Testing ATM Interoperability

Agilent Technologies Broadband Series Test System
Application Note

Introduction

ATM networks have emerged as viable transport technologies within the last few years. However, they do not yet have the stability and maturity of well-established networks such as X.25. Any new X.25 product can be tested and measured against steady components using validated Means of Testing (MoT) before it is introduced on the market. This is far from being the case with ATM. There is no Reference Implementation (RI) yet. In addition, many of the protocols that comprise ATM, such as the signalling protocols, are quite complex, which makes the validation of a new design or product that much more important.

Internet working these complex systems, which possibly come from different vendors, may also prove to be challenging. There is only one way to increase confidence that ATM products meet their functional specifications and can interwork with other ATM products: using the proper testing techniques.

Hence, testing should be used at all phases of ATM deployment:

- product development
- product validation and network.
- integration.

This solution brief describes various testing techniques that are applicable to ATM and that can help achieve ATM interoperability. Concepts and methodologies are explained, and illustrated with practical examples.

Standards and Specifications

International organizations or industry forums, such as the ATM Forum, define standards or specifications that are adopted by all member countries or companies, and this is where the conformance testing process must start.

The ATM Forum is a non-profit international industry consortium whose mission is to accelerate rapid convergence on ATM interoperability specifications based on international standards and to promote industry cooperation. For defining specifications, the ATM Forum Technical Committee has spawned a number of Sub-Working Groups (SWG). One of these is the Testing SWG, which is concerned with testing at all layers of the ATM protocol stack and has produced a series of Abstract Test Suites (ATSs), from Cell Layer to Signalling and beyond.

Contributions to the Testing SWG are on a voluntary basis. Member companies bring in their proposals which are then debated, voted on and finally adopted.Agilent actively participates in this SWG and has made major contributions to the ATM Layer Conformance and Interoperability ATSs, as well as Signalling 3.x (and soon 4.0) ATSs. The ATM Forum decides which parts of the ATM protocol stack need to be tested first and builds some priority list. Then the testing coverage of each ATS is decided among the member companies, based on both the initial contributions and the subsequent counterproposals.

In the remainder of this paper, when an ATM specification is mentioned, the reference will be the ATM Forum's ATM User-Network Interface Specification, Version 4.0, July 1996, unless noted otherwise.

From specifications, companies develop products like an ATM switch or a Network Interface Card (NIC). If the base specifications are ambiguous, inconsistent or incomplete at the start (as many newly-adopted specifications are likely to be), it is highly possible that two similar products developed from the same specification by two different companies may not work together. It is the role of testing to detect such problems.

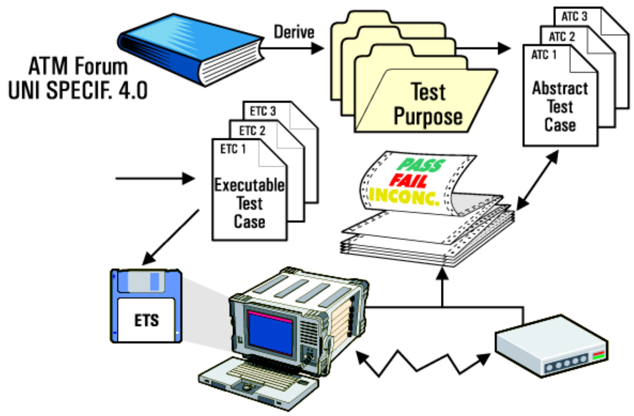

Figure 1: Major steps involved in Conformance Testing.

Testing Methodologies

There are three key testing methodologies that are necessary for a thorough validation of a product implementation:

- conformance testing,
- interoperability testing
- regression testing.

The next three sections will examine these techniques in detail.

2.1 Conformance Testing

The first step in verifying the correctness of a product is to ensure that its implementation performs in accordance with the specification it was built upon. This process is called conformance testing. In practice, the role of conformance testing is to increase confidence that a product conforms to its specification and to reduce the risk of malfunctioning when the product is implemented within a working environment, such as in an ATM network.

