A comparison of channel-management algorithms for reversible data channels

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INTRODUCTION

Present existing and proposed industry standards do not prescribe the means by which channels interconnecting two data terminals are to be managed. The problem of channel management manifests itself in those systems that utilize a channel that cannot support a primary carrier in both directions simultaneously. In such systems it is necessary that overt action be taken to cause the channel to be turned around when the direction of information flow on the primary data channel is to be reversed.

Task Group 4 of Subcommittee X3.3, the USASI Sectional Committee on Data Processing Standards, is endeavoring to produce a USA Standard on "Communication Control Procedures for the USA Standard Code for Information Interchange."[1] This standard will specify categories of procedures for ASCII[2] oriented systems. Within each category, procedures are given to establish and terminate message transmission. However, the transmission facilities (channels) which interconnect stations and the management of these channels are not covered in the proposed Standard.

Proposed EIA Standard RS 232C[3] is applicable to the interconnection of data terminal equipment and data communication equipment. It defines a means of interchanging control signals and binary serial data between the terminal and communication equipment. With regard to switched service, the area of automatic answering of calls is covered, but this standard does not specify how the interchange circuits are to be managed for establishing a connection or reversing the channel.

Channel management (Figure 1) is that part of a data system that performs the functions necessary to insure that channels are established properly and reversals are controlled and effected in a logical and consistent manner.

This paper presents a comparison of several channel management algorithms for medium-speed systems that have been devised by various terminal and computer manufacturers. These algorithms are directly concerned with establishing, maintaining, and disconnecting the physical and electrical channel between stations. The relative effectiveness of the various algorithms is also discussed.

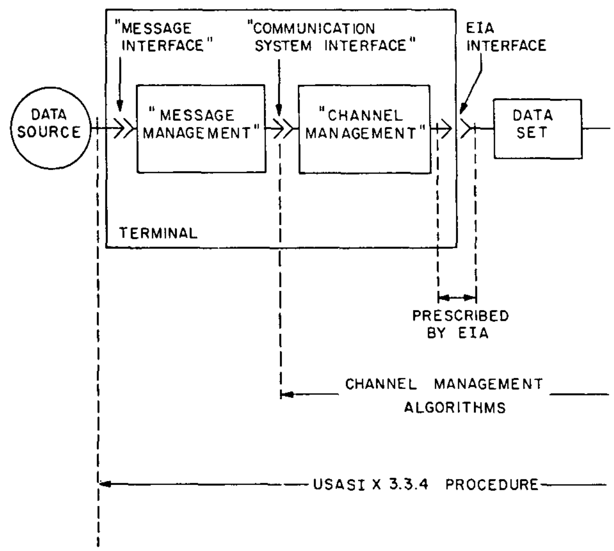

Figure 1—Channel Management

MODEL

The model (Figure 2) upon which the comparisons are based consists of medium-speed data **terminals** operating over 2-wire voice grade facilities on a **half duplex message transmission** basis using data sets equivalent to the Bell System 202[4] type. The voice grade facilities are assumed to have either echo suppressors equipped with echo suppressor disabler devices[5] or no echo suppressors.

The model also assumes reversible operation of a **primary data channel** and an associated **secondary (backward) channel.** (Reversible operation implies transmission in either direction, but only one way at a time

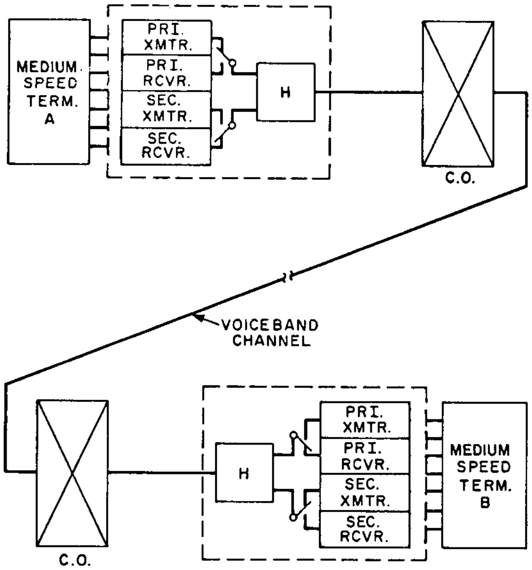

Figure 2—System Model

and with an overt change in the state of the transmission equipment required to effect a reversal.)

A **terminal** in the model is considered to be any data source and/or data sink. In this sense, both remote input/output devices as well as computers themselves are considered terminals.

A **primary data channel** is a data transmission channel having (1) the highest signaling rate capability of all channels sharing a common interface and (2) an individual set of appropriate control interchange circuits.

A **secondary channel** is a data transmission channel associated in the same interface with a primary channel, but with a lower data signaling rate capability. The secondary channel in the model is to be used as a **backward channel,** i.e., the direction of data transmission on it is always opposite to that of the primary channel. In the algorithms examined, the signaling rate capability of the secondary channel was no greater than 5 bauds. The use of this channel, for all practical purposes, is limited to performing circuit assurance and channel management functions.

Half duplex message transmission is the ability to transmit a message in either direction, but not both directions simultaneously. This type of operation is necessary when the primary channel cannot be used simultaneously in both directions. In this respect, the signals transmitted over the secondary channel are not considered "messages."

Finally, it is assumed in the model that bit serial transmission is employed and that an EIA RS 232B[6] voltage interface, as found in Bell System 202-type data sets, is used between terminals and modems.

