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Network Problem-Determination Aids in Microprocessor-Based Modems

Recent significant developments in large-scale integration (LSI) and in digital signal-processing techniques have combined to provide the base for a new generation of modems. LSI microprocessors now have the characteristics and performance to provide superior modem function as well as a design base for the addition of new function. The extendability afforded by a microprocessor-based modem design is being increasingly used to provide advanced communications network management functions. This paper describes the design objectives, implementation decisions, and design rationale for implementing these characteristics in the IBM 3863, 3864, and 3865 family of data modems. This network management function, which has been integrated into IBM Communications Network Management (CNM) offerings for IBM's Systems Network Architecture user networks, extends the problem-determination capability to cover the modems and communications lines. Support for this new function has been integrated into the 3705 ACF/NCP/VS control program and the System/370 NPDA program product.

Introduction

With the growth in computer networks and large communications-oriented applications, the need for an organized approach to the management and control of these environments has become more significant. The objective of communications network management is to provide a systematic, partially automated yet flexible system that aids network operators in performing such functions as problem-determination, change control, performance evaluation, accounting, and security.

One approach to communications network management is to provide centralized control which is integrated into the architecture underlying the user network. This approach, referred to as the "mainstream" approach, is illustrated in a recently published paper [1] which focuses on two IBM program products, NCCF and NPDA (see Appendix 1: Glossary of acronyms), that provide centralized operator control and problem-determination capabilities for a network. That paper also introduced the concept of utilizing modem-provided information to extend the problem-determination capability of this centralized approach to include the link subsystem (see Fig. 1).

In this paper, we will more fully develop the rationale and design considerations underlying the definition and implementation of the modem network management functions that are required for integrating the link subsystem into a centralized network management system suitable for user networks conforming to IBM's Systems Network Architecture.

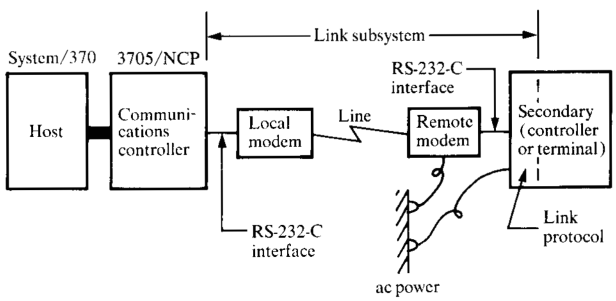


Figure 1 Link subsystem overview.

For a discussion of an alternate approach, referred to as the "sidestream" approach, the reader is referred to Ref. [2]. This concept uses additional out-of-band low-speed modems for testing and sensing the link operation. It also uses a dedicated minicomputer for collecting and analyzing the link information. The sidestream approach is independent of the user's communications network architecture and is invisible to the user's operational network.

Concurrent with the growing need for network management, developments in signal processing and in LSI technology have combined to form a base for the new generation of modems. Digital signal-processing concepts have matured at the same time that LSI is providing microprocessors on single chips.

The use of microprocessors to perform modem functions using digital signal-processing techniques now provides vastly superior implementations compared to previous analog approaches. Indeed, today's microprocessor implementations are approaching the theoretically established performance bounds. In addition, this new approach provides the advantages inherent in LSI in regard to cost, reliability, and size reduction. For a description of an implementation employing a microprocessor and digital signal-processing techniques, see the companion paper [3] by Godard and Pilost in this issue.

Significant advantages of a design approach employing a microprocessor, over previous hardwired approaches, are extendability and flexibility. In some instances, the addition of new function can be as simple as changing the programs stored in read-only storage (ROS). In the new family of IBM modems (IBM 3863, 3864, and 3865) [4], this microprocessor-based design extendability has made it feasible to provide the significant network management capability required for problem determination in the link subsystem. With these modems, most of the problem-determination function is contained in ROS-stored programs and thus can be provided with minimal cost impact.

This paper reviews the design objectives for this new problem-determination function as well as the design tradeoffs made in implementing these concepts. A detailed description of the modem network management function is presented, with a discussion of how this is supported by IBM's CNM offerings. This description is presented to illustrate the implementation results of the design decisions and represents the status as of the time this paper was written. Thus, this paper only partially describes the products and is not intended to be used in lieu of current IBM product literature.

Link problem-determination aid (LPDA)

The built-in network management function in the IBM 3863, 3864, and 3865 modems is referred to as Link Problem-Determination Aid (LPDA). All modems will respond to diagnostic commands from the attached system. The responses to these commands convey the status of any modem in the link, the status of the attached secondary terminal, and the quality of the signal received over the communications facility. Test requests and responses utilize the same data path and protocols that are used by System/370 for data transmission. Thus, diagnostic requests for status or test information can be interspersed with data transmission without interrupting terminal sessions.

Before describing LPDA in more detail, it is appropriate to review the design objectives for this function. These are the following:

1. To support centralized control with no requirement for human intervention at the remote modem site for performing problem isolation.
2. To provide sufficient status and test information on permanent errors such that the centralized facility can automatically isolate a failure to the failing component in the link subsystem. The failing component can be either the local modem, the line, the remote modem, the secondary, or the ac power. The intent is to effect error recovery or to dispatch the proper service personnel to repair the failing component.
3. To provide the capability to monitor the quality of the signal received over the line. This information is automatically collected periodically for logging at the System/370 host. The nominal time for performing this status sensing operation should be two seconds or less.
4. To enable an operator to initiate tests and to view the results from the central control point.
5. To make the formats for the test requests and test responses compatible with Synchronous Data Link Control (SDLC) [5] formats. The use of SDLC formats will enable these tests to be supported by most current and new communications controllers with little or no hardware change or cost impact.

These objectives led to the following set of design decisions:

1. The combination of test complexity and the requirement for fast test execution imply that several specialized tests will have to be defined, rather than a single comprehensive one.
2. Because of the plurality of tests, and since a modem self-test is disruptive to data transmission, test scheduling must be accomplished by the communications

controller. The modem(s) will execute a specific test only upon command from the controller and will return the results to the controller.

3. Due to the requirement that problem determination be independent of human intervention at the remote site, the communications controller must be able to execute tests on the remote modem as well as the local modem. These test commands and responses must share the communications line with data transmission.
4. When no communication can be established with the remote site, in determining the probable cause a means will be required for sensing the loss of ac power and a separate means for testing the remote modem and for reporting the results. Since it is unlikely that a failing modem will be able to respond to tests, extra hardware must be provided to identify and to signal the modem failure, in order to enable these modem failures to be separated from the line failures. Similarly, a knowledge of when power is lost is required in order for a loss-of-power condition to be separated from line and modem failures.
5. The secondary terminal power condition must be sensed by the modem to prevent the dispatching of service personnel to repair the terminal when the reason for the outage is terminal power down, or power outage, rather than terminal failure.
6. The modem must detect intermittent and transient conditions (*e.g.*, impulse noise on the line) on the signal received over the line and must hold this information until it is collected by the system. This is required for isolating intermittent problems which may not occur when a test is being executed.

