Errata

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HP References in this Application Note

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ISDN Testing techniques

Application note 397-1

for the HP 4954I and the HP 4951C/HP 4952A WAN protocol analyzers
As integrated services digital network (ISDN) quickly grows into an industry standard for voice and data transmission, greater demand is placed on network testing. Standard troubleshooting techniques have been adequate for standard networking problems. However, ISDN can impose testing requirements that demand more sophisticated testing techniques.

At Hewlett-Packard, we not only understand these challenges, we provide the tools to help you conquer them. This application note describes the most effective troubleshooting techniques that correct and prevent ISDN failures as well as the testing techniques developers need to ensure compatibility of their new ISDN developments.

We offer this application note to two groups of professionals. We lead the installation and maintenance technician through several ISDN failure modes, and provide symptoms and possible solutions. For the engineer responsible for developing and testing ISDN equipment, we also illustrate several valuable test scenarios. In both sections, we show that an HP protocol analyzer can put you in control of ISDN challenges.
Introduction

You may be a network specialist installing and maintaining ISDN lines and equipment or an engineer developing ISDN devices. In either case, you understand the importance of testing ISDN lines and equipment. We will introduce you to powerful testing techniques that will improve productivity, both in solving ISDN installation and maintenance problems and in performing R & D testing on ISDN devices.

Implementation of ISDN is more complex than traditional analog telephone service because of the wide variety and frequent revisions of ISDN features. While the end-to-end digital connectivity of ISDN technology offers numerous benefits, testing ISDN can be a formidable challenge. Incomplete ISDN standards and developers’ individualized protocol specifications are just two of these challenges. This lack of standards causes compatibility problems that require troubleshooting during installation or maintenance of terminal equipment, especially when that equipment comes from vendors other than the switch or PBX vendor.

If you develop ISDN switches or PBXs, you must test to verify that your chosen specifications are followed. Whether you are installing, maintaining or developing ISDN equipment, you will need to drastically increase testing and improve testing methodologies to ensure that features and new revisions are compatible with existing equipment.

ISDN requires different wiring from standard analog, or “plain old,” telephone service (POTS). If you are installing and maintaining ISDN equipment, new wiring is another reason that you may need greater testing capability. If you develop ISDN equipment, wiring differences mean you must develop physical interfaces with new specifications, which require a whole new range of testing.

As an ISDN installation and maintenance engineer, you need a winning combination of effective testing tools and good troubleshooting techniques for fast problem resolution. At Hewlett-Packard, we understand the critical nature of network downtime. We have dedicated the first part of this application note to troubleshooting techniques for commonly encountered problems. We will demonstrate that the HP 4951C and the HP 4952A protocol analyzers are effective tools for troubleshooting.

As an ISDN developer, your goal is to get products to market faster; we understand this well at Hewlett-Packard. Since thorough testing of your ISDN implementation is important at all stages of development, the use of correct tools is a time-saving opportunity that you cannot afford to pass up. In the second part of this application note, we present effective testing methodologies using the HP 4954I protocol analyzer. If you are not familiar with the ISDN signaling protocol, or if you wish to review some technical details, you will want to read the background information on the ISDN signaling protocol in the appendix.
Installation and maintenance testing

We begin our discussion by outlining a standard troubleshooting technique which uses a wide variety of test equipment. Then we present several ISDN-specific problem situations that can be solved only with the addition of a protocol analyzer. While this is not an exhaustive list, the examples we chose are the most common types of problems and focus on saving you troubleshooting time. The examples use, but are not limited to, the standard troubleshooting technique which follows.

Standard troubleshooting technique

Below are some simple steps that are useful for diagnosing the most commonly encountered problems. These steps require ISDN terminal equipment, ISDN switching equipment, time domain reflectometers (TDR), Test Impairment Measurement Sets (TIMS), and protocol analyzers.

Step 1. Check feature usage and switch configuration

A common problem you should consider early is that the user is not configured at the switch for a particular feature. Thus, when a user reports a problem with using a feature, first verify that the user is authorized to access that feature. Most ISDN switches provide this information on a per-user basis. For example, often users assume that they can automatically use the transfer or forward functions on their ISDN telephone. In reality, some ISDN switches must be configured to give users permission to use these features with specific telephones.

Also, just because an ISDN telephone has a data port for D channel packet switching, the user is not automatically configured at the switch to support this data port.

You can also save time by verifying that the user is properly working the function keys of the telephone.

In the section on problem situations, we will assume that the switch configuration is correct and that the user understands the use of the equipment. Therefore, we will not refer to this step in the actual examples.

Step 2. Substitute terminal equipment, especially telephones

This step is applicable to problems with the operation of ISDN telephones. Where ISDN telephones are plentiful, substituting a new telephone for the non-operational telephone can often get the user on-line quickly. In these cases, you can troubleshoot the problem using steps 3 and 4 below at a less critical time.

The substitution technique is not as commonly used with terminal adapters because many users and technicians do not have supplies of additional terminal adapters. When experiencing problems with terminal adapters, we advise that testing begin with reference point R. (See diagram under Scenario 1, page 5.) The interface is less complex at reference point R and, therefore, easier to troubleshoot than the ISDN interface. You should invest time ruling out problems at reference point R before continuing with the more complex testing of reference points S and T. For example, the cable connecting the non-ISDN terminal (TE2) and the terminal adapter (TA) is usually rather short, making it easy to check layer 1 indicators at both ends. Checking at both ends helps you verify that proper cables and connectors are being used. The interface between the TE2 and TA is also simpler to troubleshoot because it is limited to one connection with no possibility for bus contention.

Substituting a test device which has emulation capabilities can also be used in this step. The HP 18281A ISDN interface can be used with the HP 4952A protocol analyzer to emulate a TE in placing a call to the NT. Using a protocol analyzer in this step can reduce the amount of equipment that you need to carry with you in troubleshooting ISDN installation and maintenance problems.