CRITERIA

Echo suppressors, which may appear in the switched telephone network, block simultaneous transmission in both directions unless disabled. One of the basic criteria for a system which uses the secondary channel in the backward direction is the disabling of any echo suppressors appearing between stations. Disabling is accomplished when the called station enters the data mode and transmits an answer signal. This signal is typically a 3- to 5-second burst of an answer tone (typically 2025 Hz). It is necessary that this tone and no other tones be present on the line for at least 300 msec to insure the operation of the echo suppressor disablers. (The answer signal is transmitted by the data set of the called station.) Once the disablers are activated, a further requirement is that there should be no time period greater than 100 msec when no energy above a certain threshhold is present on the line, or the echo suppressors may be reenabled.

By nature, stored program terminals may not have a precisely defined response time to signals on the channel for all situations. Since computer-oriented systems are increasingly important in medium-speed systems, a second criterion is that there should be no requirements for a precise time interval between the receipt of a signal and the response thereto.

A third criterion is that the secondary channel (backward) should be used for circuit assurance and channel management.

A fourth criterion is that the algorithm should not conflict with any existing or proposed industry standards.

A fifth and final criterion is that the secondary channel should be capable of being used in simple error control systems. This is accomplished today by equating the presence of the secondary channel as a positive acknowledgment and its absence as a negative acknowledgment.

CHANNEL-MANAGEMENT ALGORITHMS

In looking at channel-management algorithms, three distinct but related areas are apparent. These areas, described immediately below, are (1) channel establishment algorithms, (2) channel turn-around algorithms, and (3) disconnect algorithms. Each section compares several algorithms for each area.

The first algorithm in each section is recommended for use in generalized systems. These recommendations are based on how well the particular algorithms meet the five criteria of the section above.

Channel Establishment Algorithm

Several procedures have been devised for the entrance into the data mode at the beginning of a call. It is during this phase of a data call that the channel is initialized, i.e., pointed in a particular direction for the first transmission of data. It is necessary that the channel be pointed in some particular direction to insure an orderly procedure and to insure that echo suppressors, when disabled, remain so.

The channel may be initialized in one of two directions: (1) with the primary channel pointed from the calling end toward the called end (hereafter referred to as the forward direction) or (2) vice versa (hereafter referred to as the backward direction).

Forward Primary Channel

A number of existing systems use the primary channel in the forward direction initially for the following reasons: the calling end will send first because (1) it either has a message to send first or (2) if the called end has a message to send first, the calling end should first send identification information so that the message is not sent to an unauthorized station.

For these systems, several procedures have been devised for entrance into the data mode at the beginning of a call. These procedures fall into two basic categories: (1) the called station waits until it detects primary channel carrier before turning on the secondary channel carrier and (2) the called station volunteers secondary channel carrier at the end of the answer signal.

Method A1. A number of systems operate on the principle that the secondary channel should be used for circuit assurance, i.e., the secondary channel carrier may be transmitted by the called station only after it has detected primary channel carrier from the calling station.

Using this principle (Figure 3) the called station (answering as a receiver) sends the answer signal and then waits. When it detects the primary channel carrier, it turns the secondary channel ON. When the secondary channel carrier is detected, the calling station may proceed to send data. This procedure puts a requirement on the calling station user; i.e., when the calling station user hears the answer tone he must put the station in the data mode **before** the end of answer signal. If the user fails to do this, it is probable that the echo suppressors will be reenabled, thus preventing the use of the secondary channel for circuit assurance or, for that matter, using the secondary channel for anything. As stated previously, the answer signal is a 3- to 5-second burst of answer tone. Human factors

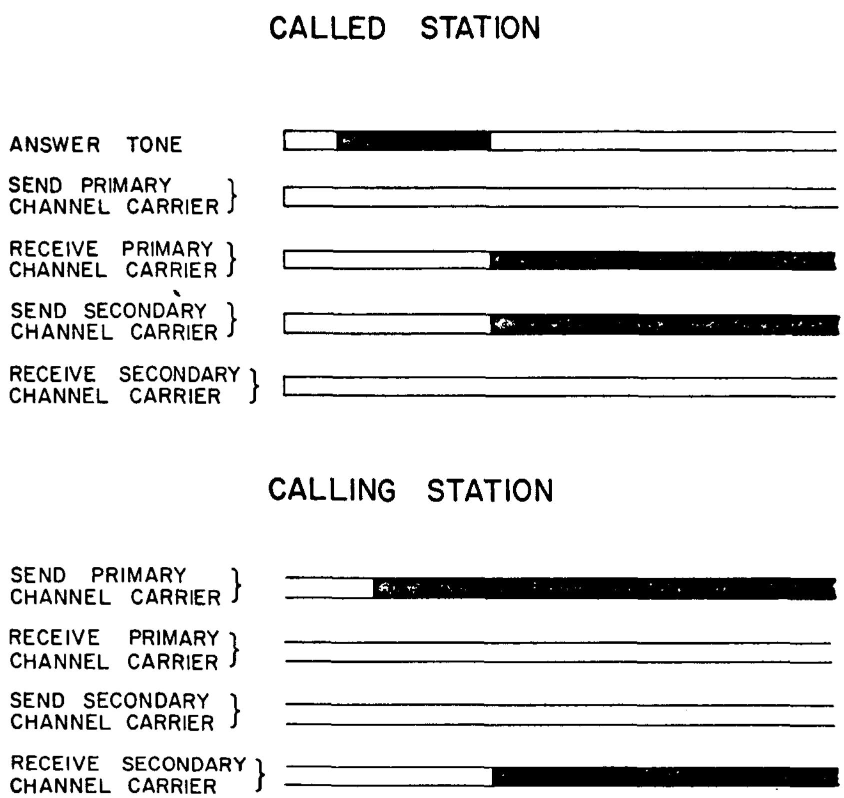

Figure 3—Method A1

studies show that a response time of 300 to 500 msec is a reasonable expectation for an operator in this type of an environment; thus, there should be minimal difficulty in having the calling station user enter the data mode (i.e., depress the data key) during the answer signal.