Overview block diagrams of the IBM 3863, 3864, and 3865 modems are shown in Figs. 2, 3, and 4, respectively. These block diagrams illustrate the relatively minimal amount of signal processing performed in classical analog fashion, with most of the functions performed in the digital domain. Also, the interface to the attached communications controller or secondary terminal is implemented with a simple bus-to-bus adapter, with the control and timing provided by ROS-stored programs. Note that all the modems have a similar structure, with additional computing power added as speed increases to meet the performance requirements for the more complex signal-processing algorithms.

- *LPDA test interface*

Given this modem structure, and remembering that the RS-232-C interface is defined for data transmission between the modem and the attached business machine [6], it is a relatively straightforward matter to extend this interface to handle test requests and responses. This was accomplished by defining two additional control signals above those required for data transmission (see Fig. 5).

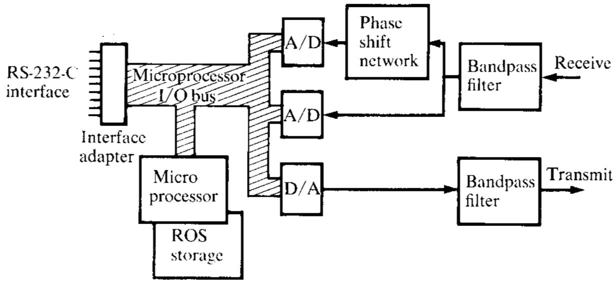


Figure 2 IBM 3863 block diagram overview. [Note: A/D = analog-to-digital converter, D/A = digital-to-analog converter, ROS = read-only storage.]

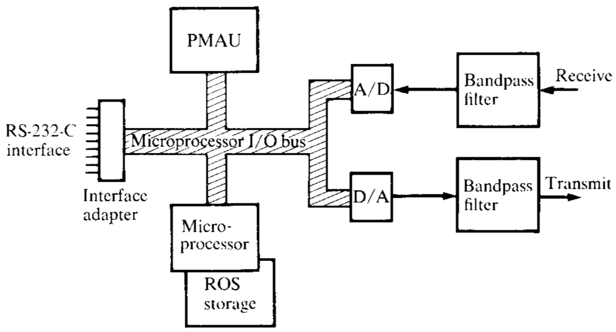


Figure 3 IBM 3864 block diagram overview. [Note: PMAU = pipelined multiplex arithmetic unit (high-speed multiplier).]

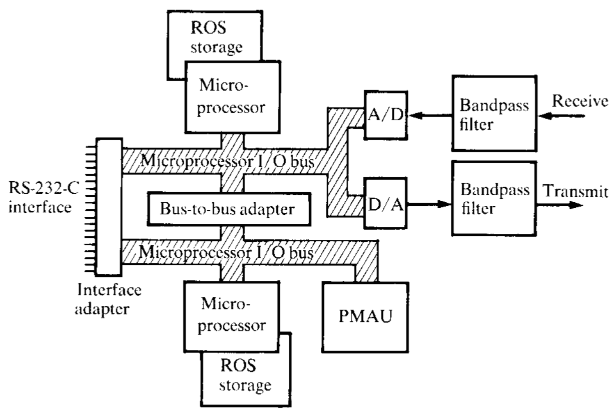


Figure 4 IBM 3865 block diagram overview.

One of the new interface signals is called Test Control (TC); the activation of this lead by the attached business machine signals the modem to switch from data mode to

Once the modem recognizes the activation of TC and switches to diagnostic mode, the transmission of the test commands and responses is accomplished with the same RS-232-C interface operation as is used for data. For a more detailed description of the operation of this interface, see Appendixes 2 and 3.

The test-request and test-response formats are SDLC-compatible and are shown in Table 1. This definition of the diagnostic interface adds minimum cost to the modem and communications controller; indeed, the 3705 communications controller could be made to support the LPDA function without any hardware modifications.

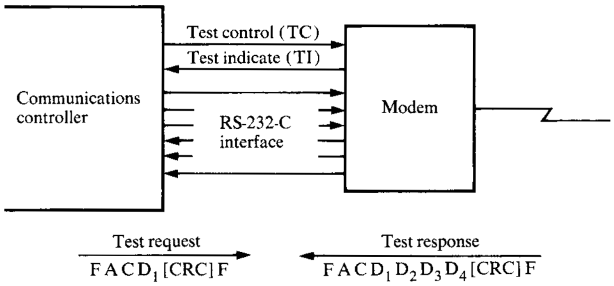


Figure 5 Link Problem-Determination Aid Test Interface.

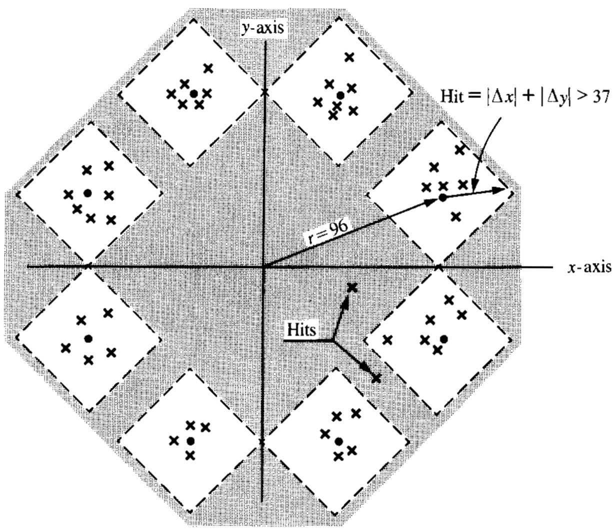


Figure 6 IBM 3864 Model 2 received-signal constellation. [Legend: ● = target points (transmitted signals), × = received points.]

Table 1 Test-request and test-response formats.

Test request	*Test response*
F A C D_1 [CRC] F	F A C D_1 D_2 D_3 D_4 [CRC] F

F: flag
A: address
C: control byte
D_1: test command
D_2, D_3, D_4: test result
[CRC]: cyclic redundancy check characters (2 bytes)

diagnostic mode. The other signal is called Test Indicate (TI); the activation of this lead by the modem indicates that the modem is in a test mode.