Conformance Testing is a well-established testing methodology based on the multi-part standard, ISO 9646, published by the International Organization for Standardization (ISO). Figure 1 depicts the major steps involved in Conformance Testing.

(1) The ATM UNI 4.0 specification refers to the previously-published UNI 3.1 specification for the regular call control procedures.

The testing work starts with the specification. For each feature or characteristic in the specification, a Test Purpose is written. For example, the ATM UNI 3.1 Specification (1), section 5.5.1.5,p. 244, specifies:

If the network can determine that access to the requested service is authorized and available, the network may send a CALL PROCEEDING message to the user to acknowledge the SETUP message and to indicate that the call is being processed, and enter the Outgoing Call Proceeding state. If the network chooses not to send the CALL PROCEEDING message, the network shall remain in the Call Initiated state.

Test Purpose

In order to test this part of the specification, a Test Purpose will be developed by the organization doing the conformance testing, that clearly indicates the expected testing procedures. For example:

If BBC class A (ASC=CBR) is supported, then verify that the instrument under test (IUT) sends a valid CALL PROCEEDING (if the IUT generates a CALL PROCEEDING) or does not respond after receiving a valid SETUP (BBC class = A, ATC=7, Tagging = No, Frame Discard = No, QOs Class = 0) when the IUT is in State N0. The final IUT state is expected to be N3 or N1.

Actually, dozens and dozens of additional tests are required to verify different combinations of the most important Information Elements (IE) in a SETUP message: such as the Broadband Bearer Capability (BBC), ATM Traffic Descriptor (ATC), and others. All these tests will refer to the same reference section 5.5.1.5 in the ATM Forum specification that was mentioned above.

Abstract Test Case

Next, each Test Purpose is turned into an Abstract Test Case (ATC). An ATC explains with all necessary details what is sent to the instrument under test (IUT), what is expected from the IUT, what the IUT must do in order to pass the test case, how the IUT can fail the test case, etc. When all aspects of a specification have been covered, a series of ATCs, called an Abstract Test Suite (ATS), is then available.

Executable Test Suite

Once implemented on a particular hardware platform, such as a protocol analyzer, the ATS becomes an Executable Test Suite (ETS). The ETS offers to the user the capability to select one or more test cases from the whole test suite, run those test cases against an IUT and generate a Test Report. Most evidently, if the Test Report uncovers any IUT error, the product designer will fix the problems found and re-run the ETS.

An important feature of Conformance Testing is that each test case, when run against an IUT, will give a clear and single verdict: either PASS, FAIL or INCONCLUSIVE. These verdicts appear in the Test Report along with the detailed trace of each test case run. See Section 4, Example Test Suite Execution and Results, later in this paper for a detailed explanation of every aspect of test suite execution and a sample Test Report.

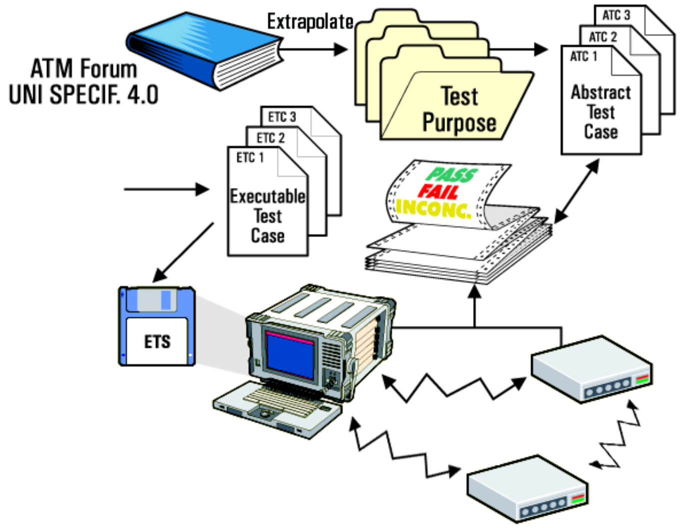

Figure 2: Major steps of the Interoperability Testing process.

