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# Overview of Integrated Services Digital Network Conformance Testing

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A11103 740081

NIST

PUBLICATIONS



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1992

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March 1992



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**National Institute of Standards and Technology Special Publication 823-1  
Natl. Inst. Stand. Technol. Spec. Publ. 823-1, 20 pages (Mar. 1992)  
CODEN: NSPUE2**

**U.S. GOVERNMENT PRINTING OFFICE  
WASHINGTON: 1992**

## Overview of ISDN Conformance Testing

### ABSTRACT

This document introduces a series of documents which focus on the conformance test specifications for the various ISDN Protocols. An overview of the current status of ISDN Conformance Testing, and the issues involved are also provided.

### KEYWORDS

Abstract Test Suite, Basic Rate Interface, BRI, Conformance Testing, Implementation Under Test, ISDN, PICS, PIXIT, Primary Rate Interface, PRI, Protocol Implementation Conformance Statement, Protocol Implementation Extra Information for Testing, Tree and Tabular Combined Notation, TTCN



## **NOTICE OF DISCLAIMER**

THIS DOCUMENT CONTAINS NIUF CONFORMANCE TESTS AS AGREED AMONG PARTICIPATING EXPERT TECHNICAL PERSONNEL TO THE TEXTS OF ISDN STANDARDS, CONFIGURATIONS AND DESCRIPTIONS THAT ARE INTENDED TO PROMOTE INTEROPERABILITY AND EFFICIENCY. THESE CONFORMANCE TESTS WERE DEVELOPED AND APPROVED BY ORGANIZATIONS PARTICIPATING IN THE NORTH AMERICAN ISDN Users' FORUM (NIUF) MEETINGS. NEITHER THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST) NOR ANY OF THE PARTICIPANTS IN THE NIUF MAKE ANY REPRESENTATION OR WARRANTY, EXPRESS OR IMPLIED WITH RESPECT TO THE SUFFICIENCY, ACCURACY, OR USE OF ANY INFORMATION OR OPINION CONTAINED HEREIN. THE USE OF THIS INFORMATION OR OPINION IS AT THE RISK OF THE USER. UNDER NO CIRCUMSTANCES SHALL NIST, OR ANY PARTICIPANT IN THE NIUF BE LIABLE FOR ANY DAMAGE OR INJURY INCURRED BY ANY PERSON ARISING OUT OF THE SUFFICIENCY, ACCURACY, OR USE OF ANY INFORMATION OR OPINION CONTAINED HEREIN.

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## **ACKNOWLEDGMENTS**

The authors would like to acknowledge Al Koenig and Jerry Linn of NIST for their valuable contributions to this document.





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1 INTRODUCTION

Advances in communication networks have increased the complexity of communications protocols and interfaces significantly, and the correct interpretation of standards has become a critical issue in ensuring interoperability of equipment from different vendors. The challenge to the telephony industry in providing high quality Integrated Services Digital Network (ISDN) service and interoperable ISDN products is unprecedented, as the ISDN protocols and interfaces are very complex and more open in terms of how services are to be provided. Conformance testing is a fundamental task in meeting this challenge.

This document is one of a group of National Institute of Standards and Technology (NIST) Special Publications that will be issued on Integrated Services Digital Network Conformance Testing. The purpose of this group of Special Publications is to publish the set of conformance test suites which were agreed upon in the North American ISDN Users' Forum (NIUF). These documents will be referenced by the Federal Information Processing Standard (FIPS) which specifies the testing requirements which ISDN equipment must meet to comply with ISDN protocol standards and agreements reached in the NIUF.

This publication, which is an introduction to the group, provides the general scope of ISDN conformance testing. Section 3 provides an overview of the abstract test suites in the group, including the test configurations of each suite. Section 4 outlines conformance testing standard guidelines and describes conformance testing development. In addition, sections 5 and 6 provide information on the use of proformas in testing, and conformance and interoperability testing.

2 SCOPE OF ISDN CONFORMANCE TESTING

Conformance testing is the process of determining whether an implementation complies with the specifications of the standard and exhibits the behaviors mandated by the standard [22]. There are two classes of testing on an ISDN network-user interface: testing from the direction of the network and testing from the direction of the user. Figure 1 shows the model of functional groups and reference points across a network-user interface [5].

The functional groups include the Exchange Termination (ET) group, the Network Termination (NT1 and NT2) group, Terminal Equipment of type 1 (TE1), and the Terminal Adaptor (TA). The TE2 functional group represents the existing non-ISDN data terminals.