Step 3. Check layer 1, the physical layer

The majority of problems are caused by physical layer problems. The most common types of networking problems for any technology are layer 1 faults and configuration or wiring problems.

At layer 1 on the basic rate interface (BRI), you must establish INFO states 3 and 4 to have a layer 1 connection. Verify the layer 1 connection by checking the INFO states at both the TE and the NT. When the ISDN telephone is receiving power, some ISDN telephones have the ability to detect layer 1 states. Some ISDN switches are able to display the INFO states. If you use a protocol analyzer to
The INFO states, if not in states 3 and 4, can indicate several different types of problems:

<table>
<thead>
<tr>
<th>At TE</th>
<th>At NT</th>
<th>Possible problem, next step in troubleshooting</th>
</tr>
</thead>
<tbody>
<tr>
<td>TE info state</td>
<td>NT info state</td>
<td>TE info state</td>
</tr>
<tr>
<td>The NT is not functioning properly; check connections at the switch; check status at the switch; as a last resort, reboot the switch.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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| 1 | 0 | 1 | 0 | The TE is not functioning properly; check connections at the TE; perform tests at the TE; cycle power on the TE. |
| 0 | 2 | 0 | 2 |

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<table>
<thead>
<tr>
<th>X</th>
<th>X</th>
<th>different value than TE</th>
<th>different value than TE</th>
</tr>
</thead>
<tbody>
<tr>
<td>If the INFO state values do not match, there is a possible wiring problem. Check the continuity of the wiring by using a time domain reflectometer (TDR). Most TDRs can be used to locate discontinuities from a wall jack to between 80 and 200 feet, depending on the device. If a discontinuity appears, fix or replace the wiring. If the continuity check does not reveal a break or short in the wiring, you can use an analog Test Impairment Measurement Set (TIMS), such as the HP 4934A, to measure the loss on each pair of the 4-wire circuit from the phone to the PBX. Compare the measured loss to the maximum permissible loss for the BRI: 6 dB at 96 KHz. If the loss is greater than the maximum permissible loss, replace the wire. Then, check the INFO states again to verify that wire replacement allows the interface to go into INFO states 3 and 4.</td>
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</table>

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detect layer 1 states, you will have an advantage over using the ISDN telephone. Using a protocol analyzer allows you to keep the telephone operational. Therefore, you can see how different uses and states of the telephone affect the INFO states. Also, with an HP 4951C, HP 4952A, or HP 4954I protocol analyzer, you can get additional layer 1 information regarding the presence of data and the error conditions on the physical interface.

If the INFO state indicators show that the interface is at INFO 3 and 4 at both the NT and TE, then layer 1 seems to be functioning properly. You should proceed to step 4 to start checking the D channel signaling protocol.

**Step 4. Check the D channel signaling protocol**

If the problem is not a layer 1 problem, verify that the D channel signaling is correct. A layer 2 connection must be established on the D channel before either X.25 packet switching can be used on the D channel or before a call setup can take place to send voice or data traffic on an ISDN bearer (B) channel. The appendix gives examples of layer 3 call setups.

You can use the customer premises equipment (CPE) intelligence to determine the state of the line regarding layer 2 connection, D channel X.25 data transfer, and layer 3 call setup. Specific key stroke sequences can give you status information, such as INFO states, on some CPE equipment.
Many CPEs give continuous status and error indications with a readable display or by illuminating specific lights.

You can determine the state of the line by using the status information available at the switch. Some ISDN switches display the TEIs in use and map them to the lines on which they are used. Some ISDN switches show the status of the line, with respect to layer 2, D channel X.25 or call setup. Some switches also print diagnostic information for a layer 2 failure.

In some cases, you can use information from the telephone and switch to narrow the problem to layer 2, D channel X.25, or call setup. Often, however, even if this information is available, it is incomplete or inconvenient. Getting switch diagnostics may not be convenient when you're troubleshooting at the user sight.

You can reboot the ISDN switch to solve some configuration problems, but it is a tactic you should use with caution. In a multi-user environment, it is an obtrusive solution to what may be a simple problem. Furthermore, there is no guarantee that rebooting the switch will solve the problem. You should attempt to pinpoint and solve the problem before rebooting the switch.

You can solve many problems by using the above steps. However, experts agree that some problems require a protocol analyzer. A protocol analyzer can help you determine the state of the line and pinpoint the problem by monitoring the ISDN signaling channel (the D channel). A protocol analyzer's ISDN decoder allows you to see the activity on the ISDN channel in real time. These decoders give specific information to diagnose the problem.

The protocol analyzer decodes show layer 2 connections, X.25 traffic on the D channel, and call setups on the D channel facilitate the use of the B channel for voice and data calls. The use of protocol analyzer decodes improves troubleshooting productivity by eliminating the guesswork.

The remainder of this section focuses on specific installation and maintenance problems, where ISDN protocol analyzers are used. The examples are organized according to six common problem sources:

- improper configuration
- incompatible equipment
- incompatible equipment revisions
- wiring
- network problems, such as network congestion
- anomalies in the implementation

Improper configuration refers to unexpected blocks in communication caused by:

- mismatched configurations, such as addresses or TEIs, between two pieces of ISDN equipment;
- mismatched switch configuration and customer's use of features;
- improper line installation for use of features.

Many of these problems cause communication over the ISDN to stop, with limited diagnostic information available from the TE and the NT. To solve these problems, you must understand their actual source. A protocol analyzer is often the best, if not the only tool, to determine the actual source of these problems.
In the following examples, we portray the symptoms, troubleshooting techniques, and the diagnosis and resolution for cases of improper configurations.

Scenario 1

Symptom

A terminal adapter is not responding to calls placed to it.

Layer 2 analysis with the HP 4952A shows that the TE2 is not responding to a poll as it drops DTR. The host must be configured to use the correct address for the TE2.

Troubleshooting problems with terminal adapters should begin at reference point R.