- *Received-line-signal quality measurement*

Several requirements had to be met in selecting a technique for the measurement of the received-line-signal quality. First, the monitoring needed to be performed during normal data transmission. This was required in order to capture information on intermittent or transient conditions for the NPDA log. This information was required for locating and isolating these intermittent problems. Second, the technique had to apply to the three speeds of modems and had to take into account designs with different modulation techniques and digital-processing algorithms. The 4800- and 9600-bit/s modems have very powerful automatic equalizers for some line impairments and thus high immunity to these conditions. Therefore, the line should not be indicated as the probable cause if it is not causing data errors, even if a parameter exceeds a tariffed or specified value. Third, the implementations had to fit within the available microprocessor capability in order to meet cost objectives and to minimize development expenses.

The technique that was chosen is based upon the effects of line impairments on the so-called "eye pattern" (also referred to as "signal constellation" or "signal space") [7], which is a representation of the actual received signal *versus* the theoretical target points. Representations of eye patterns are shown in Figs. 6 and 7. During the demodulation process the modem determines the position of the received signal at each baud time. It then determines the closest theoretical target point to be the signal transmitted. If there are no line impairments that affect the demodulation process, the received signal will fall close to the theoretical target point, and there will be no errors. However, if line impairments affect the demodulation process, the received signal can be moved closer to an incorrect target point and an error can occur.

The eye-pattern analysis is performed at the end of the demodulation process (Fig. 8). This is after the digital signal processing has adjusted the receive level with the automatic gain control, any frequency shift has been canceled with the phase filter, and the equalizer has compensated for group delay and attenuation distortion. Until these impairments exceed the range of compensation, the eye pattern is unaffected and so is the reliability of data transmission. Once these impairments exceed the range of compensation, they begin affecting the eye pattern and, depending on their magnitude, they may affect the reliability of data transmission. Thus, the operator does not have to react to line impairments that do not affect data transmission.

The eye pattern analysis consists of defining two parameters to characterize the impact of line impairments. These are as follows:

1. Quadratic error—this is the average distance by which the received signal misses the theoretical target point. It is a running average of the last N samples and is expressed in values from 0 to 15. The value 0 represents zero average miss distance (no data errors), and the value 15 represents a large average miss distance (many data errors). The value of 8 has been set empirically to correspond to one error in 10^5 bits of transmission (*i.e.*, a bit error rate of 10^{-5}). This parameter is useful for characterizing the average effects of all impairments.
2. Hit count—this parameter is intended for capturing intermittent or transient faults that are not indicated by the quadratic-error parameter. A "hit" is defined as the occurrence of the received signal missing the theoretical target point or phase by greater than a predefined limit. This is illustrated in Figs. 6 and 7; any received signal in the shaded regions is defined as a "hit." The "hit" indication is preserved by the modem by incrementing a counter for later retrieval by the system. An accumulation of up to 63 is kept by the modem, and this count is reset when read by the system. In order to prevent a single noise burst from filling the counter, the "hit" counter is incremented a maximum of one every 256 baud periods.

Also, due to the demodulation process, the received signal can be scattered away from the correct theoretical target point. Some of the received signals could be moved inside the hit limits of an incorrect theoretical target point and would not be detected. If the noise burst is several baud times long, there is a high probability of indicating a hit. However, if the noise burst is less than one baud time, and assuming that the received signal can be moved with equal probability to a point anywhere on the eye pattern, the probability of detecting the hit is roughly proportional to the magnitude of the hit region divided by the magnitude of the total region. For this, and for other reasons such as duration of sample time, operator judgment is required for interpreting the effects of this parameter.

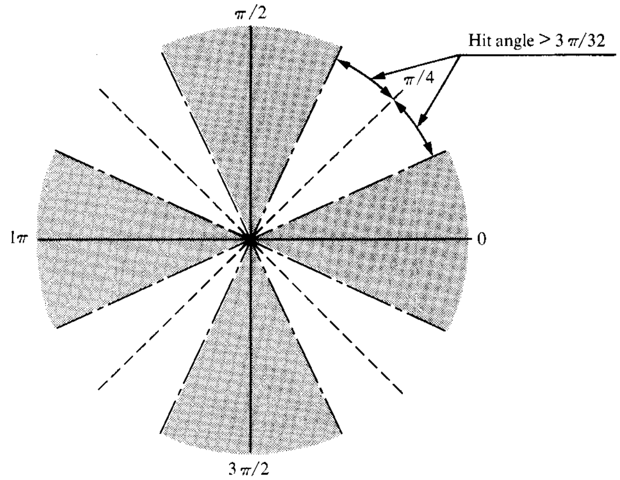


Figure 7 IBM 3863 received-signal phase constellation. Legend: --- = target phases (transmitted signals), —- = hit phase boundaries.

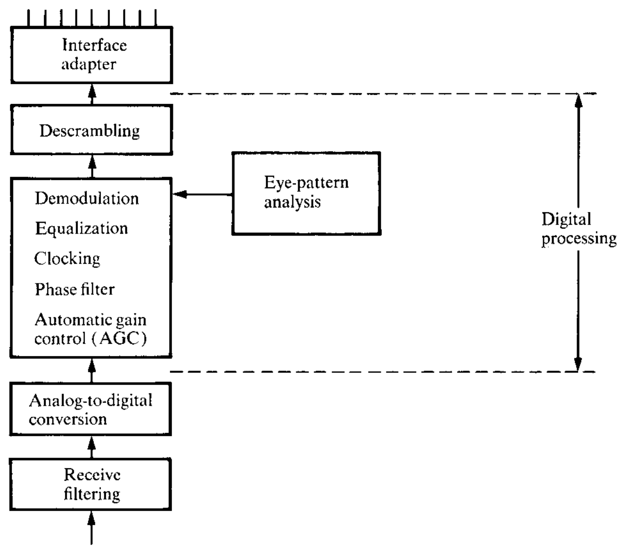


Figure 8 Receiver function distribution overview.

For additional information in applying eye-pattern analysis for problem determination, the reader is referred to Ref. [7].