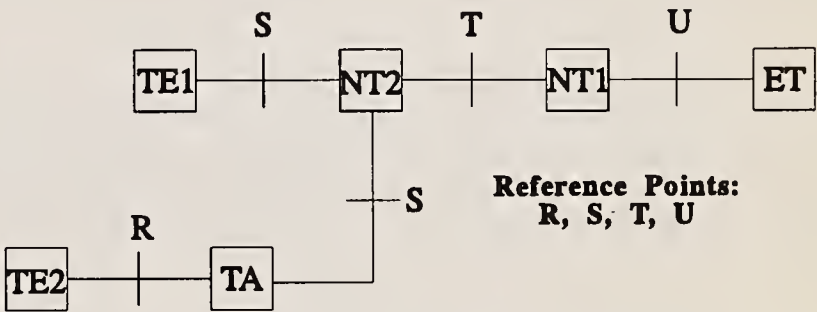


Figure 1. ISDN Interface Functional Groups and Reference Points.

The functional grouping shown in figure 1, represents only an abstract model for easier reference by protocol standards. This document refers to equipment to the left of the U reference point as the User Side equipment. An actual implementation of a user side equipment may perform more than one of these functions, for example, it may perform only the TE1 or TA function, the TE1 or TA and NT2 combined, the NT1 plus NT2, or other combinations. A TE1 or TA may be designed to connect directly to an NT1, in which case the S and T reference points coincide. When the TE and NT1 function are combined, only the U reference point is available.

There are several basic test configurations of the System Under Test (SUT) and Tester for conformance testing, given table 2.1, below. The symbol "TE" in the table 2.1 rs to either a TE1 or TA, and S/T refers to the case where S and T coincide. For testing from the direction of the network side to the user side, one



may test an NT1 at the U reference point, NT2 at T, or TE at S or S/T. Similarly, for testing from the other direction, one may test NT2 at S, NT1 at T, or ET at U. The tester must often perform more than one role. For example, to test layer 2 or layer 3 implementation of a TE at the S/T reference point, the tester must provide the layer 1 signals from the NT1 and layers 2 or 3 messages from the ET. Furthermore, additional test equipment might be needed beyond the SUT; for example, when testing an NT2 from the user side at the S reference point, the supports for the NT1 and ET must also be provided. The exact test set-up requirements depend on how much of the functional group the SUT supports.

Table 2.1. Basic Test Configurations

| Configuration | System Under Test's Role | Reference Point | Tester's Role |
|---------------|--------------------------|-----------------|---------------|
| NU.1          | TE                       | S               | NT2           |
| NU.2          | TE                       | S/T             | NT1           |
| NU.3          | NT2                      | T               | NT1           |
| NU.4 *        | NT1                      | U               | ET            |
| UN.1          | NT2                      | S               | TE            |
| UN.2          | NT1                      | S/T             | TE            |
| UN.3          | NT1                      | T               | NT2           |
| UN.4          | ET                       | U               | NT1           |

\* The NT1 function may be embedded in a TE or NT2.

Note that configurations NU.1 and UN.1, and configurations NU.1 and UN.1 each have the same setup, but the roles of the tester and IUT are reversed. Since the ISDN protocols are not always symmetric across the network-user interface, one can not share the same test script by simply exchanging roles. Each configuration requires its own test script.

Given a test configuration, conformance testing is further divided into smaller groups by protocol layers — the Physical Layer (Layer 1) at the S/T [6, 7, 13, 16] and U [12, 14] reference points, the Data Link Layer (Layer 2) [8, 15], and the Network Layer (Layer 3) [9, 10, 17, 18]. In addition, grouping is necessary by type of services (bearer circuit switching, bearer packet switching, supplementary services, etc.), and type of interfaces (basic rate access and primary rate access).

The conformance tests described in this series of documents focus on the basic access characteristics and signalling protocols specified in the ISDN standards listed. For thoroughness, conformance testing should also be done for the bearer services covered by ISDN, e.g., X.25 and Group 4 FAX. However, tests for these services are beyond the scope of this document.

Currently, most of the ISDN conformance testing activities focus on testing of ISDN terminal equipment, since there are more terminal devices from different vendors than network switching equipment.

### 3 CONFORMANCE TEST SUITES FOR ISDN

The ISDN Conformance Testing (ICOT) group of the NIUF has been developing conformance test suites for the protocol standards for ISDN layers 1, 2, and 3. Separate test suites for the user and network side equipment, and for the Basic Rate (BRI) and Primary Rate (PRI) interfaces have been, or will be,

developed. It is the intent of this group to submit these industry agreements to the related standard bodies for adoption as national or international standards, as appropriate.