If the calling station is unattended, but is under the control of an Automatic Calling Unit (ACU), it is necessary that the ACU transfer the data set to the data mode during the answer signal. ACUs offered by the Bell System have options available to allow the ACU to transfer the data set to the data mode either during the answer signal or following the answer signal.

Method A2. The procedure that is followed in this method, A2 (Figure 4), is that after the called station is put in the data mode and after the answer signal has been sent, the called station immediately begins to send secondary channel carrier to insure the continued disablement of echo suppressors. The called station does not wait until it receives primary channel carrier. When the calling station enters the data mode (usually at the end of the answer signal) it immediately sends primary channel carrier. Since the secondary channel carrier is already ON, the calling station may proceed to send data immediately.

The one disadvantage of this method is that the called station has no straightforward way of using the secondary channel (or any other means) to indicate to the calling station that it has detected primary channel carrier. The called station will not detect primary channel carrier if a transmission failure exists in the "forward" direction. The calling station would not be able to recognize this fact and would proceed to send its data into limbo. Thus, the secondary channel is only being used to maintain echo-suppressor disablement and not as an indicator for circuit assurance.

Method A3. Method A3, a variation of Method A2, is as follows (Figure 5): when the called station enters the data mode, it volunteers secondary channel carrier. The calling station enters the data mode (either during or after the answer signal) and immediately sends primary channel carrier. When the called station detects primary channel carrier, it turns the secondary channel carrier OFF for a timed period and then turns it back ON. This indicates to the calling station that primary channel carrier has been detected.

A disadvantage of this method is that error control systems which use the secondary channel may have difficulties conveying acknowledgments.