For the needs of this paper, all test case examples are taken from the ATM Forum UNI 4.0 Conformance Abstract Test Suite for the Network Side, except where otherwise noted.

Interoperability Testing

Interoperability testing is the next logical step after conformance testing. While conformance testing can increase confidence that System A conforms to Specification X and that System B also conforms to Specification X, interoperability testing will evaluate to what extent Systems A and B can actually work with (or interoperate with) each other. Figure 2 illustrates the major steps of the Interoperability Testing process:

- By extrapolating the specification under real life situations, Test Purposes are defined and then an ATS is written
- From this ATS, an Executable Test Suite (ETS) is implemented
- Then the ETS is executed on a protocol analyzer against two Systems Under Test (SUTs, such as two ATM switches)
- Finally, a Test Report is generated from this test campaign which, again, may uncover errors in any SUT

Interoperability Testing shares several common points with Conformance Testing. ATCs and ATSs look very similar at first glance, except mainly that Interoperability Testing will specify multiple ports where data are to be sent and received to the two SUTs. The processes of implementing the ATS and running the ETS are strictly the same. Here as well, each test case run will give one of the same three verdicts (PASS, FAIL or INCONCLUSIVE). Finally, Test Reports present results in a similar fashion.

However, there are fundamental differences between both testing techniques. Conformance testing looks at one aspect of the specification at a time and provides one (or very few) test case(s) to verify the behavior of an IUT with regards to this aspect.

Interoperability testing goes further: it takes one (or a few related) aspect(s) of the specification and aims at verifying how these aspects can be used in practice by two communicating network components. This often yields to more comprehensive test cases than conformance testing.

Although interoperability testing looks more appealing than conformance testing, the latter is a first, and mandatory, step. Otherwise, when an interoperability test case fails, it is not possible to determine if System A or System B is responsible for this verdict.

Regression Testing

Only in rare cases is a single product be put on the market during its life cycle. Usually, subsequent versions of a product incorporate bug fixes, enhancements, additional features, and so on. Given this context, regression testing is a technique to ensure that the existing features of an IUT are properly migrating with the product’s evolution. For example, if Version 2.0 of an ATM product fixes some known errors at the ATM Cell Layer, regression testing will make sure that the existing (and unchanged) Adaptation Layer still behaves and performs as well as before on top of the new Cell Layer. run part of their regression tests.

When Do You Test in the Product Life Cycle?

Product testing is a clear requirement of the product development, however the timing of this testing may impact both the costs of the product, and the

time when it is available to the marketplace. Different strategies can be employed for these testing functions.

For example, suppose that the product in question is a new ATM product on the market. One strategy would be to do minimal in-house testing after product development, and then go to an external test laboratory for full-scale testing. In a field like ATM where time to market is critical, some people might be tempted to save time with this approach, yielding minimal in-house testing, yet ensuring product quality with complete external testing. The major drawback with this strategy is that it often uncovers problems during the last phases of development cycle, resulting in costly and time-consuming redesigns.

The alternative is to perform conformance and interoperability testing during product development, which becomes the key to higher product quality and increasing assurance of interoperability. As such, testing can be done:

- By application engineers to test each feature of the IUT as they are implemented. Every ATM Executable Test Suite allows the user to select only a portion of the series of test cases to facilitate this type of testing. This strategy uncovers problems as early as possible in the design cycle, where problems are fixed at the least cost, and enables the engineers to add features and build on top of a solid product.
- By test and quality assurance engineers to run all applicable test cases against an IUT before it goes on production or before it is shipped to customers. Again, every ATM Executable Test Suite helps those users with the saving all test campaign setup and results. This brings a systematic approach to testing from one IUT to another and facilitates Regression Testing as well.