The following sections outline the abstract test suites which will be published in other documents as part of this group of NIST Special Publications. Included in this outline are brief descriptions of the test specifications and test configurations, as described in the Scope section of this document, for ISDN layers 1, 2, and 3, that are being developed in the NIUF. Additional test specifications include supplementary services, terminal adaptor, and packet mode bearer services. With the exception of the layer 1 test suite, the methodology used in the development of the following test suites is based on International Organization for Standardization (ISO) 9646 [22], and the test scripts are written in the Tree and Tabular Combined Notation, TTCN.

### 3.1 Physical Layer Test Specifications

Layer 1 — Physical Layer — The three parts of this specification will describe the test specifications for American National Standard (ANS) T1.605-1989 [16], ANS T1.601-1988 [14] and ANS T1.408-1990 [13]. This includes testing of functional, electrical, and mechanical characteristics of devices including TE1, TA, and NT's on the user side. The tests may include verification of framing, line bit rate, relative bit positions, D-channel access control, checking of jitter and phase, impedance, pulse shape and amplitude, pulse balance, receiver/transmitter performance, power feeding and consumption, start-up procedures, pulse characteristics, frame structure, M-channel bit functions, etc.

Part 1: Basic Rate S/T Interface, User Side [4] describes a set of test specifications which verify conformance of TEs and NTs to the ISDN Physical Layer Basic Access at the S/T reference point, as defined in ANS T1.605-1989 [16], and section 4.1.1.2 of the *NIU-Forum Agreements on ISDN* [3]. This test suite is designed for test configurations NU.1 through NU.5 and UN.1 through UN.3 in table 2.1.

Part 2: Basic Rate U Interface, User Side will describe a set of test specifications which verify equipment implementation conformance to the ISDN Physical Layer Basic Access at the U interface, as defined in ANS T1.601-1988 [14] and section 4.1.1.1 of the *NIU-Forum Agreements on ISDN* [3]. This test suite will be designed for test configuration NU.4 in table 2.1.

Part 3: Primary Rate Interface, User Side will describe a set of test specifications which verify equipment implementation conformance to the ISDN Physical Layer Primary Access at the S, T, and U interface, as defined in ANS T1.408-1990 [13] and the corresponding NIUF Implementation Agreement. This test suite will be designed for test configurations NU.1, through NU.3, UN.1 through UN.3 in table 2.1.

### 3.2 Data Link Layer Test Specifications

Layer 2 — Data Link Layer — The two parts of this specification will cover the protocol states defined in the International Telegraph and Telephone Consultative Committee (CCITT) Q.921 [8] and ANS T1.602 [15] standards. For each state, three types of tests are specified: valid, inopportune, and invalid tests. The valid tests cover the exchange of valid frames; the inopportune tests check the IUT's response to correctly formatted frames received in an unexpected state, and the invalid tests verify the IUT's error recovery procedures upon receiving an incorrectly formatted frame.

Part 1: Basic Rate Interface, User Side will define the abstract test specifications to verify equipment implementation conformance to the Layer 2 of an ISDN at the user-network interface, for the BRI access arrangements, as defined in ANS T1.602-1989 [15] and section 4.1.3 of the



*NIU-Forum Agreements on ISDN* [3]. This test suite was designed for test configurations NU.1 and NU.2 in table 2.1. This test suite is currently the base text in CCITT Study Group XI for consideration as an international recommendation.

Part 2: Primary Rate Interface, User Side will define the abstract test specifications to verify equipment implementation conformance to the Layer 2 of an ISDN at the user-network interface, for the PRI access arrangements, as defined in ANS T1.602-1989 [15] and *NIU-Forum Agreements on ISDN* [3]. This test suite will be designed for test configurations NU.3 and NU.4 in table 2.1.

### 3.3 Network Layer Test Specifications

Layer 3 — Network Access Layer — The three specifications involving layer 3 will be based on CCITT Q.931 [9] and ANS T1.607 [17] and cover the D-channel operations for user side states in the following functional areas: call setup from user and network, call clearing from user and network, and error recovery mechanisms (invalid information element and missing mandatory information element). As in the Layer 2 test suites, valid, inopportune, and invalid tests will be performed. Note that the operations of the B channels will not be covered in these tests.

Part 1: Basic Rate Interface Circuit Switch Call Control, User Side will define the abstract test specifications to verify equipment implementation conformance to the Layer 3 of an ISDN BRI at the user-network interface for the Basic Call Control Procedures, as defined by ANS T1.607-1990 [17], section 4.1.4.1.1 of the *NIU-Forum Agreements on ISDN* [3], and other corresponding NIUF Implementation Agreements. This test suite was designed for test configurations NU.1 and NU.2 in table 2.1.

