The ATM Forum
Technical Committee

Introduction to ATM Forum Test Specifications

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Walter Buehler, Editor

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1. Introduction

ATM represents a new information transfer mechanism capable of supporting a variety of existing and new services both in the public and private networking environment. One of the key success factors for deployment of any new technology is standardization and ensuring interoperability among various implementations. Ensuring interoperability among different implementations requires testing the many interfaces that are supported on the systems.

1.1 Purpose and Scope

This document provides the readers with a general overview of the different testing areas and their relationship to each other. The testing areas are conformance, performance and interoperability testing. This document should be used as a starting point for testing all ATM services and interfaces. Subsequent testing documents will include questionnaires that allow one to extract pertinent information about a particular implementation and test suites. The questionnaires are known as PICS (Protocol Implementation Conformance Statements) and PIXITs (Protocol Implementation eXtra Information for Testing). PICS are based on the specification of the protocol. They contain questions regarding features and functions, both mandatory and optional, that may be implemented. PIXITs, similar to PICS, are also used to extract information about particular implementations. However, they address other information that may be out of the scope of the specification (e.g. implementation specific details and proprietary features). Without the PICS, it would be difficult to derive the corresponding conformance and interoperability test suites.

1.2 Structure of Document

This document is structured as follows:

- Section 1 constitutes the Introduction. It describes the purpose, scope and structure of this document. It introduces some basic terms and contains a list of abbreviations that are used in subsequent sections.

- Section 2 provides a short overview of the different testing areas.

- Section 3 supplies information concerning the PICS and PIXITs proformas.

- Sections 4, 5 and 6 contain a definition each of conformance, performance and interoperability testing and some general procedures useful for all types of tests.

- Section 7 concludes this document by providing a list of the different testing documents that have been generated thus far.

- Appendix A contains a discussion on measuring QoS (Quality of Service) parameters.

1.3 References

[1] ATM User-Network Interface Specification, Version 3.0, ATM Forum, September 1993

[2] ISO/IEC 9646-1 (1991), Information technology - Open systems interconnection - Conformance testing methodology and framework.

[3] af-intro-0000, Master Index to the ATM Forum documents

1.4 Terminology

The following definitions are used in this document (most of the terms are taken from ISO/IEC 9646 [2]):

1.4.1 Basic Terms

Abstract Test Case: A complete and independent specification of the action required to achieve a specific test purpose (or a specific combination of test purposes), defined at the level of abstraction of a particular Abstract Test Method, starting at a stable testing state and ending in a stable testing state.

Abstract Test Method: The description of how an Implementation Under Test (IUT) is to be tested, given at an appropriate level of abstraction to make the description independent of any particular realization of a Means of Testing, but with enough detail to enable tests to be specified for this test method.

Abstract Test Suite: A test suite composed of abstract test cases.

ATM System: An ATM terminal equipment, an ATM network node or an ATM network.

Client: The organization that submits a system or implementation for testing.

Conformance Testing: Testing the extend to which an IUT conforms to a specification.

Executable Test Case: A realization of an abstract test case.

Executable Test Suite: A test suite composed of executable test cases.

Implementation Under Test (IUT): The part of the system that is to be tested. This can be a physical layer implementation, an SNMP (Simple Network Management Protocol) agent, etc.

Interoperability (IOP) Testing: Testing the degree of compatibility between two different implementations based on features that both have implemented.

Means of Testing: The combination of equipment and procedures that can perform the derivation, selection, parameterization and execution of test cases, in conformance with a reference standardized Abstract Test Suite, and can produce a conformance log.

Performance Testing: Performance testing consists of measuring the Quality of Service (QoS) or Network Performance (NP) parameters, which is traffic dependent.

PICS (Protocol Implementation Conformance Statement): A statement made by the supplier of a system implementation, stating the capabilities and options, which have been implemented and those that have been omitted.

PICS Proforma: A document in the form of a questionnaire designed by the protocol or test suite specifier (e.g. the ATM Forum) which when completed becomes the PICS.