- *Extended diagnostic feature*

The objective to provide sufficient information for problem isolation without assistance from an operator at the remote modem site created the following requirements:

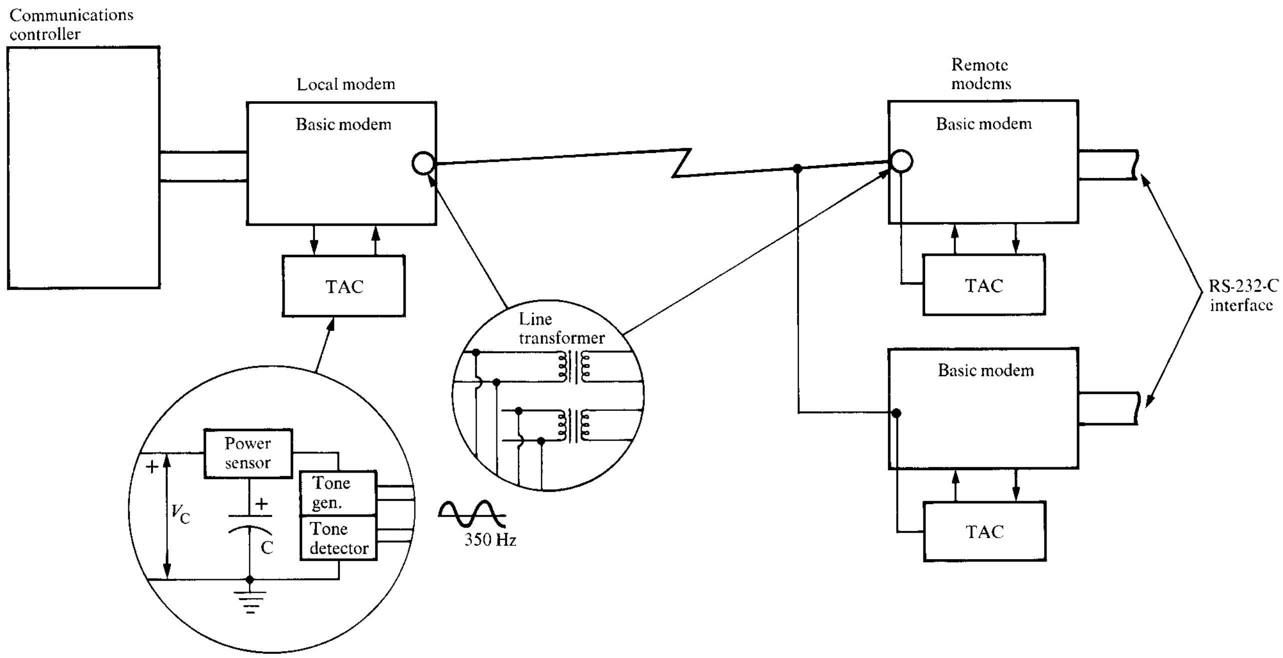


Figure 9 Extended diagnostic feature overview.

1. The capability for the remote modem(s) to signal the local modem when power is lost.
2. The capability for the local modem to test the remote modem(s) without requiring operational remote modem(s). This capability is required because a failing remote modem has a significant probability of not being able to respond to a test request from the local modem, or to signal that it has failed, even when the failure condition is known by the modem.

These capabilities are provided with the Extended Diagnostic Feature (Fig. 9), which consists of a Test Alarm Card (TAC) and additional ROS-stored programs in the local modem for the control and sensing of this card. The TAC card consists of a 350-Hz tone generator and detector, a circuit to sense the loss of power, and a capacitor circuit to provide a temporary power source for sending the tone when power is lost.

The loss of power on the remote modem is signaled by the sending of a short burst of the 350-Hz tone by the remote modem TAC. The tone is detected by the local modem TAC, and this loss-of-power condition is stored in the local modem for retrieval by the system. The loss-of-power condition will be retained for three minutes, or until the condition is read by the attached DTE, whichever occurs first. If the loss of power occurs on a modem connected to an operational terminal, the communications controller will recognize this as a logical network failure and will gather the link status before the loss-of-power indication is reset. If, however, the loss of power does not cause a network failure (*e.g.*, end-of-day power off), the condition will be reset after three minutes. This time correlation of a logical network failure (*e.g.*, station inoperative) to a change in the link status (*e.g.*, modem power loss) greatly improves the problem-isolation effectiveness. Also the operator need not react to link subsystem changes that do not affect the logical network operation.

The testing of the remote modem(s) with TAC(s) is performed as follows: the local modem, as part of its self-test, initiates the TAC to send a short burst of the tone, and then monitors the tone detector for a tone response from a remote modem TAC. Upon recognizing this tone, the remote modem TAC will force a self-test of the remote modem. The TAC will monitor this test to see that there is a successful completion and also that no faults are detected during the test. If these conditions are not met, the TAC will transmit a tone back to the local modem TAC. When the local modem recognizes this tone response, it interprets it to be a modem failure and will report this condition as a remote modem failure as part of the self-test results.

Table 2 LPDA test duration times.

	Nominal test times (seconds)						
	3863		*3864*		*3865*		
	Leased	*Switched*	*Leased*	*Switched*	*Point-to-point*	*Multi-point*	*Overall worst case*
Local Modem Self-Test	4.9	4.8	4.6	3.8	4.5	4.5	5.0
Remote Modem Self-Test	3.3	3.3	3.2	3.0	4.9	4.9	5.0
Local/Remote Modem Status Report	2.1	2.3	0.8	2.2	0.9	0.9	2.6
Local Modem Status Report	0.1	0.1	0.1	0.1	0.02	0.02	0.2
Remote DTE Interface Status Report	0.5	0.7	0.6	1.3	0.5	0.5	1.4

The structure is such that the presence or absence of the tone conveys the required information. Also, since data transmission is suspended when the tone is used for testing the remote modem(s), and since the tone transmission for signaling power loss is a short burst, the designer need not be concerned with the tone interfering with data transmission. These considerations simplify the design and improve the reliability *versus* using a modulated 350-Hz signal for passing command and test results, as is done in most sidestream implementations.

• *Link-status monitoring*

In addition to the received-line-signal quality monitoring and the power-loss indication, monitoring of other status conditions or changes in status conditions in the link subsystem can be helpful for problem determination. This can be particularly true when the problem is intermittent.

Following are brief descriptions of the additional status conditions that are monitored.

1. Secondary DTE interface leads
   - Data Terminal Ready (DTR) is monitored for a deactivation of this line. In leased-line configurations, the deactivation of this line indicates a non-operational terminal.
   - Transmit Data (TD) is sensed to determine if the DTE is powered off.
   - Request To Send (RTS) in multipoint configurations is monitored for a continuous-on condition of greater than 40 seconds. This condition is called streaming and indicates that the terminal is in a failure condition.
2. Line status
   - Loss of carrier is indicated if the carrier signal drops in data mode for those configurations where continuous carrier is expected. This indication is reset when reported to the system.
   - "SNBU connected" is indicated where the Switched Network Back-Up (SNBU) connection is active for recovery from a leased-line failure.
3. Modem status
   - Modem re-initialization is indicated when the modem has been re-initialized due to a power-on or machine check. This indication is reset when reported to the system. The frequent occurrence of this indication indicates an intermittent power or modem problem.

Again, due to the microprocessor-based design, it was very easy to add this additional monitoring function. Except for an additional circuit to sense the DTE power-on condition, the function was implemented with additional stored programs in ROS.

• *LPDA test menu overview*

LPDA is comprised of seven tests to meet the various requirements. Following is a short description of each test and the information content of its response. Where appropriate, the detailed test results are shown in Appendix 4. Test duration times are shown in Table 2.