Troubleshooting technique

In step 2 of the standard troubleshooting technique, we advised that you begin terminal-adaption testing with reference point R. By the time a technician is dispatched, most users have checked the most common configuration problems; for example, the TE2 and TA are configured for the same baud rate. To diagnose the problem, you should determine if there is successful communication between the terminal and the terminal adapter.

While monitoring the line between the TE2 and TA, the LEDs on the protocol analyzer show the TE2 has dropped data terminal ready (DTR). You can detect this by disconnecting the TE2 from the TA and reconnecting it. When the TE2 is first connected to the TA, the TE2 sets DTR high. Use the protocol analyzer to monitor the status of the leads and decode the data sent between the TE2 and TA. After the TE2 is polled for data, the TE2 drops DTR and becomes inactive. With this correlation of events, you determine that the TE2 does not respond to the poll. You then investigate the poll.

By checking out the various protocol fields in the polling sequence and comparing them to the configuration of the TE2, you discover that the host is using an incorrect address for polling the TE2.

Problem diagnosis and resolution

You used the protocol analyzer to determine that the TE2 was dropping DTR when polled by the host. Further investigation revealed that the host was using an incorrect address for polling the TE2. You must reconfigure the host to use the correct address for the TE2.

You can easily adapt the same protocol analyzer that you use to troubleshoot a large installed base of V-series interfaces, including RS-232C, for ISDN testing. For example, an HP 4951C or an HP4952A that is used for testing on V-series interfaces becomes an ISDN protocol analyzer with the addition of an ISDN interface and the installation of ISDN software.
Scenario 2

The terminal adapter at site A is being used unsuccessfully to transfer a file to a terminal at site B.

Symptom

A terminal adapter (TA) is being used to transfer a file from a terminal at site A to a terminal at site B. The terminal at site B supports the rate-adaption scheme used by the TA at site A, but the file transfer is not successful.

Troubleshooting technique

Troubleshooting at reference point R reveals no obvious problems between the TE2 and TA at site A. Checking layer 1 at the S/T reference point at site A, as outlined in step 3 of the standard troubleshooting technique, reveals no problems.

With layer 1 appearing to be operational, you can focus on the D channel. A protocol analyzer, monitoring between the TA and NT at site A, displays a SETUP message sent from the TA to the NT while placing a call. The SETUP message is sent with a bearer capability of 56 Kbps and an information element for V.110 rate adaption. When rate adaption is used, the site A terminal TA requires information regarding V.110 if it is to correctly interpret the data from the TA at site B.

Using a protocol analyzer at site A, you can see that the switch responds to the TA's SETUP with a CALL PROCEEDING message, which indicates a successful call setup.

The SETUP message transmitted by the TA at site A includes the low layer compatibility information element that contains information specific to V.110 rate adaption.
SETUP messages from the terminal at site B are transmitted with information elements, but the protocol analyzer at site A also shows no information elements on the SETUP messages. Information elements are being stripped from all SETUP messages before being transmitted in either direction.

**Problem diagnosis and resolution**

You used a protocol analyzer to determine that the information elements that communicate rate adaptation are not being transmitted end-to-end. These information elements are referred to in CCITT specifications as low layer compatibility.

When 56 Kbps trunks are used to connect ISDN switches (rather than an intelligent signaling system number 7 link), both switches are restricted in their capabilities. Until signaling system number 7 is installed between the ISDN switches, rate adaptation cannot be supported between terminals.

**Scenario 3**

**Symptom**

A user of an ISDN telephone cannot use the conferencing feature, which allows more than two telephones to communicate. During a conversation with one person, the user presses the conference button and dials the third person’s phone number. The user expects a ring to indicate that the third person is being called, but there is no ring. The original call can be retrieved.

**Troubleshooting technique**

Substituting a telephone makes no difference. INFO states indicate layer 1 is successful. Using a protocol analyzer, you see that the telephone is correctly sending a CONFERENCE message. The switch, however, is not responding with a CONFERENCE message but with a CONFERENCE REJECT message. There is no cause code on the CONFERENCE REJECT message to help you diagnose the problem.

Neither the CONFERENCE nor CONFERENCE REJECT message is defined by CCITT. Therefore, you must use documentation from the ISDN equipment vendor to find out if there are any obvious reasons for an NT rejecting a request for call conferencing. By reading the ISDN manuals, you learn that at least one call appearance must be set up for the user who is conferencing. Call appearance occurs when a user’s telephone is down or in use, and the call appears on another designated telephone. Call appearance is part of the translation that describes the user’s telephone/terminal and services to the switch.

**Problem diagnosis and resolution**

You used a protocol analyzer to determine that the terminal is...
transmitting a CONFERENCE message, to which the switch is responding with a CONFERENCE REJECT message. A request for conferencing is being rejected because at least one call appearance is not operational at that number. You must change the translation to include at least one call appearance for the user who is trying to use the conference feature.

**Scenario 4**

**Symptom**

A user is unsuccessfully trying to place an X.25 data call to a system on which he has been working for months.

**Troubleshooting technique**

It is not as practical to substitute a terminal as it is a telephone. Therefore, you should start troubleshooting by checking layer 1, which appears to be normal.

By monitoring the D channel, you see that the user's terminal successfully sets up a data call on channel B2. Focus your attention on the bearer channel. In this situation, a protocol analyzer that can monitor both the D and B channels is a real advantage.

By monitoring the B channel, you see that the user's terminal is sending a call request packet on the B channel. Instead of receiving a call confirmation packet as expected, the terminal receives a clear indication packet. Further analysis of the clear indication packet shows a cause code of local procedure error and a diagnostic code of invalid called address.

**Problem diagnosis and resolution**

You used a protocol analyzer to determine that the terminal used an incorrect X.25 address. This can occur if the device at the destination is removed or given a different address. To resolve the problem, find out the address of the destination system and reconfigure the terminal to send the correct address.

**Scenario 5**

**Symptom**

The user is not getting a dial tone after an ISDN telephone is installed in a BRI point-to-point configuration.