4. Example Test Suite Execution and Results

This section describes the various steps for running an ETS against a particular IUT:

- preparation
- execution
- results

These steps are also described in part 4 of the ISO 9646 methodology standard.

Test Suite Parameterization

An ATS is designed to adapt its behavior to all sorts of IUTs. For example, if the specification says that a given feature can be optionally implemented, and a number of test cases have been included in the ATS to test this feature, then those test cases should not be run against an IUT that does not have this optional feature. Another example: if, in a given situation, the IUT can react in two different and valid ways, the test suite must know before the execution begins which way has been chosen for this particular IUT in order for the test suite to adapt its sequence of events.

This customization is accomplished through a Protocol Implementation Conformance Statement (PICS) and a Protocol Implementation eXtra Information for Testing (PIXIT) document. Both documents contain a series of questions for parameterizing the ATS to a particular IUT. A PICS document is protocol specification oriented and indicates which capabilities and options have been implemented in the IUT. A PIXIT document is rather IUT dynamic -behavior-oriented and contains additional parameters used to tailor the execution of some test cases (such as the duration of timers, or the value of certain fields in information elements). Both ATM Signalling Conformance PICS and PIXIT proformas are created by the ATM Forum Testing SWG, along (and sometimes before) the related ATS.

In preparation for a test campaign, a test operator will normally go through the following steps:

- Get the PICS and PIXIT proformas and fill in the questions on paper. This first step is required by testing laboratories before a conformance testing session can take place. However, if the ETS is to be run privately in some R&D lab, the test operator can go directly to the following step.
- Load the ETS on the protocol analyzer and fill in on-line the same PICS and PIXIT questions. The answer to these questions will be used as parameters (called Test Suite Parameters) to the ETS.
- Answer additional questions for customizing the test campaign (e.g. number of times each test case should be run, how detailed should the test case traces be, etc.).

An ETS package typically allows the operator to save all PICS, PIXIT and additional settings to save time and add consistency to further test campaigns, as well as to facilitate regression testing at a later stage.

Test Case Selection

Before the test execution can begin, a test case must be selected. In other words, the operator must tell the ETS which test cases should be run for the present test campaign. Some test cases may not be selectable like in the above example where the IUT has not implemented an optional feature. Among the test cases that are selectable, the operator may choose to run just a few to concentrate on some aspects of the IUT.

In fact, this notion of selectability is clearly defined in conformance testing. For each test case, there is a boolean expression (called a Test Case Selection Expression) that must produce the value TRUE before the test case can be selected. Each Selection Expression is based on one or more Test Suite Parameters. Consider the following test case selection example, shown on Figure 3:

Test Case:	**NO V0001_1**
Selection Expr:	**CBR_A_YES**
Def. of CBR_A_Yes	**BBC_A_SUPP_AND_CBR_SUPP**
ParameterBBC_A_SUPP:	**Answer to the PICS question: Broadband Bearer Capability Class A is Supported**
Parameter CBR_SUPP:	**Answer to the PICS question: ATM Service Category CBR is supported**

Figure 3: Test Case Selection Expression based on Test Suite Parameters.

Thus, test case N0_V0001_1can only be selected if the IUT supports BBC Class A and CBR service.

In addition, an ETS package normally allows the operator to disregard the Test Case Selection Expressions and to select any test case (e.g. for testing abnormal situations).

Test Case Execution

Once one or more test cases have been selected, the test suite can be run. During execution, the analyzer will send messages to the IUT, analyze its reaction (contents of the messages sent by the IUT, if any, time when these messages are sent, etc.), compare the expected and the observed behavior of the IUT, assign a verdict to the test case, display as well as record on disk all protocol data exchanged and proceed with the next test case. This type of testing is called

stimulus-and-response testing, since the analyzer expects some response from the IUT after some stimulus has been sent.