Backward Primary Channel

The preceding section was based on the premise

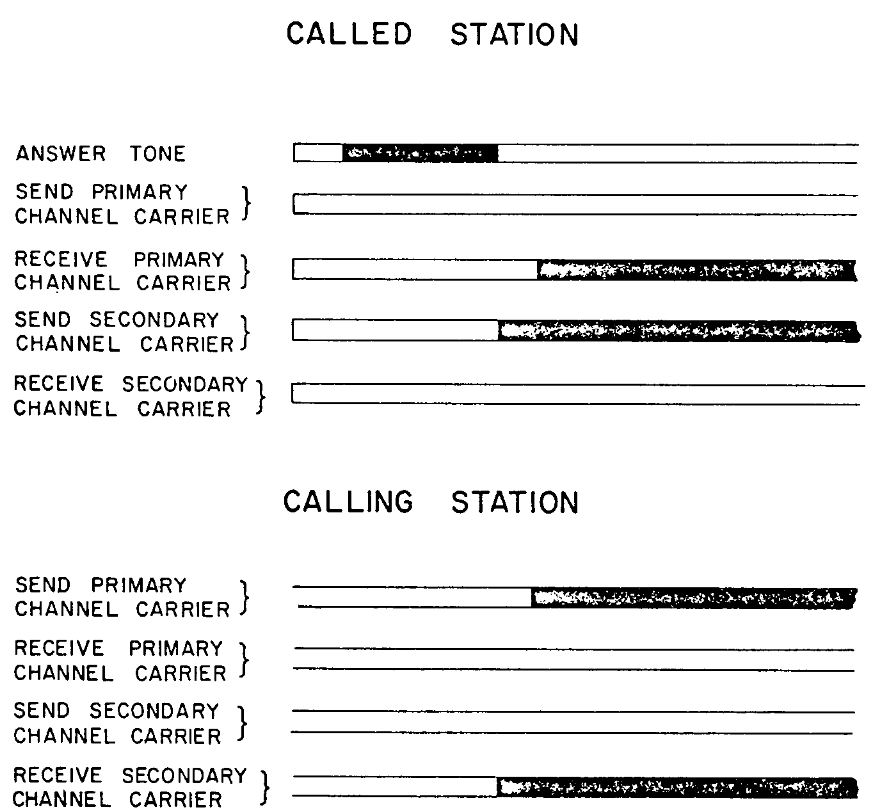

Figure 4—Method A2

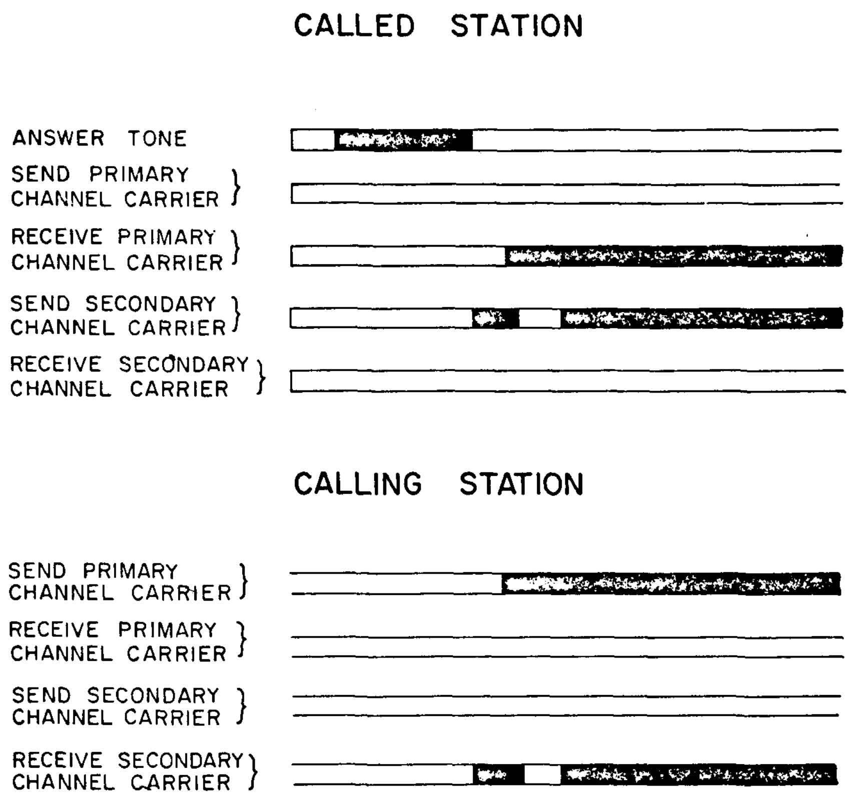

Figure 5—Method A3

that the line was established with the primary channel initialized in the forward direction. This section deals with cases where the primary channel is initialized in the backward direction.

Disadvantages of this type of operation are: (1) if the calling station has a message to send, the channel (primary and secondary) must be turned around (i.e., pointed in the forward direction) before the calling station can send and (2) if the called station has a message to send, further safeguards must be provided to prevent an unauthorized delivery of the message. There are, of course, cases when this type of operation would not be objectionable, but in the general case it would be.

Method A4. When the called station (Figure 6) is put in the data mode, it first sends the answer signal and then immediately begins to send primary channel carrier. At the calling station, when the station enters the data mode (usually at the end of the answer signal) it waits until it detects primary channel carrier before it transmits secondary channel carrier as a confirmation. The called station, having detected secondary channel carrier, may now send data.

The disadvantage of this method is a possible conflict with the proposed USA Standard for Control Procedures which specifies tha the calling station be the first sender of data.

Method A5. A second method, A5 (Figure 7), has the called station volunteer primary channel carrier at the end of the answer signal and also has the calling station transmit primary channel carrier as follows:* when the called station is put in the data mode, it sends the answer signal and then immediately begins to send primary channel carrier. When the user at the calling station enters the data mode, usually at the end of the answer signal, the calling station also transmits the primary channel carrier. After a delay of several seconds, the called station user puts the called station in a receive state. This causes primary channel carrier to be turned OFF. When the called station detects primary channel carrier from the calling station, it then puts secondary channel carrier ON. The calling station, having detected secondary channel carrier, may now send data.

This procedure was adopted by one terminal manufacturer after it was discovered that users were having difficulty with maintaining echo suppressor disable-

*Note that both stations, when idle, are conditioned to be in the send state when each enters the data mode.