Part 2: Primary Rate Interface Circuit Switch Call Control, User Side will define the abstract test specifications to verify equipment implementation conformance to the Layer 3 of an ISDN PRI at the user-network interface for the Basic Call Control Procedures, as defined by ANS T1.607-1990 [17], section 4.1.4.1.1 of the *NIU-Forum Agreements on ISDN* [3], and other corresponding NIUF Implementation Agreements. This test suite will be designed for test configurations NU.3 and NU.4 in table 2.1.

Part 3: Packet Switched Call Control will define the abstract test specifications to verify equipment implementation conformance to the Layer 3 of an ISDN at the user-network interface for the Packet Switched Call Control Procedures, as defined by ANS T1.608-1990 [18], section 4.1.4.2 of the *NIU-Forum Agreements on ISDN* [3], and other corresponding NIUF Implementation Agreements.

### 3.4 Additional Test Specifications

Supplementary Services will define the abstract test specifications to verify implementation conformance to the Supplementary Services at the user-network interface, as defined in ANS T1.610 [19], section 4.1.4.11.2 of the *NIU-Forum Agreements on ISDN* [3], and other appropriate ANS documents and their corresponding NIUF Implementation Agreements.

Packet Mode Bearer Services Control Procedures will define the abstract test specifications to verify implementation conformance to the Packet Mode Bearer Services Control Procedures.

Terminal Adaption will define the abstract test specifications to verify equipment implementation conformance to the ISDN Circuit-Mode Data Terminal Adaption using Statistical Multiplexing, as defined by ANS T1.612-1990 [20] and the corresponding NIUF Implementation Agreement.



In order to ensure that conformance tests produce correct and consistent results, it is essential that test suites be standardized. The costs involved, in terms of time and resources, to develop test scripts, implement testbeds, and perform tests, is a strong incentive to standardize conformance tests. This section first presents the standard for guidelines in conformance testing, and briefly describes the conformance test development process including implementors' agreements, abstract test suite development and validation, and supplemental information required for testing a vendor's product.

4.1 Conformance Testing Standards

The ISO and the CCITT have developed a standard for Open Systems Interconnection (OSI) conformance testing. The resulting standards, ISO 9646, "OSI Conformance Testing Methodology and Framework" [22] and CCITT X.290 [11] (with the same title), cover most aspects of the conformance testing process shown in figure 2. ISO 9646 is a five part standard consisting of:

- Part 1 General Concepts — introduces conformance testing concepts and terminology;
- Part 2 Abstract Test Suite Specification — defines test methods for test suite specification, and types of tests which should be included in an abstract test suite;
- Part 3 The Tree and Tabular Combined Notation (TTCN) — defines a language for writing abstract test suites;
- Part 4 Test Realization — specifies requirements and gives guidance concerning the realization of a means of testing IUTs; and
- Part 5 Requirements on Test Laboratories and Clients for the Conformance Assessment Process — specifies requirements on both the test laboratory and the client, for the conduct of the conformance assessment process.

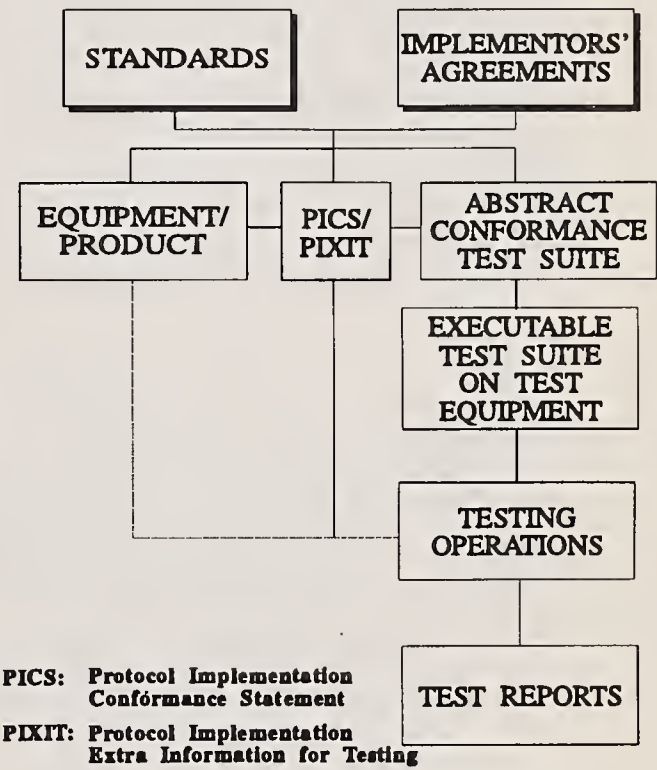


Figure 2. Conformance Testing Steps.

