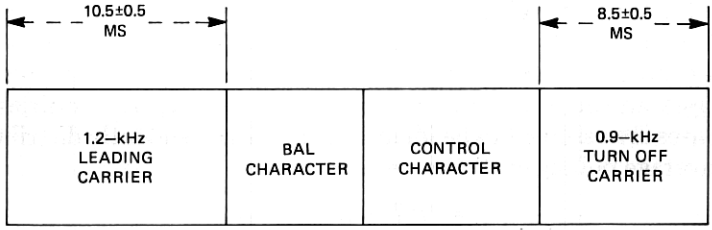

Fig. 5—Polled access control sequence transmitted by the Transaction Network.

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.

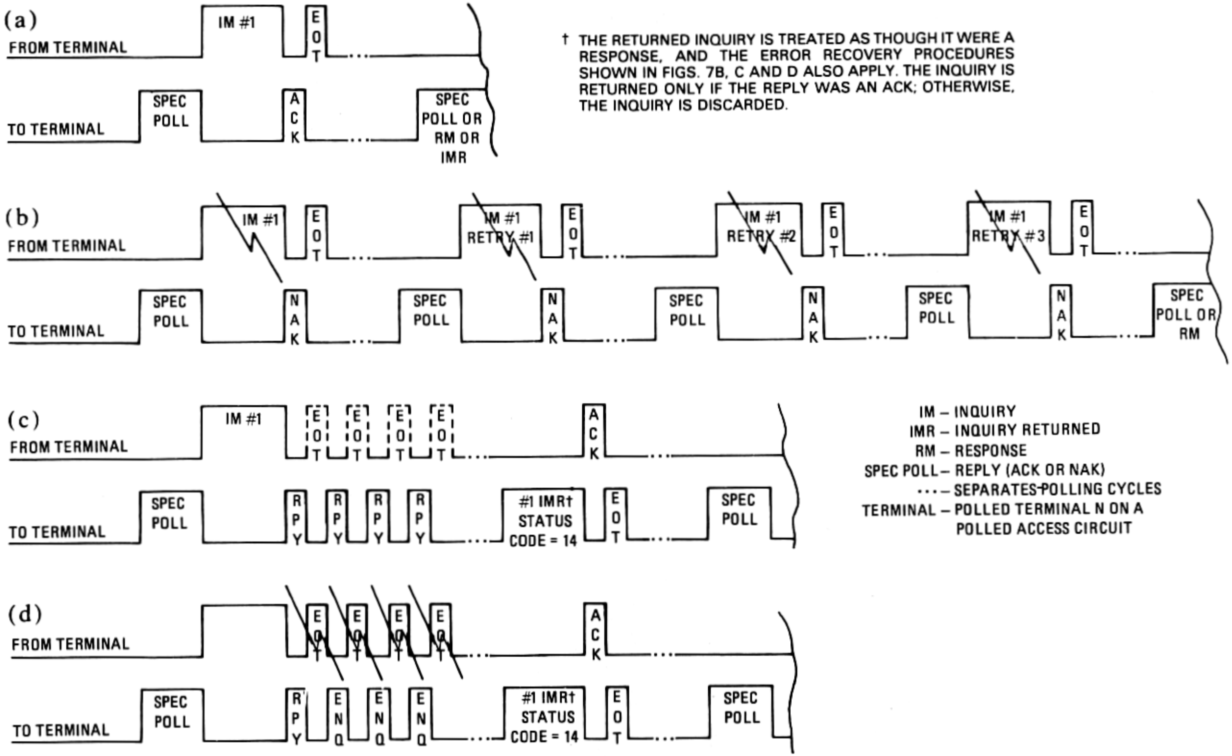

Fig. 6—(a) Normal inquiry transfer. (b) Garbled inquiry from the terminal. (c) Lost termination from the terminal. (d) Garbled termination from the terminal.

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.

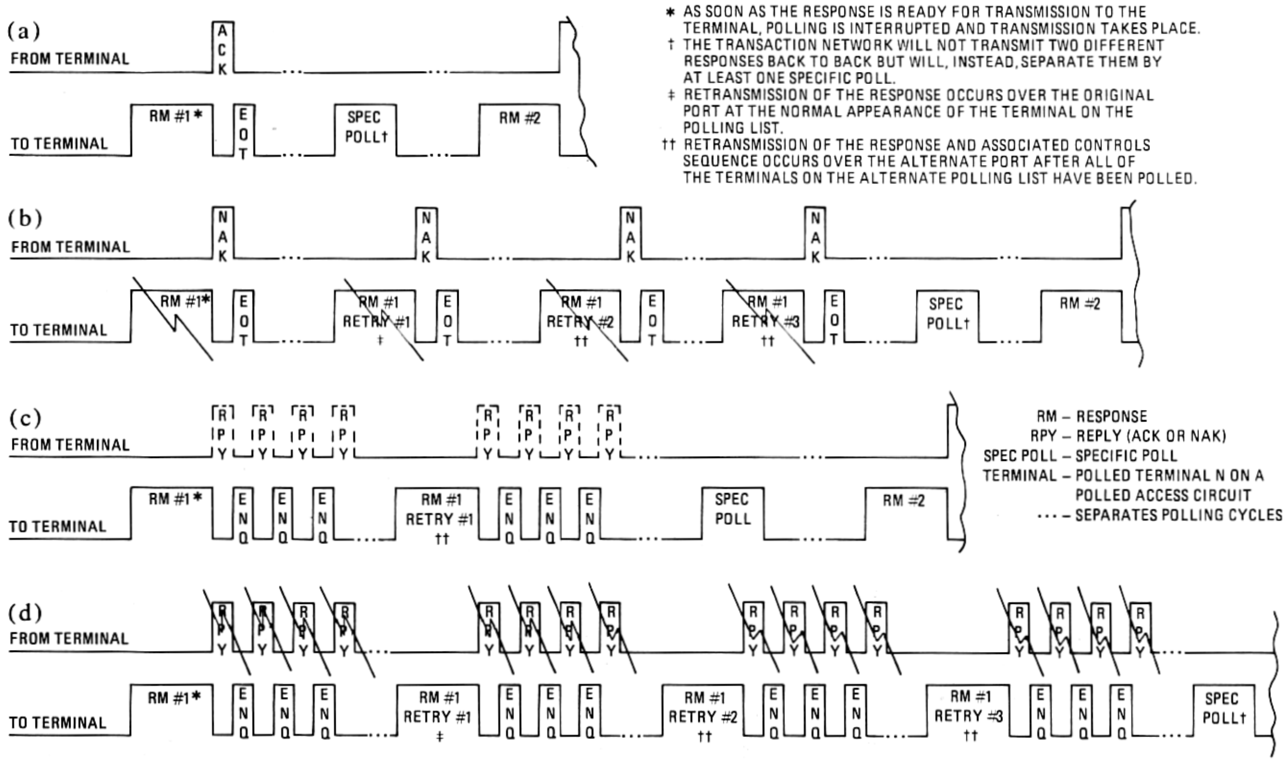

Fig. 7—(a) Normal response transfer. (b) Garbled response from the Transaction Network. (c) Lost reply from the terminal. (d) Garbled reply from the terminal.

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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