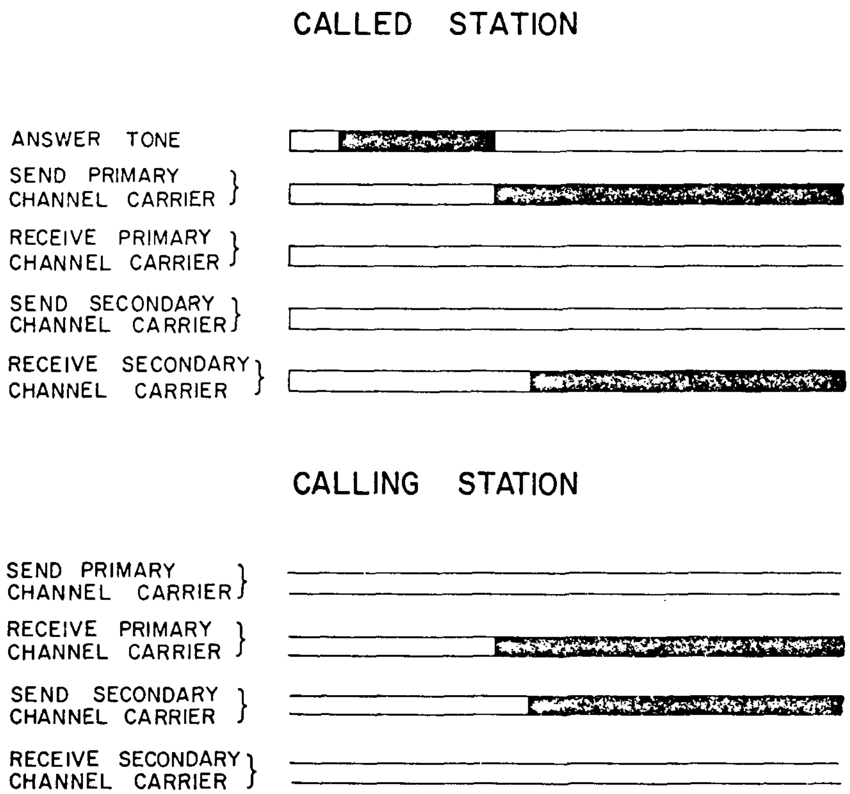

Figure 6—Method A4

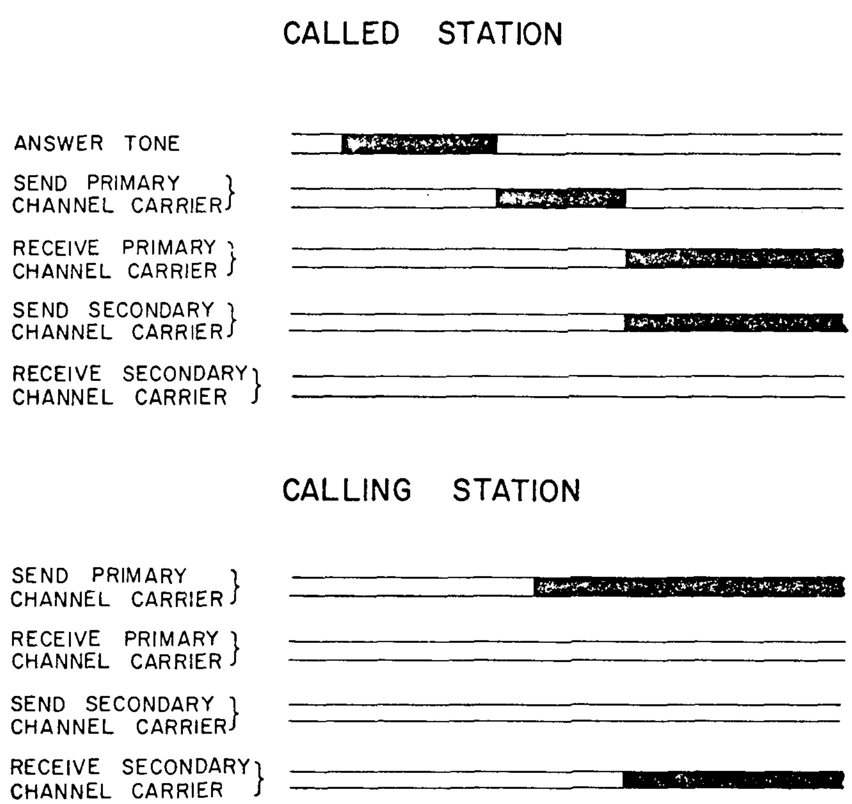

Figure 7—Method A5

ment. This difficulty was due to the fact that the calling station users had been instructed to enter the data mode at the end of the answer signal. It was almost impossible for that user to do so within the 100 msec necessary to guarantee echo suppressor disablement.

However, with primary channel being sent by both ends, it is possible that a beat null below the disabler threshold longer than 100 msec could occur. If it does, the echo suppressors will be reenabled and the use of the secondary channel will be lost. This method also requires that the called station be attended.

Channel Turn-Around Algorithms

This section presents several channel turn-around algorithms presently in use. Before discussing actual algorithms, it is appropriate to discuss what is meant by **channel turn-around** and its relationship to **master status.**

Channel turn-around is defined herein as the reversal of information flow on the primary data channel; i.e., the send station becomes the receive station and vice versa. Turn-around is the result of some overt action taken at either end by the station user (or processor-controlled device) or by some particular function-representing character(s). The result of this action must be conveyed to the distant station.

Master status is defined as the state of having control over the flow of information. Channel turn-around does not necessarily imply relinquishment of master status. For example, in a system using an error-control scheme which requires block transmission and block acknowledgment, master status is not relinquished if the channel is turned around for the acknowledgment and then restored. Also, in a time-sharing system, if the processor has emptied its output buffer but has more data to send after some delay and does not require further input from the remote station, it also should neither relinquish master status nor turn around at that time.

Task Group X3.3.4, in its proposed standard, specifies when master status should be interchanged and when replies without a master status reversal should occur. This means that there are several situations which call for a channel reversal that do not imply a master status reversal. ASCII characters that would cause a turn-around but no master status reversal are ENQ, ETX, ETB, ACK, and NAK, while the ASCII character that calls for a channel reversal **and** master status reversal is EOT.

In the following sections, two different classes of algorithms will be discussed. There are (1) the class in which the turn-around is requested by the sending terminal and (2) the class in which the turn-around is requested by the receiving terminal. In the following paragraphs, station A is that station which is in the sending state, while terminal B is that which is in the receiving state at the time the turn-around commences.

Sender Initiated Turn-Around

The various sender initiated turn-around algorithms investigated will be treated in the following three sections.

Method B1. Upon detecting a local request for a channel turnaround (Figure 8), station A turns its primary channel carrier OFF and then waits. When station B detects the loss of primary channel carrier, it turns its primary channel carrier ON. In Bell System 202-type data sets, turning primary channel carrier ON causes the secondary channel carrier to be turned OFF. When station A detects primary channel carrier ON, it turns secondary channel carrier ON, thus completing the channel reversal and maintaining full circuit assurance. When station B, now sending primary channel carrier, detects the secondary channel carrier ON, it may now proceed to send "data". In some error-control systems, the data sent may only consist of a block acknowledgment which in turn precipitates a second turn-around. This is an example of the first station requesting a turn-around, but not relinquishing master status.

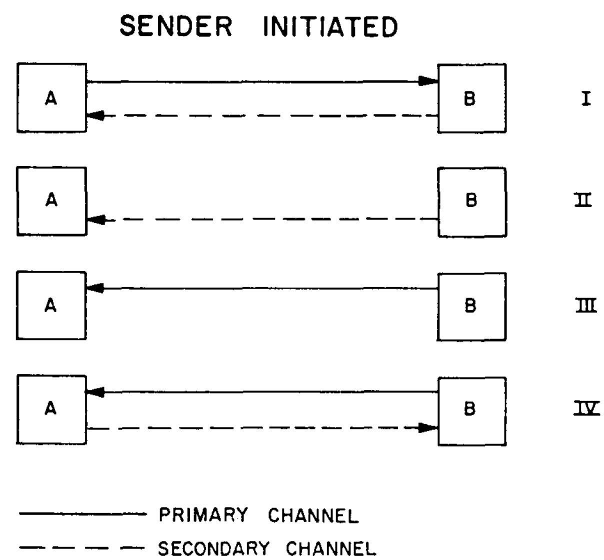

Figure 8—Method B1

Method B2. Upon detecting a local request for a channel turnaround (Figure 9), station A turns its primary channel carrier OFF and simultaneously turns the secondary channel carrier ON. When station B detects the loss of primary channel carrier, it turns its primary channel carrier ON (and simultaneously turns the secondary channel carrier OFF). Station B, now sending primary channel carrier, is now capable of sending data since the secondary channel carrier was previously turned ON.