With the HP 4952A you can see the unsuccessful link setup which is keeping this user from getting a dial tone. The HP 4952A displays the TEI value, which does not match the switch configuration.

**Troubleshooting technique**

You substitute a telephone, but that does not resolve the problem. Layer 1 testing reveals no problems.
Receiving a dial tone is a function of D channel signaling. Therefore, use a protocol analyzer to monitor D channel signaling between the TE and the NT. You see that the telephone is trying to establish a layer 2 connection with the NT by sending a SABME (Set Asynchronous Balanced Mode Extended). The NT is responding with a DM (Disconnected Mode), rather than with a UA (Unnumbered Acknowledgment), which would complete the link setup.

Look at the SABME to determine why the NT is sending a DM. The only user-definable field in the SABME command is the TEI (Terminal Endpoint Identifier). The TEI used in the SABME is 34. These TEIs can be assigned in two ways. The network can automatically assign them with values (64 to 126) with automatic TEI management or, as in this situation, the equipment can be coded by the user with fixed TEI values between 1 and 63, inclusive.

The next step is to check the NT's configuration for the TEI value expected, which is found to be 40.

Problem diagnosis and resolution

You used the protocol analyzer to determine that the NT and TEI are using different TEI values. These different values prevent the establishment of a layer 2 connection, which is a prerequisite to getting a dial tone. You can solve the problem by reconfiguring either the TE or the NT so that both use the same TEI value.

Scenario 6

Symptom

A telephone that is connected to a NT in a passive bus configuration appears to be powered-on, but there is no dial tone.

Troubleshooting technique

Neither substituting a telephone of the same type nor checking layer 1 solved the problem.

Using status information from the telephone and the switch, you determine that a layer 2 connection has not been established. The status information at the telephone does not provide further information. Using status information at the switch, you find that no TEI value has been assigned to this line.

In order to perform further testing on this line, restart the line at the switch. Then use a protocol analyzer to monitor the D channel signaling when the telephone tries to establish a layer 2 connection.

You can see that the switch is not responding to the SABME sent by the telephone. Looking more closely at the SABME as in the previous example, you discover that the switch is not configured to accept TEI 4, which is a fixed TEI value coded by the user. The switch does not respond with a message; instead, the line goes dead.

There are few protocol fields in the SABME that could cause a problem. The SAPI value of 0 is a standard value. The TEI is the most variable field and most likely to cause a problem. Most switches provide the ability to determine which TEI values are already assigned. By using this capability, you determine that the TEI value of 4 is already in use.

Obtaining status information from the switch without a protocol analyzer is not useful, because the switch does not record the TEI value of 4 for the terminal which is experiencing problems. Looking at assigned TEI values will never show more than one terminal using the same TEI.

Problem diagnosis and resolution

You used a protocol analyzer to determine that more than one telephone is using the same TEI value. The NT disabled the TEI. To resolve the problem, you must change the TEI value of one of the TEs and reconfigure the switch accordingly.
Incompatible equipment

We stated earlier that due to a lack of complete ISDN standards, eager ISDN implementors are developing equipment to their own standards. Not surprisingly, many installation and maintenance problems are caused by incompatible combinations of equipment, often from different vendors. Pinpointing the cause of the incompatibilities is a strength of the protocol analyzer.

Scenario 7

Symptom

An ISDN user has a personal computer connected to his ISDN telephone/terminal. The user sees a code on the telephone’s display that indicates that the X.25 packet connection on the D channel is not working.

Troubleshooting technique

Substituting an ISDN telephone will not fix this problem. Layer 1 tests indicate no problems.

The ISDN telephone is sending an X.25 call request packet. The host PAD is sending back an X.25 clear indication packet with a cause code indicating an invalid facility request. The protocol analyzer decode shows that the X.25 call request packet is to reconfigure the pad in the terminal to use a default window size that is implemented by the ISDN switch.

Scenario 8

Symptom

An ISDN user is unsuccessfully trying to set up a D channel packet call to a remote host. As in the previous example, the user sees a code on the telephone’s display that indicates the X.25 connection is not working.

Troubleshooting technique

Substituting another telephone does not solve the problem. Layer 1 appears to be normal.

D channel monitoring with a protocol analyzer shows that the layer 2 link setup is not occurring. The display shows that the terminal is sending a SABME to bring the link up, but the NT is responding with a DM rather than with the expected UA. As in Scenario 5, you use the protocol analyzer to determine that the TEI value used by the telephone is 10. You then check the
configuration of the switch to determine that this is the TEI value expected by the NT.

CCITT recommendations for ISDN recommend that Modulo 128 (extended control) be used for X.25 packet switching on the ISDN channel. Since much existing X.25 equipment supports Modulo 8 only, however, it is possible that an ISDN NT has implemented support for Modulo 8 but does not yet support Modulo 128.

successful because the NT did not support Modulo 128 for X.25 packet switching on the ISDN D channel. To resolve the problem, one of the devices must be reconfigured so that both devices are using the same control format (Modulo 8 or Modulo 128). If neither device can be reconfigured, you should consider the equipment incompatible.

Troubleshooting technique
Substituting a telephone does not correct the problem. Layer 1 testing does not reveal any problems.

Status information from the telephone and the switch shows the original call is successful without giving information for problem troubleshooting.

Using a protocol analyzer, you see that the phone sends a CONFERENCE message to which the switch responds with a HOLD ACKNOWLEDGE that looks normal. You then expect the telephone to send a SETUP message, but none is sent. The first call can be retrieved but a conference cannot be established. The telephone simply continues to send layer 2 messages.

Check the switch configuration for this line even if this user has previously initiated conference calls. The switch configuration tells you that this user is configured to make conference calls. This user is also configured for a type C terminal. Telephone documentation shows that the user has a type D terminal.