PIXIT (Protocol Implementation eXtra Information for Testing): A statement made by a supplier or implementor of an IUT which contains or references all of the information (in addition to that given in the PICS) related to the IUT and its testing environment, which will enable the test laboratory to run an appropriate test suite against the IUT.

PIXIT Proforma: A document in the form of a questionnaire provided by the test laboratory, which when completed prior to testing become a PIXIT.

System Under Test (SUT): The system in which the IUT resides.

Test Laboratory: An organization that carries out conformance, performance and/or IOP (interoperability) testing.

Test Case: A series of test steps needed to put an IUT into a given state to observe and describe its behavior.

Test Event: An indivisible unit of test specification (e.g. sending or receiving a single PDU).

Test Group: A named set of related test cases.

Test Step: A named subdivision of a test case, constructed from test events and/or test steps.

Test Suite: A complete set of test cases, possibly combined into nested test groups, that is necessary to perform conformance testing or interoperability testing for an IUT or a protocol within an IUT.

1.4.2 Terminology for Conformance Testing

Conforming Implementation: An implementation, which satisfies both the static and dynamic conformance requirements, consistent with the capabilities stated in the PICS.

Dynamic Conformance Requirement: A requirement, which specifies what observable behavior is permitted by the specification.

Static Conformance Requirement: A requirement that specifies the limitations on the combinations of implemented capabilities permitted in a real open system, which is claimed against the specification.

1.4.3 Terminology for Performance Testing

Performance: The behavior of a system related to time and resource.

Performance Parameters: The performance aspects of a system that can be measured.

1.4.4 Terminology for Interoperability Testing

Static Interoperability: IUTs are statically interoperable if they implement a common and compatible set of features, functions and options. Compatible means that there are no conflicting requirements, which will prevent them from achieving interoperability.

1.5 Abbreviations

IOP	Interoperability
ISO	International Organization for Standardization
IUT	Implementation Under Test
NP	Network Performance
NPC	Network Parameter Control
PDU	Protocol Data Unit
PICS	Protocol Implementation Conformance Statement
PIXIT	Protocol Implementation eXtra Information for Testing
PVC	Permanent Virtual Circuit
QoS	Quality of Service
SUT	System Under Test
SWG	Sub Working Group
SVC	Switched Virtual Circuit
UPC	Usage Parameter Control

2. Overview of Testing

In order to ensure that different ATM products will be able to communicate with each other, it must be determined whether the products meet the specifications and whether they can interoperate without observable problems. Furthermore, the products should be able to perform under various load conditions. Three types of testing, conformance, performance and interoperability testing are used to provide the users with some level of confidence that the products meet these requirements. Each of these types of tests can be quite extensive and costly. They are also independent of each other and one is not necessarily a prerequisite to the other two. In addition, success or failure of one kind of testing is also not a prerequisite or indicative to the others. The combination of all three types of testing will provide the highest degree of confidence.

Conformance testing attempts to evaluate an implementation against a specific protocol specification. Performance testing attempts to evaluate an implementation under different traffic and load conditions to see how well it performs. Interoperability testing attempts to evaluate an implementation against other implementations; regardless of how well it meets the protocol specification.

Although independent, these tests share some common proformas and procedures. Prior to any kind of testing, whether conformance, performance, and interoperability, PICS and PIXIT proformas are used to extract information from the supplier or the implementor's details of the implementation. These questionnaires request information on what features and functions have been supported and what values or ranges of values are permissible. This information will be used to determine which tests are necessary and what modifications, if any, are needed and in some cases, which tests can be omitted.

The reminder of this section discusses some of the proformas that are used prior to testing and each of the testing areas in detail.

3. Proformas

3.1 PICS

To evaluate any implementation, it is necessary to have a statement of the capabilities and options, which have been implemented. The PICS for each IUT will help the test laboratory to compose an appropriate test suite to be executed, and to explain the results obtained. The PICS can also be used to evaluate the static conformance of an IUT or the static interoperability of two IUTs. In the later case, PICS for both IUTs would have to be obtained.

The PICS proforma is a fixed-format questionnaire for a given protocol. Answers to the questionnaire should be provided, either by simply indicating a restricted choice (such as Yes or No), or by entering a value or a set or range of values.