1. Local Modem Self-Test—this test command causes the local modem to perform an extensive diagnostic test of itself. The results returned to the attached business machine will include pass or fail indication, sus-

pected failing element if the test failed, information on configuration installed, strapping options (*e.g.*, point-to-point or multipoint, etc.), indication of the engineering-change level, and (if the Extended Diagnostic feature is installed) an indication of whether a remote modem failed during the test.

2. Remote Modem Self-Test—this test command, after decoding by the local modem, is transmitted to the remote modem. The remote modem then performs an extensive self-test and returns the test results to the local modem for transmission to the communications controller. The test results are the same as for the Local Modem Self-Test.
3. Local/Remote Modem Status Report—this single command collects modem status from both the local and remote modems. The local modem, after decoding this command, transmits it to the remote modem. The remote modem then transmits its status to the local modem for relaying to the communications controller. At the completion of transmitting the remote modem status message to the communications controller, the local modem will follow with a message containing its status. This complex test was created to facilitate periodic sampling of the line, modem, and secondary station interface status for the NPDA file.
4. Local Modem Status Report—this command collects status from the local modem. The contents are the same as for the local modem status in the Local/Remote Modem Status Report. This command is used when the Local/Remote Modem Status Report fails.
5. Remote DTE Interface Status Report—this test command, after decoding by the local modem, is transmitted to the remote modem. The modem then sends a message containing the interface status information to the local modem for relaying to the communications controller. This status information includes the current state of selected RS-232-C interface signals as well as information concerning whether there has been a transition on the interface signals since the last test. Also included is an indication if the attached DTE has lost power or if the modem has changed speed (*e.g.*, full speed to half speed) since the last test. This test is performed under operator control to help isolate DTE failures from modem problems.
6. Local Loop-Back Test—this test command causes the local modem to disconnect the transmitter and receiver from the communications line and to "loop" the transmitter back to the receiver. With this connection, the information on the TD line of the modem is looped through the modem back to the RD line of the modem. The attached DTE must check the received data for validity. The test duration is controlled by the DTE, and the test is terminated when the DTE deactivates TC.
7. Remote Modem Loop-Back Test—this test command, upon decoding by the local modem, is passed to the remote modem. This command causes the remote modem to "loop" the received data back onto the TD line. This loop-back is performed at the digital level. The local modem, after transmitting the command to the remote, operates as a normal modem. This creates a data path from the DTE that goes through the local modem, over the communications line, through the remote modem, back through the remote modem, back over the line, through the local modem, and to the DTE. The attached DTE must check the received data for validity. The test duration is controlled by the DTE, and the test is terminated when the DTE deactivates TC.

LPDA system operation

The major premise of the CNM support of LPDA is to use ACF/NCP/VS link statistics for problem detection and to use LPDA information for problem isolation. No attempt is made to use the LPDA information to alert the operator of a link problem. There are two major reasons for this design philosophy:

1. The ACF/NCP/VS program is the only component to know for sure whether errors are actually occurring in the link subsystem.
2. The link test and status information can be used only to estimate the probability of errors occurring. This is particularly hazardous where line quality is concerned. A line quality reading of 8 on average will give acceptable operation. But, depending on the actual combination of impairments and data block sizes, the operation may be unacceptable for the customer. Also, DTE power-off may be a normal power-off or a power outage, and the LPDA information cannot differentiate between these two conditions.

The programming support for LPDA is part of IBM's CNM offerings for SNA networks and is integrated into NCP and NPDA. This support extends the NPDA problem-determination capability to cover the link subsystem. With this support, NPDA will automatically do "probable cause" analysis down to the failing component in the link subsystem. Prior to this, NPDA/NCCF could only isolate the failure to the link. For more complete and current information regarding the NPDA facilities, the interested reader is referred to the general information product documentation [8].

The programming support for LPDA testing can be separated into the three categories of permanent error analysis, statistical data collection, and operator-initiated testing.

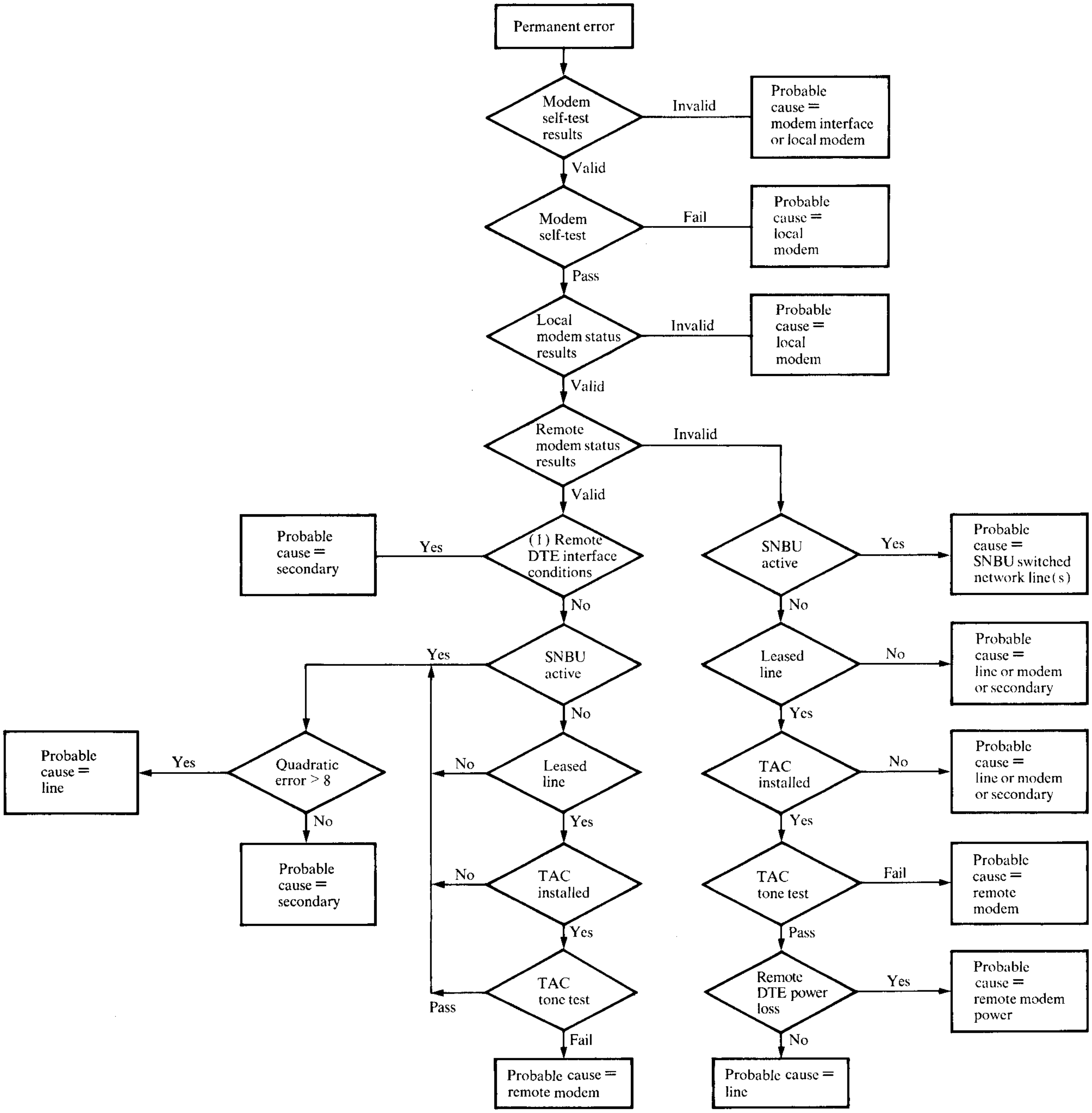
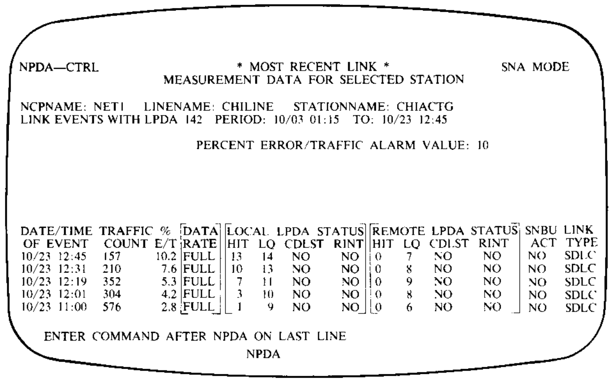