You can use the HP 4952A to determine how the NT responds to a SABM, which is sent to bring up the layer 2 link when Modulo 8 is used. This is an example of where simulate capabilities on a protocol analyzer, such as the HP 4952A, are important for installation and maintenance testing. The NT responds with a UA, successfully completing the link setup.

Problem diagnosis and resolution
You used a protocol analyzer to determine that the layer 2 connection between the ISDN terminal and NT was not

Scenario 9
Symptom
A user of an ISDN telephone cannot initiate a conference call, even though he has done so before.

The HP 4952A can help you get to the bottom of problems caused by interchanging incompatible equipment. In this case, the terminal is expecting additional information elements on the HOLD ACK message.
Additional ISDN references tell you that when call conferencing is used with type D telephones, the switch tells the telephone through the HOLD ACKNOWLEDGE message on which button to put the second call. This is called terminal management. If the line from the switch were configured for terminal management (type D terminal), there would be an information element in this HOLD ACKNOWLEDGE message called Selected Call Appearance (SCA).

The SCA could contain a number indicating the button for the second call. There are no information elements in this message.

Problem diagnosis and resolution

You used a protocol analyzer to determine that the telephone and switch are sending the correct message types to set up a conference call. With the help of some documentation on ISDN equipment, you determined that the line from the switch must be reconfigured for a type D terminal, which requires terminal management.

Incompatible equipment revisions

ISDN vendors continually upgrade hardware and software to increase their ISDN features. Although vendors try to protect their installed customer base by being compatible with old revisions, there remains a chance for small differences. In these cases, a protocol analyzer expedites the detection of the incompatibility problem so that the new revision can be quickly updated.

Scenario 10

Symptom

A user of a new ISDN telephone cannot place calls.

Troubleshooting technique

When substituting with a similar but older model telephone, the user can successfully make calls. Because the user wants the features of the new telephone, you are encouraged to continue troubleshooting with the new telephone.

Status information from the telephone and the switch reveals a call setup is unsuccessful. Additional information is unavailable.

Looking at D channel signaling with a protocol analyzer, you see the telephone sending a layer 3 SETUP to the NT, indicating that the layer 2 connection and any necessary TEI management is probably okay. The NT, however, is not responding to the TE's SETUP with an expected positive acknowledgment. A RELEASE COMPLETE message, which releases the call rather than sets up the call, is sent in response to the SETUP message. Using ISDN specifications you can determine that the cause field of the RELEASE COMPLETE message indicates, "Information element non-existent or not implemented."

The HP 4952A can help you understand why the ISDN switch is not accepting calls from the terminal.
This is an example of where data compatibility between the HP 4954I and the HP 4952A is an advantage. Rather than using ISDN specifications to decode the cause for the RELEASE COMPLETE, if you have an HP 4954I at a central site, you can upload the data captured by the HP 4952A to the HP 4954I through a remote connection (or by floppy disk). Using the HP 4954I you can see that the NT does not recognize the information element used.

You can determine which information element is new by comparing the new telephone’s SETUP message to that of the old telephone.

In the new SETUP message, the T6 is using codeset 6. The information element is not supported in the current implementation of the switch.

Data compatibility between the HP 4954I and the HP 4952A is an advantage when more specialized information is needed.

The HP 4952A proves to be an excellent tool for quickly pinpointing incompatibility problems caused by new equipment revisions. The use of codeset 6 by the new telephone must be supported by the switch for successful communication.

The ISDN switch to support codeset 6.

Problems caused by wiring

Although most of the wiring problems can be detected by independent layer 1 testers, TDR, and TIMS devices, the protocol analyzer is helpful in narrowing the source of complex wiring problems.

Scenario 11

Symptom

A telephone in a passive bus configuration stops functioning. There is no set pattern in which the telephone stops functioning. For example, sometimes it stops when placing a call and sometimes when disconnecting a call.

Troubleshooting technique

Substituting a new telephone does not solve the problem.

Following step 3 of the standard troubleshooting procedure does not reveal any physical layer problems.

Status information from the telephone and switch indicates that layer 2 on the D channel is down after these abnormal occurrences, but you do not know what is causing layer 2 to go down. You need more information.
You monitor the link between the telephone and the NT with a protocol analyzer. This shows that the telephone is sending two messages where it should only be sending one. When this occurs, the NT removes the TEI with a layer 2 command, because the NT is detecting more than one device using the same TEI.

The second message looks like a reflection of the first, which indicates a possible wiring problem.

Problem diagnosis and resolution

The protocol analyzer indicated that the messages from the CPE were being reflected. Consequently, the switch that detects two devices with the same TEI cut off communication with the CPE. These reflections led to a more in-depth investigation of the wiring. The terminal was located too far from the NT, causing reflections to interfere with proper communication. The solution is to stay within the manufacturer's criteria for bus lengths.

The HP 4952A proves helpful in narrowing some problems caused by wiring. Here the HP 4952A shows that messages sent by the telephone are being duplicated, a result of reflection caused by using bus lengths which exceed the manufacturer specifications.

No layer 1 problems are detected.

While the physical layer appears to be operational, the next logical step is to find out the condition between the telephones and switch, while the calls are being placed. Status information from the telephones and switch indicates that layer 2 is up both

Using the HP 4952A you determine that the telephone sends each digit individually. This means that additional digits must be sent before the NT sends the CALL PROCEEDING message, which would indicate that the call is successfully established.

Scenario 12

Symptom

Many ISDN telephone users at one site are having intermittent problems in placing outgoing calls. These telephones are in a passive bus configuration.

Troubleshooting technique

Because many different users are affected, this is not an isolated case where replacing one telephone would be effective.

before and after the users keyed in the telephone numbers. No call setup is established once the phone numbers are dialed.

At this point you know that calls are not being established, but you do not know why. Monitoring the lines with a protocol analyzer can help narrow the cause of the problem. If the telephones are not transmitting the destination telephone numbers, the problem is probably in the telephones. If the telephones
are transmitting the entire phone numbers, the problem is probably in the switch.