A supplier may also provide additional information, categorized as exceptional or supplementary information. This additional information should be provided as items labeled X.<i> for exceptional information, or S.<i> for supplementary information, respectively for cross-reference purposes, where <i> is any unambiguous identification for the item. The exceptional and supplementary information is not mandatory and the PICS is complete without such information.

PICS are also the basis that one uses to develop conformance and interoperability test suites. There is no standardized format for the questions in a PICS (see [2]). Each question should pertain to at least one of the requirements, mandatory or optional, in the specification. Subsequent interoperability and conformance test suites highlight each of these requirements. Note however that there may not be a one-to-one correspondence for each PICS question and a test case. It is possible to have individual test cases that address multiple requirements and likewise multiple test cases that address single requirements.

3.2 PIXIT

In order to test a protocol implementation, the test laboratory requires information relating to the IUT and its testing environment in addition to that provided by the PICS. This PIXIT will be provided by the client submitting the implementation for testing.

The PIXIT may contain the following:

1. information needed by the testing laboratory in order to be able to run an appropriate test suite on the specific system;

2. information already mentioned in the PICS and which needs to be made more precise;

3. information to help determine which supported capabilities are testable and which are not testable;

4. other administrative matters (e.g. the IUT identifier, reference to the related PICS).

4. Conformance Testing

ATM conformance testing consists of verifying that an ATM product conforms to the specifications defined by the ATM Forum or any standardization body. A conformance testing framework and methodology is proposed in [2]. Conformance testing is generally extensive as it consists of testing an IUT against every feature and function defined in the specification (e.g. signalling, ILMI, etc.). A conformance test suite targets a specific layer or protocol. A product can meet conformance at one layer but not at another.

Conformance testing can also be used whenever an interoperability problem arises between different pieces of equipment, to further explain the nature of the problem.

Conformance testing is performed by a tester (a conformance test equipment) which is connected to the SUT. A generic test configuration is shown in Figure 4.1.

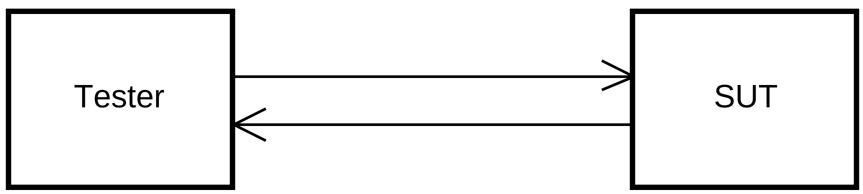

Figure 4.1: Generic Test Configuration for Conformance Testing

4.1 Conformance Assessment Process Outline

The conformance assessment process is given in ISO/IEC 9646-1 [2]. It can be summarized in the flowchart shown in Figure 4.2. A test laboratory receives the PICS and PIXIT for the IUT of the manufacturer. After analyzing the PICS, a number of conformance tests are selected for execution. Conformance tests are executed and results are analyzed. A final test report is prepared.