In most cases, the test suite runs automatically, without any operator intervention. The only exception is when the test suite asks the operator to manually trigger some IUT event. For example, in testing Signalling User Side, the test operator will be asked to trigger the call establishment process so that the IUT starts the test case by sending a SETUP message to the analyzer. This affects a very small number of test cases in the whole test suite.

Verdicts and Results

A conformance test campaign necessarily produces a verdict for each test case run. There are three possible verdicts:

- PASS: when the IUT has met the Test Purpose. The IUT has behaved exactly as stated in the abstract test case. For example, correct messages sent with the correct contents at the correct moment.
- FAIL: when the IUT has not met the Test Purpose. An event contrary to what is stated in the abstract test case happened at least once. For example, an incorrect message was sent, a message containing incorrect contents was sent, or a correct message was sent too late.
- INCONCLUSIVE: when something wrong happened but the tester was never able to verify whether the IUT met the Test Purpose or not. For example, operator intervention was required to trigger an IUT event but the operator failed to proceed, or incorrect behavior was encountered in the early stages of the test case (called the preamble), before the Test Purpose could be verified.

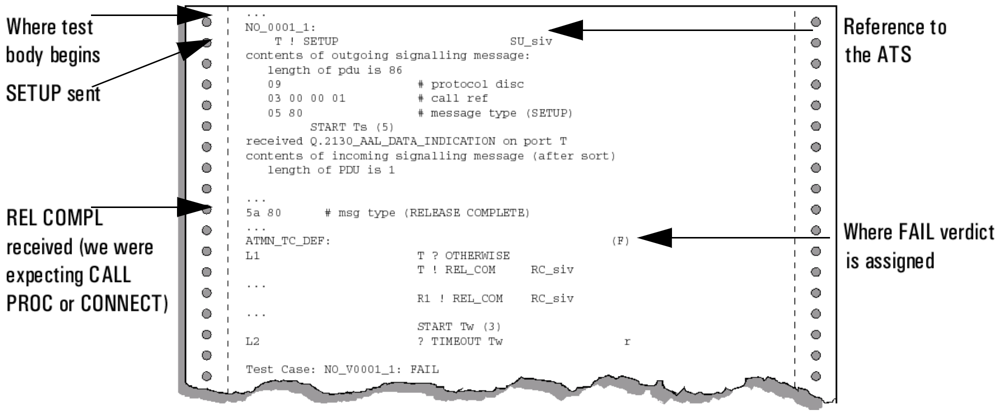

Figure 4: Example of test case trace.

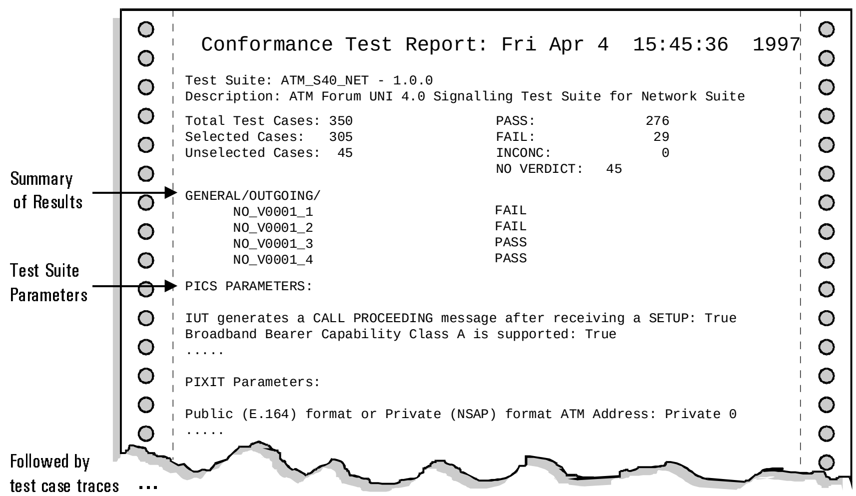

Figure 5: Beginning of a detailed test report.