A protocol analyzer monitoring the D channel shows you that the telephones are set up correctly at layer 2 before call setup information is being sent at layer 3. With the protocol analyzer you can see that these particular telephones send each digit individually (rather than “en bloc,” or all in one SETUP message). Even if the users dial entire telephone numbers, the telephones often stop sending digits before the entire number is sent. Using the protocol analyzer, you learn that it is not clearly a telephone problem or a switch problem.

Evidently, the problem is an intermittent one that requires troubleshooting beyond the standard method outlined earlier. By placing a telephone on one of the lines at the switch, you determine that the switch side of the line and the telephones are fine.

Such a mysterious problem warrants investigation of the wiring. You discover that when the wiring was installed in this area, Universal Service Order Code (USOC) “straight through” wiring standards were followed. According to these standards, wires for pins 3 and 4 are twisted together, and wires for pins 5 and 6 are twisted together. ISDN BRI standards specify that pins 4 and 5 are used for CPE transmission, and pins 3 and 6 are used for CPE reception. If USOC wiring is used for ISDN basic rate, then half of the transmit pair is twisted with half of one receive pair. This wiring “split” makes it likely to have high amplitude on one wire but not on the other CPE problem. This kept you probing instead of jumping to conclusions, and further probing led you to the resolution.

![Diagram of ISDN wiring](image)

Crosstalk can result when ISDN wiring standards are not followed. This crosstalk can terminate communication over the ISDN.

You know that in a passive bus environment, a terminal, such as a telephone, relies on NTs echoing bits, which are transmitted by the terminal, to signal the terminal to transmit. Crosstalk on wires for either pin 3 or 6 could make it look like the NT is sending a different pattern of echo bits. The terminal would wait, expecting that it is another terminal’s turn to send. The terminal assumes a lower priority for placing calls and discontinues its attempt to place a call.

Problem diagnosis and resolution

The problem is wiring to non-ISDN specifications. This is a problem which can be solved by cutting and reconnecting the ends of the wires. The protocol analyzer was used at an intermediate point of troubleshooting to determine that the problem was not obviously a switch problem or a
Network problems, such as network congestion

The user cannot always tell that an obstacle in communication is a network problem. In some cases, the only answer to network problems is a protocol analyzer at your site.

Scenario 13

Symptom

While trying to place a call, an ISDN customer gets a busy signal when he knows the number should not be busy.

The HP 4952A can quickly identify the problem here as network congestion.

Troubleshooting technique

Substituting a different telephone does not solve the problem. Layer 1 indicators show that the physical layer is normal.

You monitor the D channel with a protocol analyzer. The ISDN telephone sends a SETUP message as expected, when the telephone is taken off hook. Instead of responding with a SETUP ACKNOWLEDGE message or CALL PROCEEDING message as expected, the switch is sending a PROGRESS message. The information elements within the PROGRESS message show that network congestion is causing the busy signal.
Anomalies in the implementation

Scenario 14

Symptom

A development engineer is testing a new ISDN telephone in your ISDN service provider's lab. The engineer asks for your help because he cannot place a call with this telephone.

Troubleshooting technique

You substitute telephones and are able to place a call to the ISDN switch. However, you still do not know why the new telephone cannot place a call.

Layer 1 indicators show no problems.

The telephone's status information is still in preliminary form and does not provide useful information. Status information from the switch indicates that there is no call set up, but there is not enough information to pinpoint the actual problem.

Layer 2 connection seems to be established and the telephone sends a SETUP message. The switch does not respond with a SETUP ACKNOWLEDGE or with a CALL PROCEEDING message. Instead, the switch responds with a DISCONNECT message, and the cause information element indicates an invalid call reference value.

Problem diagnosis and resolution

You used a protocol analyzer to determine that the new ISDN terminal sent a call SETUP message with an invalid call reference value. In this case, the ISDN developers need to change the use of this field for this new implementation.

This example shows there is not always a clear division between the use of a protocol analyzer for installation and maintenance and for R & D. This is especially true for the implementation of ISDN, where ISDN service providers support development and implementation by providing test labs for developers. In these labs, development engineers test the functionality of their equipment. When the equipment under development is not communicating properly, the cause may be configuration or implementation problems. It may still be your responsibility as a ISDN service provider technician to determine the cause of these problems.

A protocol analyzer in installation and maintenance testing

The preceding examples showed that you can use a large array of tools to solve your ISDN problems. These examples also showed how a protocol analyzer is indispensable for troubleshooting and fixing problems as quickly as possible.

The HP 4952A can save troubleshooting time by providing information on implementation anomalies, such as invalid call reference values.
Research and development testing

The goal of research and development organizations is to get a high quality product to market in a timely manner. As an R & D engineer, your goal is to optimize quality without sacrificing time.

At all phases of development, comprehensive testing is important in meeting these requirements. As development progresses, both the amount of time needed to correct implementation anomalies and the risk of introducing new anomalies increase dramatically. The key to saving time is to perform comprehensive testing as early as possible in the development cycle.

Hewlett-Packard's protocol analyzers are excellent test tools that support you in achieving your goals. The HP 4954A provides comprehensive test capabilities, especially appropriate for early developmental testing. Since the HP 4954A is menu-driven and easy to use, learning time is short so you can start testing quickly.

Two prerequisites for a quality product are a good design and a complete test plan. Critical in a complete test plan is testing as many cases as possible and catching problems early in the implementation. Three types of testing are found in a complete test plan:

- Error injection testing determines whether your device responds properly in error conditions.

- Monitoring while the implementation under test (IUT) is interacting with other ISDN devices during special test conditions verifies that your ISDN implementation works correctly with the designated equipment.

The remainder of this section shows that Hewlett-Packard protocol analyzers are excellent tools for research and development testing.

Functional testing

As a design engineer, you perform functional testing to determine how well the IUT can communicate with other ISDN devices. Whether the product under development is terminal equipment (TE) or network termination (NT) equipment, functional testing requires an ISDN device or emulation of an ISDN device.