Part 2 defines abstract test methods: local, distributed, coordinated and remote methods.

The remote single layer testing, as shown in figure 3, is the most common method used for ISDN layer 2 and 3 protocol testing. The Implementation Under Test would be either the layer 2 or layer 3 implementation, which would exchange layer N (2 or 3) Protocol Data Units (PDUs) with the tester through the lower layer services. The lower layer services for the IUT and lower tester are assumed to be available and are not under test. The "lower tester" refers to the means of providing indirect control and observation of the lower boundary of the IUT via the underlying service provider. There is one Point of Control and Observation (PCO) where the lower tester observes the messages being exchanged between the lower tester and the IUT and assigns verdicts (test results) accordingly.

For the remote single layer testing, the upper layer support of the IUT is not specified, and no *explicit* test coordination procedures are assumed, although they may be present. As an example, during testing of the ISDN Layer 2 protocol, the tester may require the IUT to send a link setup frame, which would require some activities from Layer 3. The tester may only be able to generate a request to the test operator for necessary manual intervention to the IUT to trigger the link setup. The exact method which the tester uses to accomplish the link initiation is not defined in an abstract test script. It is outside of the scope of the requirements of this test method in an abstract test script and is dependent on the particular implementation of the IUT.

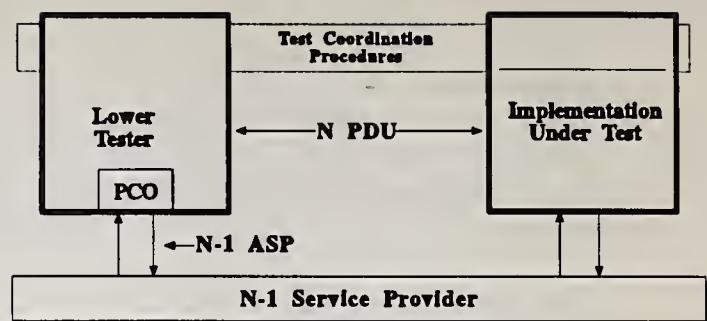


Figure 3. Remote Single Layer Test Method.

The TTCN language, defined in Part 3 of ISO 9646, allows one to write a precise description of the behavior of both the tester and the IUT, as well as the exact contents of the Protocol Data Units exchanged. TTCN has two forms, the tabular or graphic form (TTCN.GR) for human reading, and the machine processable form (TTCN.MP) for computer processing. Figure 4 is a sample of a test script written in TTCN.GR taken from the NIUF LAPD test suite. A test case consists of a sequence of frames sent (indicated by !) and received (indicated by ?) by the tester, and related timing operations specified in the Behavior Description Column. Each event may specify the PDU name and its exact contents in the Behavior Description column and the Constraints Reference column, respectively. The PDU and constraint names refer to entries in other tables in the test suite.

| Test Case Dynamic Behaviour  |       |                      |     |          |
|--|-------|----------------------|-----|----------|
| Reference: LAPD/MFO/S70/DL70_V14   |       |                      |     |          |
| Identifier: DL70_V14   |       |                      |     |          |
| Purpose: Verify that the IUT sends a SABME/P=1 in response to a DM/F=0 in Multiple Frame Established state (7.0). The IUT is expected to enter Awaiting Establishment state after sending the SABME/P=1. |       |                      |     |          |
| Defaults Reference:  |       |                      |     |          |
| Behaviour Description  | Label | Constraint Reference | V   | Comments |
| DL70_V14   |       |                      |     |          |
| +DL70_PREAMBLE   |       |                      |     |          |
| !DM  |       | DM0_NR               |     | F=0      |
| START Td   |       |                      |     |          |
| ?SABME   | L700  | SABME1_UC            | (P) | P=1      |
| +DL51_VERIFICATION   |       |                      |     |          |
| +DL_POSTAMBLE  |       |                      |     |          |
| +DL70_UNEXPECTED   |       |                      |     |          |
| GOTO L700  |       |                      |     |          |
| ?OTHERWISE   |       |                      | (F) |          |
| +DL_POSTAMBLE  |       |                      |     |          |
| ?TIMEOUT Td  |       |                      | (F) |          |
| +DL_POSTAMBLE  |       |                      |     |          |

Figure 4. Example of an ISDN Layer 2 (LAPD) test script in TTCN.