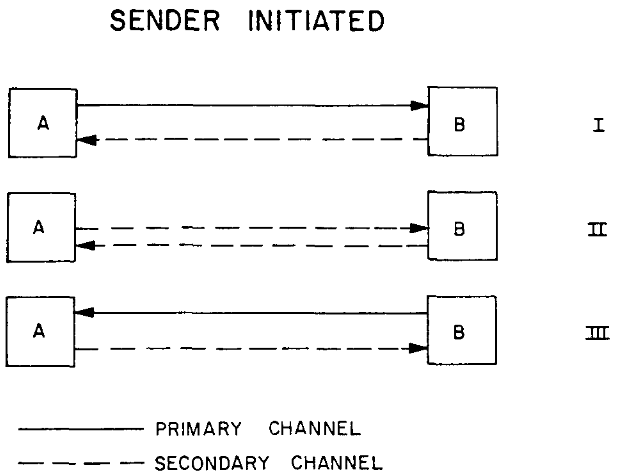

Figure 9—Method B2

The following are disadvantages of this method: (1) the secondary channel is not being used in a circuit assurance capacity and (2) with both stations sending secondary channel carrier during the turn-around, it is possible that a beat null below the disabler threshold longer than 100 msec could occur. If it does, echo suppressors will become enabled and the use of the secondary channel will be lost.

Method B3. Method B3 requires manual intervention at both ends of the channel. When a channel turn-around is desired (Figure 10), the call is taken out of the data mode and returned to the voice mode. This data-to-voice transfer is done at both ends of the channel. While in the voice mode, each station changes state manually; i.e., the sending station is changed to a receiving station and vice versa at the other station. The stations then reenter the data mode with the primary and secondary channels pointed in the new directions.

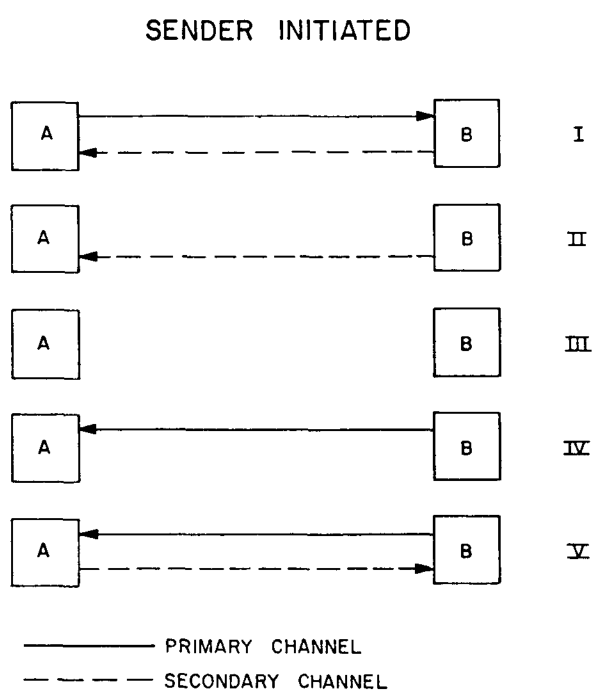

Figure 10—Method B3

The major disadvantages of this method are: (1) coordinated manual intervention is required at both stations and (2) this procedure is more time-consuming than those which are automated.

The main advantage of this scheme is that the problem of which end station will receive and which will send is handled by voice coordination. Also, echo suppressor disablement during the data portion of the call is insured.

Receiver Initiated Turn-Around

There are also several ways in which the receiving station may initiate a request for a primary channel turnaround.

Method C1. Method C1 (Figure 11), which can be used by station B to indicate to station A the desire to reverse the direction of information flow, is as follows: when station B detects a local request for a channel turn-around, it turns its secondary channel carrier OFF for a timed period and then turns it back ON* and waits. When station A detects first the sec-

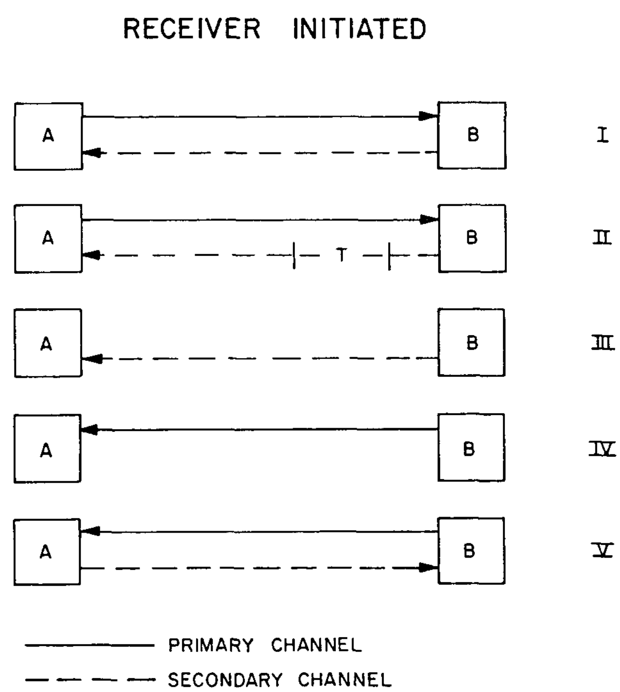

Figure 11—Method C1

*This may be considered analogous to the BREAK signal used in many low-speed systems.

ondary channel carrier OFF and then it returns to the ON condition within an appropriate time, it recognizes this as a request by station B for a turn-around and proceeds in the same manner as if it had detected a local request for a turn-around.