Figure 10 "Probable cause" decision flowchart. [Valid/invalid: test did/did not execute correctly (*e.g.*, no results received). Pass/fail: test results indicate a pass/fail of the tested component. (1): Remote DTE interface conditions are: DTE power off, DTR off, or DTE streaming.]

• *Permanent error analysis*

Permanent errors are defined by the fact that NCP has exhausted its Error-Recovery Programs (ERPs), and the network resource (*i.e.*, station or link) must now be made inoperative. Upon reaching this condition, NCP will initiate a series of LPDA tests to collect link information for inclusion with NCP error information in an error record to be sent to NPDA. This error record will be used by NPDA to do the "probable cause" analysis.

The LPDA tests executed on permanent errors are the following:



NPDA—CTRL * MOST RECENT LINK * SNA MODE
MEASUREMENT DATA FOR SELECTED STATION

NCPNAME: NET1 LINENAME: CHILINE STATIONNAME: CHIACTG
LINK EVENTS WITH LPDA 142 PERIOD: 10/03 01:15 TO: 10/23 12:45

PERCENT ERROR/TRAFFIC ALARM VALUE: 10

DATE/TIME	TRAFFIC	%	DATA	LOCAL LPDA STATUS				REMOTE LPDA STATUS				SNBU	LINK
OF EVENT	COUNT	E/T	RATE	HIT	LQ	CDLST	RINT	HIT	LQ	CDLST	RINT	ACT	TYPE
10/23 12:45	157	10.2	FULL	13	14	NO	NO	0	7	NO	NO	NO	SDLC
10/23 12:31	210	7.6	FULL	10	13	NO	NO	0	8	NO	NO	NO	SDLC
10/23 12:19	352	5.3	FULL	7	11	NO	NO	0	9	NO	NO	NO	SDLC
10/23 12:01	304	4.2	FULL	3	10	NO	NO	0	8	NO	NO	NO	SDLC
10/23 11:00	576	2.8	FULL	1	9	NO	NO	0	6	NO	NO	NO	SDLC

ENTER COMMAND AFTER NPDA ON LAST LINE
NPDA

3863, 3864, 3865, Modems with NPDA

Figure 11 Sample display of local/remote modem status report. [Legend: data rate—modem data rate (full or half speed), hit—hit count value, LQ—average line quality (*i.e.*, quadratic error), CDLST—receive carrier lost where continuous carrier is expected, RINT—modem re-initialized, SNBU ACT—switched network backup (SNBU) active.]

1. Local/Remote Modem Status Report:
   - Line-failure indicators (hit count, loss of carrier, quadratic error), which point to a degraded line.
   - DTE-failure indicators (DTE power-off, DTR deactivation streaming condition), which point to a DTE failure.
   - Modem-failure indicator (modem re-initialization), which points to an intermittent modem or temporary power failure.
2. Local Modem Status Report (if Local/Remote Modem Status Report cannot be successfully executed):
   - Remote modem power failure indicator.
3. Local Modem Self-Test:
   - Local modem failure indicator.
   - Remote modem failure indicator (if extended diagnostic feature is installed).

The results of these three tests provide the failure indicators for NPDA to do the "probable cause" analysis to the failing link component. Figure 10 illustrates the decision flow chart used to determine the "probable cause" of the failure.

- *Statistical data collection*

Statistical data collection is used to periodically collect link information for logging in the NPDA file. NCP collects traffic statistics (*e.g.*, total messages and messages in error) in a series of counters for each of the stations on the link. Upon reaching a pre-defined threshold by any of the counters, NCP will initiate the Local/Remote Status Report, and at the conclusion of the test will send the results along with the contents of the counters to NPDA. NPDA will log this information and will also analyze the traffic statistics to see if the station is experiencing an excessive error rate. If the error rate (*i.e.*, total errors/total messages) exceeds the customer-specified criteria, an alert is generated.

The network operator can now view the file (Fig. 11) as an aid in the problem determination. (Note: the NPDA screens are displayable via the NCCF network operator.) This display shows the traffic counts, the magnitude of the performance degradation (% E/T error-to-traffic ratios), multiple samples for spotting trends, and line quality information at both the local and remote modems. By examining the hit count and the quadratic error values, a determination can be made whether the line problem is intermittent or transient (*e.g.*, impulse noise), or is a long-term impairment.

The algorithm for distinguishing intermittent or transient impairments from long-term impairments is as follows: If the quadratic error value is high (*i.e.*, >8), the problem is a long-term impairment. If the hit count is high (*i.e.*, 63) and the quadratic error is low (<4), the problem is intermittent or transient. Of course, several samples should be examined to be confident in the conclusion.

- *Operator-initiated tests*

Two operator commands are provided which cause the execution of LPDA tests. These commands are used for problem determination or to verify the link operation after repair.