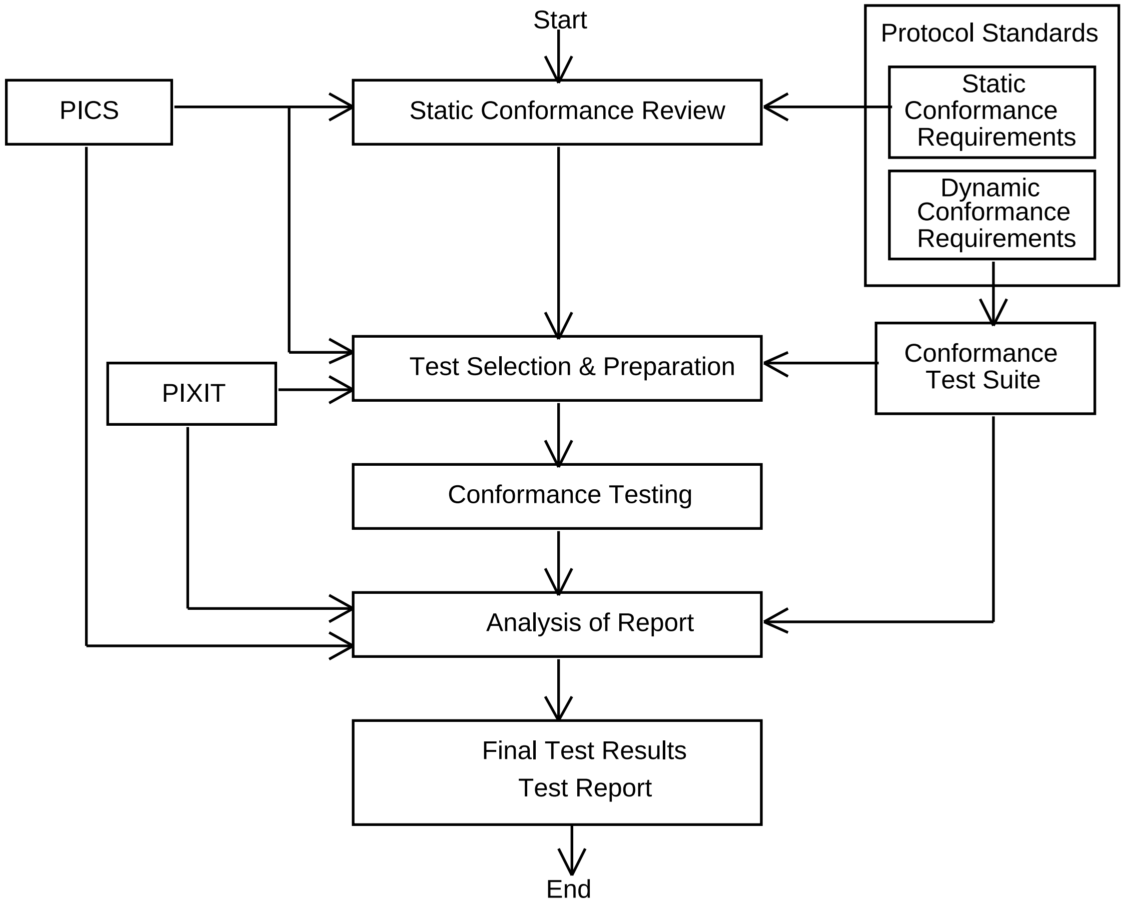

Figure 4.2: Conformance Testing Process Outline

5. Performance Testing

Performance testing consists of measuring QoS or NP parameters that are traffic dependent under well-known traffic conditions (load and profile).

Performance testing falls into two categories of tests:

- Measurement of QoS or NP parameters: QoS or NP parameters must not exceed a certain level under "normal load" condition. "Normal load" condition is, for example:
  -- for the ATM layer: Cell traffic load compliant to the traffic contract;
  -- for SVC connections: Signalling traffic less than a certain specified level.
- Overload Testing: The SUT has some overload defense mechanism implemented which should be tested.

Examples:

- UPC (usage parameter control) or NPC (network parameter control) at the ATM layer;
- Call/Connection rejection at the signalling level.

In general, performance testing involves two kinds of test equipment: a Generator and an Analyzer, which can be built in a single piece of the test equipment. A generic test configuration is shown in Figure 5.1. The Generator generates different patterns of traffic (cell traffic to test PVC or calls to test SVC connections) while the Analyzer measures such performance parameters as: cell error ratio, cell transfer delay, cell delay variation, etc.

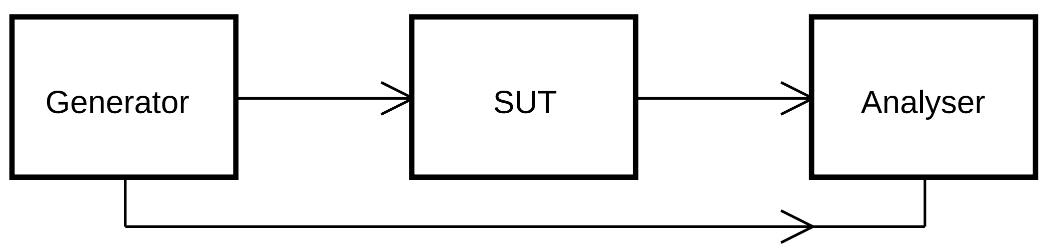

Figure 5.1: Generic Test Configuration for Performance Testing

5.1 Performance Assessment Process Outline

For further study.