This method has the disadvantage that simple error control systems cannot use the secondary channel to indicate the acceptance or rejection of data (unless a different timed period is used). However, it does have the two following advantages: (1) the secondary channel has maintained its usability as an indicator of circuit assurance and as a supervisory means of channel management and (2) echo suppressor disablement is insured throughout the data portion of the call.

Method C2. In another method, C2 (Figure 12), when station B detects a local request for a channel turn-around, it begins by turning its secondary channel carrier OFF. When station A detects the loss of secondary channel carrier it will then turn its primary channel carrier OFF and simultaneously turn its secondary channel carrier ON. When station B has detected primary channel carrier OFF and secondary channel ON, it will then turn its primary channel carrier ON. The primary channel will then be "pointed" in the desired direction.

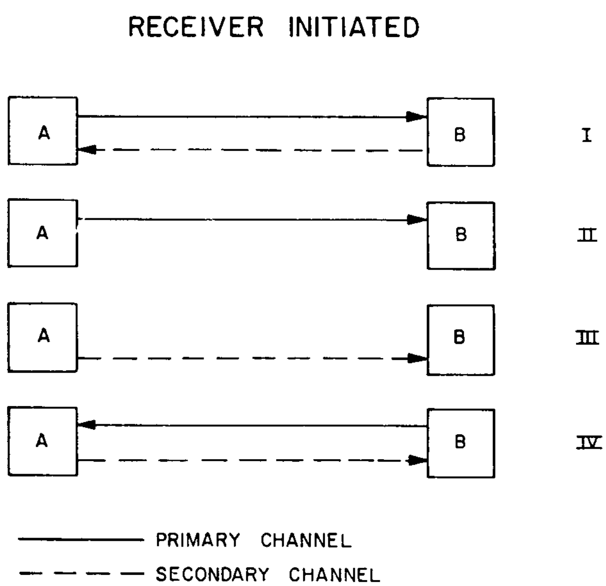

Figure 12—Method C2

This method has two disadvantages: (1) circuit assurance cannot be obtained from the secondary channel (since it is volunteered by A) and (2) many simple error control systems would not be able to use the secondary channel to signal positive or negative acknowledgments to the sending station.

The main advantage of method C2 is that a signal is present on the line at all times during the turn-around, thus insuring that the echo suppressors will remain disabled throughout the duration of the data call.

Method C3. A third method, C3 (Figure 13), which is a variation of the first, is one in which station B, detecting a local request for a channel turn-around, will begin by turning OFF the secondary channel carrier and then waiting. When station A detects the loss of secondary channel carrier, it will then turn its primary channel carrier OFF and also wait. Station B, upon detecting the loss of the primary channel carrier, will then turn its primary channel carrier ON. Station A will then turn its secondary channel carrier ON after detecting primary channel carrier from station B.

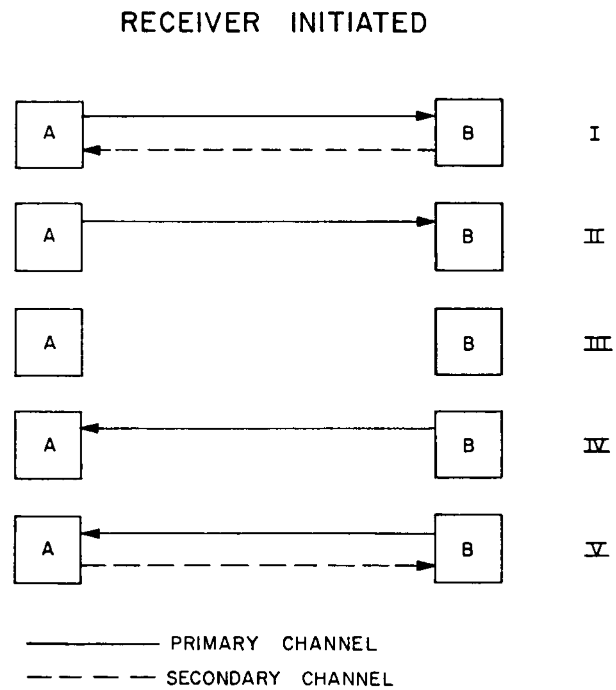

Figure 13—Method C3

This method also has two disadvantages: (1) The probability that no energy will exist on the line for a time period greater than 100 msec is quite high; this will cause the loss of echo suppressor disablement and forfeit the circuit assurance and channel management capabilities of the secondary channel for the remainder of the data call. (2) As in the second method (C2), simple error-control systems will not tolerate this type of behavior.

The advantage of this method is that the secondary channel still maintains its capability of notifying the distant station of the receipt of primary channel carrier.

Method C4. A fourth method, C4 (Figure 14), is that when station B detects a local request for a channel turn-around, it begins by turning OFF secondary channel carrier and simultaneously turning ON primary channel carrier and waiting. When station A detects the loss of secondary channel carrier, it then turns its primary channel carrier OFF. When primary channel carrier is detected by station A, it turns secondary channel carrier ON. Station B, now sending primary channel carrier, may send data after detecting secondary channel carrier.