1. Link Status and Test:
   This operator command initiates the same series of tests that are automatically executed when a permanent error occurs. By executing this single operator command, the status of the modems, the communications line, and the DTE interface can be determined. A sample display of the test results is shown in Fig. 12.
2. Remote DTE Interface Test:
   This operator command enables the network operator to initiate an operation with the station (*e.g.*, poll) and then to view the activity that transpired on the RS-232-C interface (Fig. 13). This operator command is useful for isolating DTE problems that do not manifest themselves via the deactivation of DTR. For example, a problem where the DTE activates Request To Send but does not send any data on Transmit Data could be pinpointed to the DTE by using this test. A sample display of these test results is given in Fig. 13.

Concluding remarks

The communications network management facilities provided by LPDA and their support in the mainstream SNA components are a state-of-the-art solution for link network management that is being installed in customers' networks. This has been made possible by the maturation of LSI microprocessor technology and digital signal-processing methodology resulting in an implementation that could provide LPDA function without any significant cost impact.

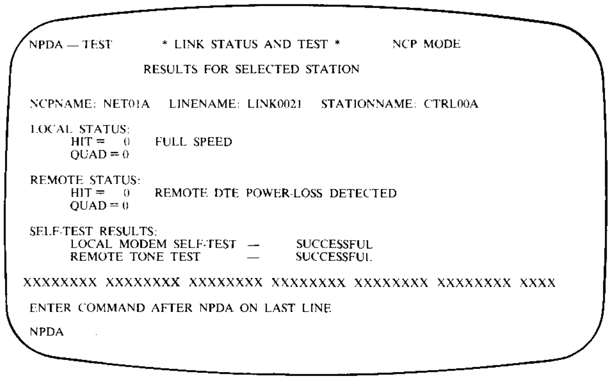


Figure 12 Sample display of link status and test.

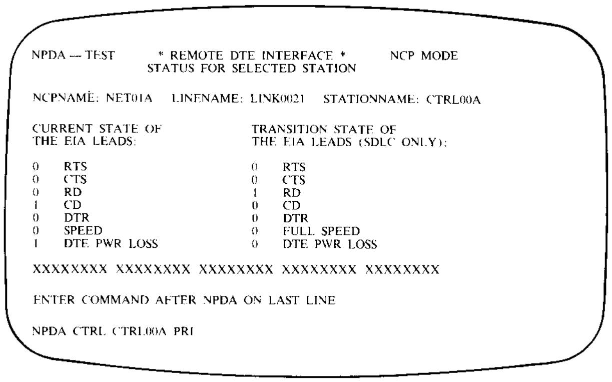


Figure 13 Sample display of remote DTE interface report. [Legend: Speed—modem data rate (1 = full speed, 0 = half speed), DTE PWR loss—DTE power loss.]

Appendix 1: Glossary of acronyms used in the text

ACF/NCP/VS: Advanced Communications Function/Network Control Program/Virtual System—program resident in the 3705 communications controller.

CNM: Communications Network Management.

CTS (or RFS): Clear To Send (or Ready For Sending)—line defined as CCITT V24-106 [9] or RS-449-CB [10].

DCE: Data Terminating Circuit Equipment—used to represent a modem (*mo*dulator-*dem*odulator).

DSR: Data Set Ready—line defined as CCITT V24-107 or RS-449-CC.

DSRS: Data Signaling Rate Selector—line defined as CCITT V24-111 or RS-449-CH.

DTE: Data Terminal Equipment—used to represent a terminal, a communications controller, a host, or a communications subsystem.

DTR: Data Terminal Ready—line defined as CCITT V24-108 or RS-449-CD.

ERP: Error-Recovery Procedure.

FRU: Field-Replaceable Unit—a unit of replacement for a failed hardware part, *e.g.*, a card or a subassembly part.

LPDA: Link Problem-Determination Aid.

NCCF: Network Communications Control Facility—program resident in a System/370 host.

NCP: Network Control Program.

NPDA: Network Problem-Determination Application—program resident in a System/370 host.

RD: Receive Data—line defined as CCITT V24-104 or RS-449-BB.

RTS: Request To Send—line defined as CCITT V24-105 or RS-449-CA.

SDLC: Synchronous Data Link Control.

SNA: Systems Network Architecture.

TC: Test Control—line defined as CCITT V24-141 or RS-449-LL.

TD: Transmit Data—line defined as CCITT V24-103 or RS-449-BA.

TI: Test Indicator—line defined as CCITT V24-142 or RS-449-TM.

Appendix 2: LPDA protocol on the DTE/DCE interface

The protocol to be used by the local DTE to initiate and terminate the LPDA functions in the modems (both local and remote) consists of a request-response sequence with various message protocols. When a request (command) signal is sent through the interface, a response signal is presented at the interface acknowledging that command. This is a form of "closed loop" that enhances system integrity and reliability. This protocol is established according to four phases, as follows:

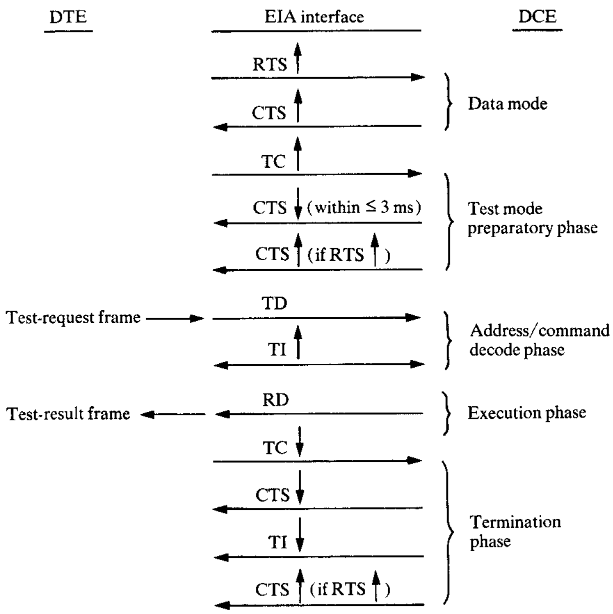


Figure 14 Protocol on DTE/DCE interface for a local modem status report.

1. Initialization phase
   This phase is used by the local DTE to the local modem to be prepared to receive the test-request message frame. The TC signal is used for that purpose. The reaction from the local modem is to deactivate the line RFS (or CTS), serving as an acknowledgment to the local DTE; then within a very short time, it again activates RFS if RTS is maintained activated by the DTE. The purpose of activating RFS is to signal the DTE that the modem is now ready to accept the test-request message frame.
2. Address/command decode phase
   This phase is used by the DTE to send the test-request message frame, and is also used by the local modem to activate whatever test and/or report function is to be executed. The local DTE transmits the test-request frame on the line TD. If the test-request frame is checked to be valid, the local modem will acknowledge this by activating line TI.
3. Execution phase
   This phase is used to execute the test request in the modem. For test-request types other than loop-back in the modem(s), the DTE just awaits the test-result message frame on the line RD. If a loop-back test is to be executed, the DTE will send test data on the TD line and will check for that data on the RD line.
4. Termination phase
   This phase is used by the local DTE to signal to the local modem that the test sequence is terminated. The DTE will deactivate the line TC. The local modem will acknowledge this by deactivating RFS and TI. The modem will then return to data mode.