Functional testing involves a variety of normal communication situations, i.e., sending a variety of possible data sequences and verifying that the ISDN device responds correctly.

Using the actual device with which the IUT will communicate can be helpful in functional testing. For example, when testing a terminal implementation, testing communication with the ISDN switch is very useful. Often, however, testing with only the actual switch can have one or more of the following shortcomings:

- Incomplete. Often the ISDN switch cannot be forced to send all of the possible data sequences that an ISDN switch can be expected to send. There are some messages that require stimulation in the form of data transmitted by the telephone. If
the telephone cannot initiate some types of messages, you cannot perform some important test cases with just the switch.

- Inconvenient. Even when the switch can send the required messages, it may be inconvenient for you to learn how to configure the switch for all possible messages.

- Time consuming. Changing switch configurations in order to send the different messages and waiting for the switch to reboot require a great deal of time.

- Cost prohibitive. When the ISDN implementation is required to work with more than one switch, it may be prohibitively expensive to buy all of the different switches for testing.

- Convenient. Hewlett-Packard protocol analyzers are easy to use and consistent for your testing convenience.

- Time saving. Changing configurations on the protocol analyzer can often be done with the change of one menu parameter or with just a few softkey strokes.

- Cost effective. Using a protocol analyzer is usually very cost effective compared with the expense of buying or renting actual ISDN switching equipment. This is especially true when the ISDN implementation must function with equipment from more than one vendor.

Several consecutive hours. However, it may be difficult to force another ISDN device to run continuously. With a programmable protocol analyzer, you can test continuously for many hours and store test results to the hard disk for post analysis.

Programmatic functional testing

Using a protocol analyzer to perform complete functional testing requires testing flexibility that is provided by a programming language.

A protocol analyzer overcomes all of these shortcomings, because as a test tool it is:

- Complete. With a protocol analyzer such as the HP 4954I, you can send all types of messages without any type of stimulus from the IUT.

Long term functional testing

A type of functional testing that is especially important during later phases of development is long term functional testing. Long term functional testing consists of running the IUT against another ISDN device for several consecutive hours.
The HP 4954I allows you to concentrate on testing layer 3 by providing a layer 2 emulator, which automatically implements the layer 2 protocol. This emulator can be invoked through DataCommC function calls.

**Interactive functional testing**

In some cases you may want more flexibility than that of a compiled programming language. For example, assume you have recorded several call setup messages sent between the switch and the IUT that you want to duplicate with a protocol analyzer. You may not want to edit, compile, and link several programs (or the same program several times) in order to perform all of these tests.

<table>
<thead>
<tr>
<th>TE</th>
<th>CCITT</th>
<th>HT</th>
<th>NT</th>
</tr>
</thead>
<tbody>
<tr>
<td>16:30:12.667</td>
<td>L000:INFO</td>
<td>16:30:12.667</td>
<td></td>
</tr>
</tbody>
</table>

**Error injection testing**

Error injection testing ensures that the implementation under test can properly handle various error conditions. Examples of error conditions include invalid sequence numbering, frame check sequence errors, unsupported field values, and illegal frame lengths.

Although you can perform some error injection testing with a switch, there are some errors that are difficult or impossible to transmit with a switch, such as frame check sequence errors. Using an actual switch for error injection testing has the same possible shortcomings as those listed for functional testing.

You can easily configure Hewlett-Packard protocol analyzers to send almost any error sequence, making them advantageous for error injection testing. You can run your IUT through a complete set of error conditions by using the ISDN interactive tester or a DataCommC program.

**Monitoring during developmental testing**

At all phases of ISDN equipment development, you will be testing the operation of the IUT with other ISDN devices. When there is a communication failure between the IUT and other ISDN devices, you will want to determine the problem. The troubleshooting technique is similar to that used by installation and maintenance specialists. The following scenarios will illustrate these techniques.

The ISDN interactive tester, a time-saving tool for developmental testing, provides an excellent means of sending test stimuli to a device under test.

In such cases, it is useful to interactively send data over the line without developing a program. Protocol analyzers, which provide a tool for interactive testing such as an interpreted language, are advantageous for such an application. The HP 4954I's ISDN interactive tester is an excellent method of sending test stimuli to a device under test. With keyboard interaction, you can send subsequent real-time responses to the IUT. The HP 4954I's preconfigured softkeys allow easy configuration of ISDN parameters for

The HP 4954I can easily be configured to send almost any error sequence. This is especially easy with the ISDN interactive tester.
Scenario 1

Testing needs

You are trying to establish a call between your ISDN telephone implementation and an ISDN switch. You are unable to place a call.

Testing technique

Check for possible cabling and connection problems. Then check the INFO states to verify that layer 1 communication is working.

Implementation anomalies such as an invalid general format identifier on the ISDN B channel are easy to detect with the HP 4954i, especially when using dual channel mode.

Use a protocol analyzer to monitor the interaction over the ISDN D channel. Determine that your ISDN telephone is successful in setting up layer 2 and layer 3 on the D channel.

With the HP 4954i you can easily see that the ISDN telephone is sending digits one at a time rather than "en bloc," or all in one SETUP message.

By using the dual channel mode of the HP 4954i, you can monitor both the D channel and one of the B channels simultaneously. This provides information on channel coordination without reconfiguring the analyzer.

Using the protocol analyzer on the ISDN B channel, you see that the IUT is sending an X.25 call request packet. The ISDN switch is responding with a clear packet and a diagnostic code indicating an invalid general format identifier.

Scenario 2

Testing needs

You are unsuccessfully trying to establish an X.25 data call, using a B channel, between your ISDN telephone implementation and an ISDN switch. You cannot determine if the problem is on the ISDN D or B channel.

Testing technique

Check for possible cabling and connection problems. Then check the INFO states to verify that layer 1 communication is working.