## **4.2 Conformance Testing Development**

Several steps are required to develop conformance tests from the protocol specification. These steps, shown in figure 2, include the development of an abstract conformance test suite, the implementation of executable test scripts on test equipment, the testing operations, and the preparation of the test reports. The following sections describe the steps through which the abstract test suites in this series were developed and the initial steps in progressing to an executable test suite. The details of the testing operations and test reporting requirements may be provided in other publications. The first step in the development of an abstract test suite begins with the precise interpretation of the base standards.

### **4.2.1 Implementors' Agreements**

Protocol and interface standards are specifications for products and services. Most standards are written in natural language (e.g., English, French) and are subject to different interpretations. Since a standard may involve many options and variable fields, the test suite developer may need to rely on additional implementors' agreements which specify or constrain the choice of options and allowable fields. North American Implementors' Agreements for ISDN are developed by the Access Signalling Working Group in the Implementor's Workshop of the NIUF. Implementors' Agreements specify 1) options to be implemented (or excluded) and the PDU codings; 2) stacks of protocol with options preselected, when offering specific services; and 3) test suites to be used for assessing conformance of the items above. The Implementors' Agreements determine the set of test suites required for testing conformance of a stack of protocols, and the selection of test cases and portions of the test scripts within a test case for a given standard. Once a set of implementor's agreements are in place for a particular protocol, the development of an abstract test suite begins.

### **4.2.2 Abstract Conformance Test Suite Development**

The ISDN Conformance Testing (ICOT) Working Group was formed as a permanent implementor's subgroup of the NIUF to develop abstract conformance test suites based on the NIUF Implementor's Agreements. ICOT consists of testing experts from organizations such as AT&T Bell Laboratories, Bell Atlantic, Bell Northern Research, Bell Communications Research (Bellcore), Corporation for Open Systems (COS), IBM, IDACOM/Hewlett Packard, NIST, Northern Telecom, NYNEX, TEKELEC, and Telecommunications Techniques Corporation. Test suite development for the Layer 2 test suite, for example, began with a complete review of the protocol standard Q.921, to determine the desired coverage by the test suite. The test scripts were developed in the TTCN, reviewed, and validated by the participating members during numerous NIUF and interim meetings. The validation process is described below.

### **4.2.3 Test Suite Validation**

The validation of test suites was provided by different means during the development of the abstract test suite. First, selected groups of test cases were coded into executable test cases for test equipment and evaluated in parallel to the test suite development. The results of these preliminary tests were reported to ICOT, and refinements were discussed. The entire test suite was coded as executable tests and evaluated during the final development of the test suite.

A second validation method was developed at NIST during the development of the NIUF Layer 2 (LAPD) test suite, and subsequently used for test suites for other protocols. Figure 5 shows the system development process. Based on the Q.921 states/events matrix, a protocol model of the LAPD protocol standard, was developed using the formal description language Estelle [21]. It simulates the behavior of the IUT and can be used to exercise most of the test cases in the test suite. In parallel, a tester was implemented using the TTCN-to-C translator, described in section 7. The abstract test suite is compiled into an executable test

suite in C code. As part of this process, both semantics and syntax checking is performed on each test case. The protocol model of the implementation and the tester run concurrently as two independent processes on a UNIX™ system. The Layer 1 Service Provider function, shown in figure 3, is simulated by means of a UNIX™ inter-process communication facility called shared memory. In this system, an abbreviated Layer 3 software is implemented to realize the test coordination procedures required by the lower tester. Thus, no real ISDN hardware is required. At the end of each test case, the test log and the simulator execution trace are compared to find any discrepancies between the test script and the behavior of the IUT.