Figure 14 shows an example of the protocol on the DTE/DCE interface for a local-modem status report.

Appendix 3: LPDA protocol on the communications line between modems

The protocol between modems also has four phases as with the DTE/DCE interface. To help compensate for a possibly defective data channel, an identifiable line signal is used by the local modem to transmit (at a lower, more reliable signal rate, or service speed) to the remote modems during the preparatory, address/command decode, and termination phases.

The protocol between the local and remote modems will take place when the local modem has decoded that the test-request message frame is intended for the remote modem. The response of the addressed remote modem consists of deactivating RFS and activating TI. The test-result message frame is transmitted from the remote modem, at service speed, to the DTE (requestor).

Figure 15 gives an example of protocol on the transmission line for a remote-modem self-diagnostic test.

Appendix 4: LPDA test results

- *Result Format for Local Modem Status Report:*

Byte D2: *Hit count:* A hit count is incremented by one if one or more hits occurred during a time of 256 baud.

Modem re-initialization: This bit is set at power-on of the modem or at reset time on a machine check.

Loss of carrier in data mode: This bit is set if the carrier signal is interrupted in data mode for those configurations where continuous carrier is expected.

Byte D3: *Quadratic error*

Remote modem power loss indication

Full/half speed: This bit is used to indicate the actual speed of data transmission on the line.

Four-wire-SNBU-connected indication: This bit is set when the four-wire switched network back-up connection is in use.

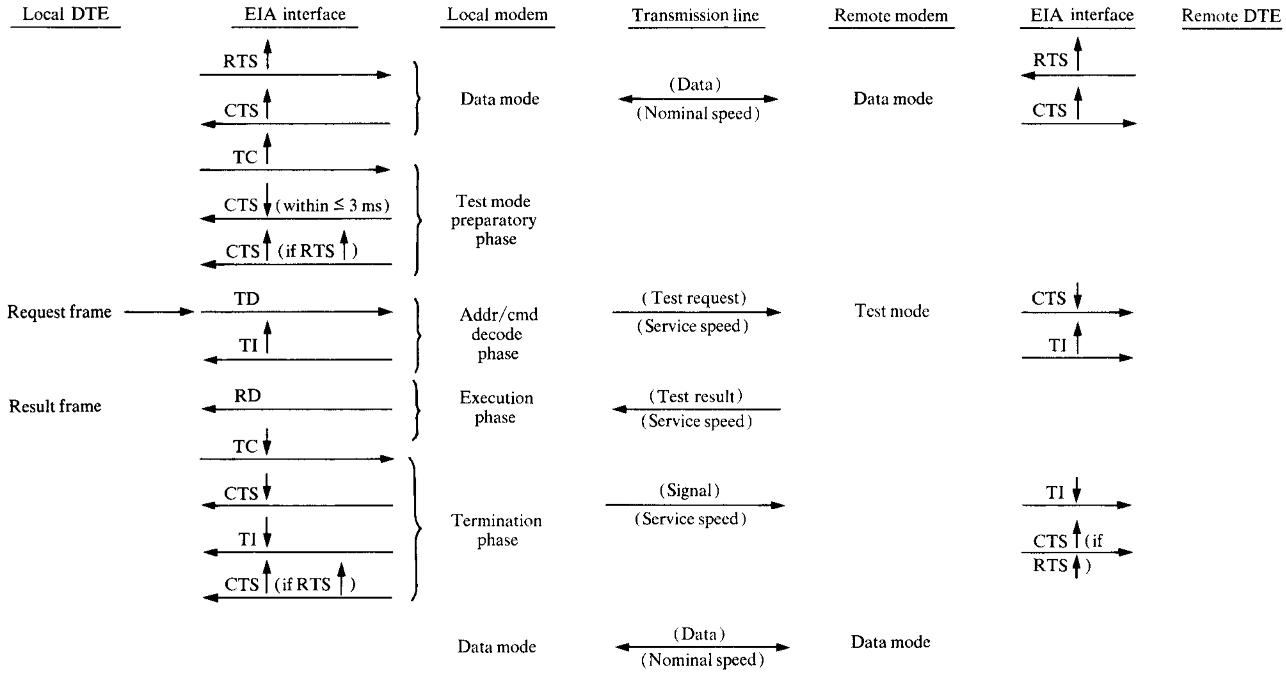


Figure 15 Protocol on DTE/modem/line/modem/DTE interface for a remote modem self-test.

Byte D4: All zeros.

- *Result Format for Remote Modem Status Report:*

Byte D2: As for the local modem status report.

Byte D3: *Quadratic error*

Remote DTE power-off detected

DTR drop detected

Four-wire SNBU-connected indication

Streaming condition detected: This bit is set when the remote modem detected that its DTE has kept RTS activated for more than 40 seconds (valid only for a tributary modem).

Byte D4: All zeros.

- *Result Format for Modem Self-test:*

This result format of the information field is used to answer either a local modem self-test or a remote modem self-test.

Byte D2: IBM 3863 or IBM 3864 or IBM 3865
Leased/1 = switched
Point-to-point / 1 = multipoint*
Primary or control/Secondary or tributary*
RFS delay : normal/exceptional
CDS sensitivity : normal/limited

*Always 0 in switched network.

Byte D3: Test failed
Remote self-test via tone failed†
FRU suspected in error

†Unused when answering a remote modem self-test or if TAC not installed.

Byte D4: Features installed
Microcode EC level

- *Result Format for Remote DTE Interface Status Report:*

This result format is used to answer a remote DTE interface status report request.

Byte D2 of the information field contains the current state of selected EIA interface lines.

RTS : Request To Send
CTS : Clear To Send or Ready For Sending (RFS)

TD : Transmit Data
DTR : Data Terminal Ready
Full/half speed
DTE power loss

Byte D3 of the information field contains an indication of the transition(s) of selected EIA interface lines since the last test occurrence.

RTS : If 1, RTS was activated at least once
CTS : If 1, CTS was activated at least once
RD : If 1, data was received
TD : If 1, data was transmitted
CD : If 1, carrier loss was detected at least once
DTR : If 1, DTR dropped at least once
Speed was changed at least once
DTE power loss was detected at least once (stand-alone modem only)

Byte D4 of the information field contains all zeros.

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