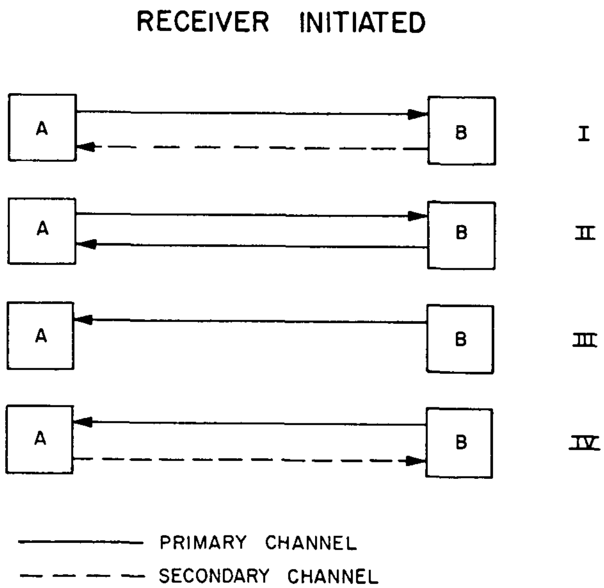

Figure 14—Method C4

The one disadvantage of this method is that with both stations sending primary channel carrier, the probability of occurrence of a beat null below the disabler threshold longer than 100 msec is not insignificant. This would cause loss of echo suppressor disablement and forfeiture of the ability to signal in both directions simultaneously.

Disconnect Algorithms

The one remaining area to be covered is that of taking down the physical and electrical connections when both stations are finished; i.e., disconnect. Here also, several methods are available.

Method D1. In Method D1, it is assumed that the station in the sending state has the ability to initiate a normal disconnect. If the station in the receiving state desires to initiate a disconnect, it should first request a turn-around and then proceed to initiate the disconnect. This method utilizes the recommendations of USASI Task Group X3.3.4, i.e., when the sending station detects a local request for a line disconnect, the station should send the sequence of two ASCII characters DLE EOT (Data Link Escape, End of Transmission). The transmission and reception of this sequence should cause the respective stations to return to an idle on-hook (if the call was switched) condition.

As in Method D3, this algorithm requires no manual intervention at either station involved in the call.

Method D2. In Method D2, when the transmission of data is finished, both stations return to the voice mode for manual verification of the preceding transmission(s). When both ends confirm that the transmission(s) appeared to be acceptable, the call is terminated as any normal voice-to-voice call.

The primary disadvantage of this method is that coordinated manual intervention is required at **both** stations involved.

Method D2 does, however, allow the operators to request a retransmission "immediately" if an obvious malfunction has occurred.

Method D3. The third method, D3, is similar to Method D1 and is as follows: when one or both stations desire to disconnect, the user merely "hangs up" (takes the data set out of the data mode). The other station, if unattended, will stop receiving (or sending), time out, and take similar action. In most cases, the time-out is started by a loss of either primary or secondary channel carrier.

This method does not require manual intervention at both ends and in some instances can be completely automated.

RECOMMENDATIONS AND SUMMARY

Recommendations

As explained in the previous section on Channel-Management, Algorithms in each subsection that fol-

TYPE OF ALGORITHM	METHOD	CRITERIA 1	2	3	4	5
	A1	√	√	√	√	√
CHANNEL ESTABLISHMENT	A2	√	√		√	√
	A3	√	√		√	
	A4	√	√	√		√
	A5		√	√		√
TURN-AROUND SENDER INITIATED	B1	√	√	√	√	√
	B2		√		√	√
	B3	√	√	√	√	√
TURN-AROUND RECEIVER INITIATED	C1	√	√	√	√	(*)
	C2	√	√		√	
	C3		√	√	√	
	C4		√	√	√	
DISCONNECT	D1	NA	NA	NA	√	NA
	D2	NA	NA	NA		NA
	D3	NA	NA	NA		NA

* SEE TEXT
NA-NOT APPLICABLE

Figure 15—Summary Table

lowed, the algorithm discussed first is the one recommended for use in generalized systems. These recommendations are based on the criteria mentioned in the section on criteria, which are as follows (Figure 15):

Channel Establishment Algorithms

Method A1, which calls for the primary channel to be pointed in the forward direction initially and further calls for the secondary channel carrier to be turned on in response to the receipt of primary channel carrier, meets the five criteria mentioned. In addition, this method also conforms to the X3.3.4 proposal (see Subcategories 2.1 and 2.2: 2-Way Alternate; Switched Point-to-Point and 2-Way Alternate; Switched Point-to-Point with ID, respectively).

Methods A2, A3, A4, and A5 either fail to meet all the criteria or fail to follow the proposed standard.

Channel Turn-Around Algorithms

For sender-initiated turn-around algorithms, Method B1 satisfies the five criteria. This is the method that requires a compelled sequence of operation. There is no time period during which no energy is present on the line, so echo suppressors remain disabled. Also, the secondary channel is only turned on in response to primary channel carrier and thus it is used in a circuit assurance capacity. Therefore, Method B1 is recommended for use in generalized systems.

Method C1, in which the secondary channel carrier is turned OFF for a timed period and then turned back ON, analogous to a BREAK in many low-speed systems, is the recommended receiver initiated turn-around algorithm. This method satisfies the first four criteria. It fails to satisfy the criterion that the secondary channel be used for acknowledgments in simple error control systems; however, as stated in the section on method C1, if a different timed interval is used to indicate a negative acknowledgment, this method then satisfies the five criteria.

Disconnect Algorithms

In selecting a disconnect algorithm for generalized systems, the basic criterion to be followed is the one that calls for close adherence to any existing or proposed standards. Because of this, Method D1, which calls for the transmission of the ASCII sequence DLE EOT, is recommended.

Summary

This paper has presented a comparison of several channel-management algorithms for a variety of medium-speed data systems. It has pointed out (1) the various ways that the physical and electrical connections may be established, (2) the different channel turn-around algorithms being used, and (3) the ways the physical and electrical connection may be released.

Finally, a set of algorithms for channel management has been recommended for use in generalized systems.

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