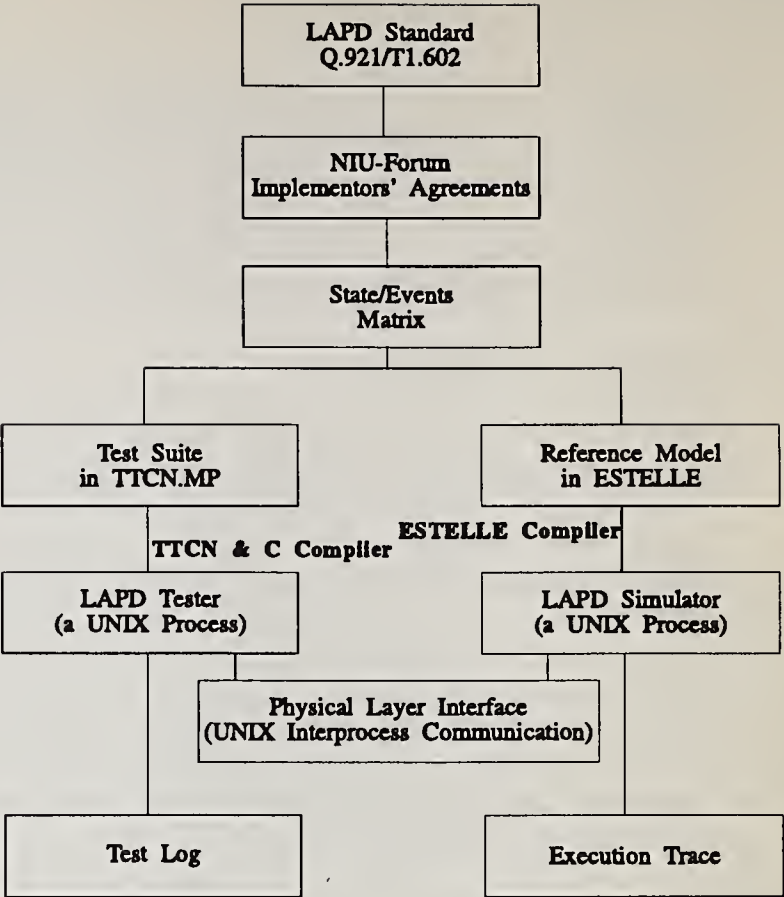


Figure 5. LAPD Test Script Validation System.

## 5 USE OF PICS AND PIXIT

It is likely that an entire test suite is not applicable for all IUTs. Therefore, a test selection procedure must be performed to determine the applicability of each test case to a particular IUT. Such selection is based on the Protocol Implementation Conformance Statement (PICS) and the Protocol Implementation Extra Information for Testing (PIXIT). The guidelines for developing both PICS and PIXIT are provided in ISO 9646 [22].

The PICS proforma, in the form of a questionnaire, becomes the PICS when completed by a supplier for an ISDN implementation. The PICS specifies the capabilities and options which have been implemented, and any features which have been omitted, so that the implementation can be tested for conformance against relevant requirements, and against those requirements only. Static conformance assessment is based upon information provided about the IUT in the PICS; e.g., are all of the mandatory features implemented, and are related conditional options implemented when there are inter-dependencies. The conformance testing guidelines of ISO 9646 recommends that the PICS proforma become part of the protocol standard.

Additional information related to the IUT and its environment is needed before a test campaign can commence; this information is contained in a PIXIT and supplements information contained in a PICS. The PIXIT questionnaire should be completed by the manufacturer of the IUT, or the test laboratory client, when submitting an IUT for testing. The PIXIT contains information regarding system specific details required by the test laboratory to run the test suite. Timer values, for example, may be specified in the PICS as a range of values for a particular timer. The PIXIT questionnaire may request a specific timer value. In this way, the PIXIT provides a refinement of the PICS information. The values of test variables and parameters for conditions regarding test case selection are derived by the test laboratory from the information supplied in the PIXIT. ISO 9646 recommends that the PIXIT questionnaire be part of the related abstract test suite.



6 CONFORMANCE VS. INTEROPERABILITY TESTING

Since conformance testing is done in a controlled environment, the fact that equipment passes conformance tests does not guarantee that it will interoperate without problems. Interoperability may depend on 1) all manufacturers implementing the same set of options; 2) system loads, which may impact the availability buffers; and 3) implementation and synchronization of timers, i.e., a mismatched timer may cause a call to be aborted. Conformance testing only increases the confidence that the equipment was implemented as specified in the standard. External factors, such as the condition of the communication port, may also affect the outcomes of the conformance tests. Furthermore, conformance testing does not imply complete and exhaustive testing of every aspect of a standard. The dynamic behaviors of ISDN protocols are so complex that it is not economically feasible to perform exhaustive testing. Conformance testing is the first step in product quality testing and is supplemented by interoperability tests and system load tests.

7 THE NIST TTCN TRANSLATOR

The purpose of developing the TTCN-to-C language translator was two-fold: 1) to provide a tool to industry which would expedite the process of converting an abstract test suite (specified in TTCN) into an executable test suite (specified in the C language), and 2) to provide a tool which could be used in the test suite validation process described above.