You used a protocol analyzer to determine that the telephone is sending one digit at a time. Because the switch expects to see all digits in one message, you must change your implementation to send the dialed digits "en bloc," when your implementation is working with this particular switch.
Scenario 3

Testing needs

You want to test the ability of your ISDN switch to support calls on all B channels of an ISDN primary rate interface at 1.544 Mbps. You are able to set up the calls and want to verify that all of the 23 calls will stay connected simultaneously.

The Automonitor seek feature appropriately routes the next successful call to the HP 4954I screen or handset. This allows you to focus on new calls.

Automonitor allows you to monitor the status of all channels on the ISDN PRI interface and to change the channel you are monitoring through a few softkeys. You save valuable testing time since testing does not stop while you are changing channels.

Testing technique

The HP 4954I’s Automonitor program is ideal for monitoring multiple ISDN calls on one interface. The Automonitor screen shows the state of each channel, for example, “v” for channels with active voice calls, “d” for channels with active data calls.

The Automonitor scan feature automatically and individually routes active data calls to the HP 4954I screen and active voice calls to the handset. When in the scan mode, the HP 4954I cycles sequentially through all channels, and waits momentarily at channels with active calls. By turning the scan mode off, you can focus on a particular channel.

Testing results

The ISDN Automonitor is an excellent tool for monitoring the status of the ISDN PRI channels. Using the channel status line of the HP 4954I Automonitor program, you can watch “v” and “d” appear for each channel placed. You can thus determine the maximum number of calls your ISDN implementation can support.

Scenario 4

Testing needs

You want to test your ISDN terminal adapter’s handshaking protocol supporting DMI mode 2. Although you have the hex data available, you could save time by using a tool to decode this data.

Troubleshooting technique

The HP 4954I and HP 4952A/HP 18281A easily monitor the DMI mode 2 rate adaption scheme and allow you to see the handshaking messages being exchanged across the ISDN interface.

Problem diagnosis and resolution

When developing terminal adapters, there are numerous configuration parameters e.g., rate of data transfer, that can cause communication problems. Hewlett-Packard protocol analyzers support V.110, V.120, and DMI modes 0, 1, 2, and 3 rate adaption schemes.

Rate adaption monitoring, provided by Hewlett-Packard protocol analyzers, saves you valuable testing time as you develop terminal adapters.
Other advantages

When you perform developmental testing, intermittent problems sometimes occur. It is not a good investment of your engineering time to watch every data transaction looking for these intermittent problems. A protocol analyzer can save you valuable engineering time by storing data in a buffer or on a hard disk for post analysis.

Conclusion

We have shown that ISDN requires more sophisticated testing techniques than do traditional analog networks. We have demonstrated that standard troubleshooting techniques can adequately solve basic network problems. However, when valuable downtime is costing money and customer satisfaction, a protocol analyzer provides the fast problem isolation paramount to your company’s profitability. Inevitably, the installation and maintenance technician will be confronted with a problem that can be solved most efficiently with a protocol analyzer.

When your goal is to develop and deliver ISDN equipment, a protocol analyzer helps fulfill this goal by reducing testing time and promoting timely delivery of high quality products. Competitive products require feature updates, and no company that develops ISDN equipment is willing to lose valuable customer satisfaction from incompatible revisions. Therefore, a protocol analyzer is an indispensable tool for the design engineer responsible for developing and testing ISDN equipment.

Whether you are responsible for installation, maintenance, or development of ISDN, Hewlett-Packard has the protocol analyzer to put you in control of the growing ISDN challenges.
Appendix

Background information on the ISDN signaling protocol

Before you read about ISDN lines and equipment testing, it is important to understand some of the terms used. In an ISDN network, TE refers to terminal equipment, while NT refers to network termination.

TE1 refers to terminal equipment that supports ISDN. TE2 refers to non-ISDN terminal equipment that requires a terminal adapter (TA) to connect to an ISDN network.

Terminal adapters use rate adaption to put data onto ISDN lines at 64 Kbps. Various rate adaption schemes are used by the different implementors: V.110 is used in Europe and Japan; V.120 has been standardized by the CCITT for use in ISDN rate adaption; DMI modes 0, 1, 2, and 3 are used by AT&T, and TLINK is supported by Northern Telecom (TLINK is not supported by Hewlett-Packard protocol analyzers).

NT is used in this application note to refer to any network termination. This is typically a PBX or an ISDN switch.

The physical layer of ISDN for basic rate access

Handshaking takes place between the TE and NT whenever a physical layer connection is established, maintained or disconnected. There are four specific information (INFO) signals that occur on reference points S and T during communication between the TE and the NT. These signals are defined by CCITT I.430.

Either the NT or the TE can be activated first. INFO 3 is sent by the TE and INFO 4 is sent by the NT when the physical link is established and synchronized for the proper flow of frames.

A deactivated TE sends INFO 0. When the TE is first activated, it sends INFO 1. When it detects that the NT is activated (sending INFO 2), the TE will send INFO 3.

A deactivated NT sends INFO 0. When the NT is first activated, it sends INFO 2. When it detects that the TE is activated (sending INFO 1), the NT will send INFO 4.
Once a layer 2 link has been established, layer 3 messaging on the D channel is required to set up an ISDN call. Because CCITT recommendations for this layer have not been strictly defined, the layer 3 setup varies considerably from implementation to implementation.

For more information on ISDN, please refer to Hewlett-Packard’s ISDN Basics manual part number, 18356-98201.

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Once the physical layer connection is established, a layer 2 connection must be established between the TE and NT. LAPD, known as Q.921, is the link layer protocol used for the ISDN D channel.

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The point-to-point configuration allows only one TE to be connected to the NT.

There are two types of assigning Terminal Endpoint Identifiers, or TEIs. With a "fixed" TEI assignment, a TE keeps one TEI value for all communication. With automatic TEI assignment, the TE requests a TEI from the NT.
The layer 3 message format is shown above.

The types of layer 3 messages defined by CCITT are shown above.