Results of a test campaign also include a trace of each test case run. A Test Case Trace contains:

- The test case identifier plus date and time when execution began
- All messages sent to and from the IUT, in their original transmission order, time stamped, with all IEs and fields decoded
- Optionally, some statements as coded in the abstract test case, to help the operator follow the course of events and detect where a problem (if any) occurred and what was expected instead, according to the ATC
- The verdict assigned to this test case
- Date and time when the test case execution ended. Figure 4 gives an example of a test case trace

Test Report

A detailed Test Report comprises all results produced by the tester during a test campaign.It provides a summary table to indicate:

- Date and time when test report is produced
- Test suite name and version number
- Environment: type of IUT, company name, location (optional)
- The number of test cases selected
- The total number of PASS, FAIL and INCONCLUSIVE verdicts
- The list of all test cases run, with their respective verdicts
- A list of all PICS and PIXIT questions with the answers given by the test operator
- A complete trace for every test case run

Figure 5 shows the beginning of a detailed test report.

5. Overall Benefits of Conformance and Interoperability Testing

Testing complex protocols, such as signalling protocols, is a rigorous task, since hundreds of different tests may be required to verify all aspects of the protocol. Faced with competitive pressures, few product developers have the time to implement their own series of tests. Therefore, expert organizations, or standards bodies, such as the ATM Forum, have developed pre-defined tests that are used as a reference point for a particular protocol. In many cases, these approved test suites are designed to be run automatically, thus further simplifying the verification process.

In summary the major benefits of conformance and interoperability testing are:

- An industry-wide, agreed-upon set of rules on how to test a protocol implementation.
- The ATM Forum adds credibility to the test suite coverage and brings a systematic approach to testing.
- It provides an automated and customizable stimulus-and-response environment for verifying the functionality of an ATM implementation.
- It clearly and simply summarizes test results with the use of verdicts (such as PASS or FAIL).
- Written test campaign results can be produced, including a detailed test report.
- When used during R&D design cycle, testing can help pinpoint problems in the early stages of an ATM product development, thus avoiding costly and time consuming redesigns.
- Testing can reduce overall time to market.

Additionally, every ATM Executable Test Suite offers the following benefits:

- Off-the-shelf test solutions based on recognized ATSs.
- Increased focus on specific aspects of the IUT by selecting only relevant test cases.
- A concentration on problems, once preliminary results have been obtained, by selecting only test cases that have previously FAILed (for example) or allowing the termination of testing at a later time by selecting test cases that have never been tested previously.
- The ability to review and analyze traffic with flexible data recording and playback capabilities.
- A means to quickly locate the source of a problem and correlate the execution of a test case to its ATC with embedded diagnostic information in the test case trace.
- The capability to save and restore test campaign setups and results to allow for quick regression testing

.

Conclusion

This paper has presented several testing methodologies to verify the correctness of an ATM implementation. We covered conformance and interoperability testing and described the various steps involved in these testing techniques, from designing ATSs to executing ETS and obtaining Test Reports. Through the use of these testing techniques, ATM products can be brought to market more efficiently, and continue to be technical viable throughout their product life cycles.

Acronyms

ATC	Abstract Test Case
ATS	Abstract Test Suite
CPE	Customer Premises Equipment
ETC	Executable Test Case
ETS	Executable Test Suite
IE	Information Elements
ITU-T	International Telecommunications Union –Telecommunication Standardization Sector
IUT	Implementation Under Test
MoT	Means of Testing
NSP	Network Service Provider
PICS	Protocol Implementation Conformance Statement
PIXIT	Protocol Implementation eXtra Information for Testing
RI	Reference Implementation
SWG	Sub-Working Group
UNI	User-Network Interface

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5965-9334E 05/00 Rev B

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