The NIST TTCN translator [2] accepts a test script in machine processable form, TTCN.MP, and translates it into C language statements. It can be used to transform an abstract test suite into an executable test system with minimum effort. Figure 6 shows the process needed to implement an executable test system

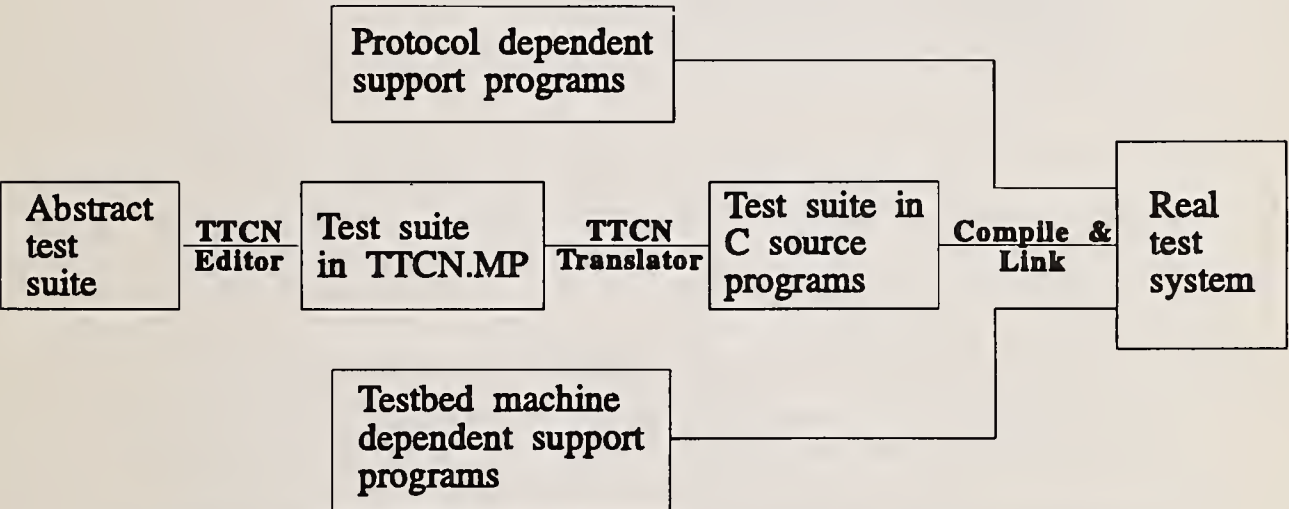


Figure 6. Implementation of a Test System Using the NIST TTCN Translator.

using the NIST translator. The abstract test suite in TTCN.MP form is generated using one of the TTCN tools described above. It is then input into the TTCN translator which produces a set of C language programs. These programs are compiled on the target testbed and bound with other support programs to make an executable test system. The protocol and system dependent support programs include such items as formatting and analyzing PDUs, controlling the ISDN ports, and handling timers or clocks. The translator has been used to validate the correctness of the NIUF LAPD test suite, and to implement real test systems.

## ANNEX A ABBREVIATIONS

|       |  |
|-------|--|
| ANS   | American National Standard                                   |
| ASP   | Abstract Service Primitives                                  |
| BRI   | Basic Rate Interface   |
| CCITT | International Telegraph and Telephone Consultative Committee |
| ET    | Exchange Termination   |
| FIPS  | Federal Information Processing Standard                      |
| ICOT  | ISDN Conformance Testing Working Group of NIUF               |
| ISDN  | Integrated Services Digital Network                          |
| ISO   | International Organization for Standardization               |
| IUT   | Implementation Under Test                                    |
| LAPD  | Link Access Procedure on the D-channel                       |
| NIST  | National Institute of Standards and Technology               |
| NIUF  | North American ISDN Users' Forum                             |
| NT    | Network Termination (NT1 and NT2)                            |
| OSI   | Open Systems Interconnection                                 |
| PCO   | Point of Control and Observation                             |
| PDU   | Protocol Data Unit   |
| PICS  | Protocol Implementation Conformance Statement                |
| PIXIT | Protocol Implementation Extra Information for Testing        |
| PRI   | Primary Rate Interface                                       |
| TA    | Terminal Adaptor   |
| TE1   | Terminal Equipment of type 1 (ISDN)                          |
| TE2   | Terminal Equipment of type 2 (Non-ISDN)                      |
| TTCN  | Tree and Tabular Combined Notation                           |



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| 4. TITLE AND SUBTITLE<br><br><div style="text-align: center;">Overview of Integrated Services Digital Network Conformance Testing</div>  |  |   |           |                          |   |                                     |  |                                     |  |  |  |
| 5. AUTHOR(S)<br><br>Leslie A. Collica, Kathleen M. Roberts, David Su   |  |   |           |                          |   |                                     |  |                                     |  |  |  |
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