6. Interoperability Testing

The problem of interoperability arises when end-users need to interconnect equipment from different manufacturers and to have a certain confidence level that these pieces of equipment can interoperate. The purpose of interoperability testing is to confirm the degree of interoperability.

An SUT may claim to conform to the ATM Forum UNI Specification if the following features/functions are implemented (see Figure 6.1):

- all of the mandatory ones;
- none or some of the optional ones;
- other unspecified features/functions.

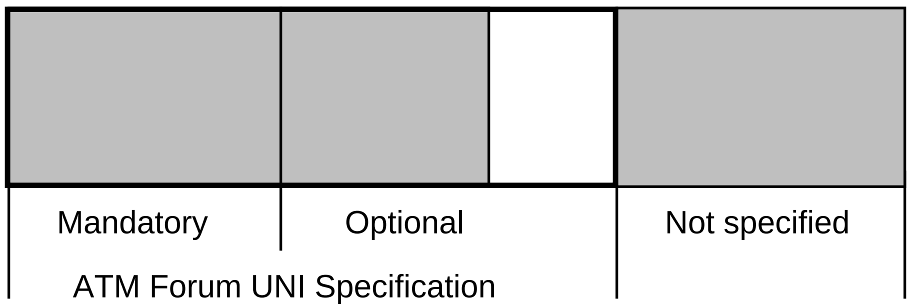

Figure 6.1: Features/Functions Implemented in SUT

For two SUTs to interoperate, two situations can be observed which can impact their ability to do so:

a) The two SUTs implement the same mandatory features/functions, but differ with regard to their optional and unspecified ones (see Figure 6.2). In this case, their ability to interoperate depends on these optional and/or unspecified features.

b) The two SUTs implement different mandatory features/functions. This situation may occur during the evolvement of standards. In this case, if there is a sufficient overlap, the two SUTs may be able to interoperate (see Figure 6.3).

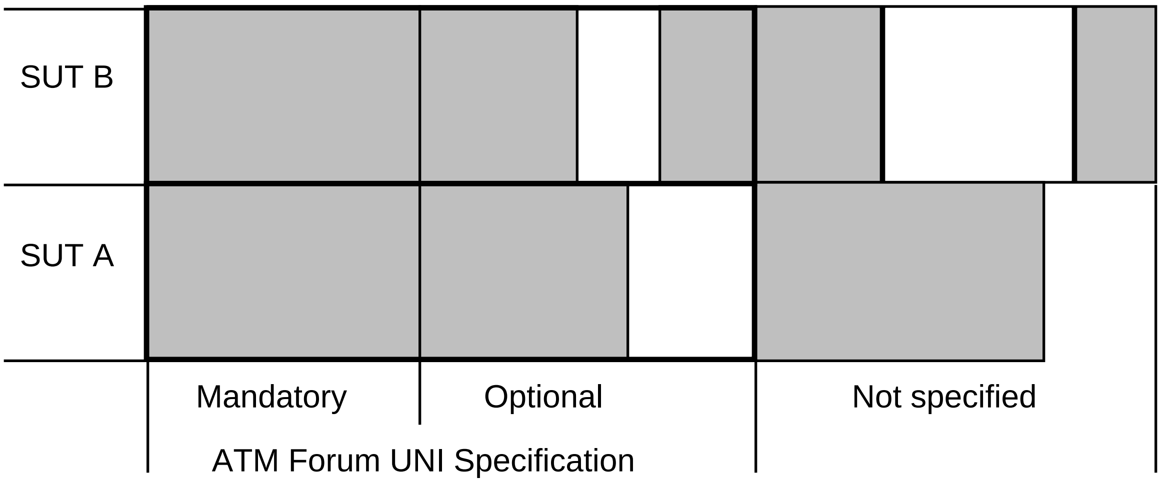

Figure 6.2: Two SUTs with the Same Mandatory Features/Functions Implemented

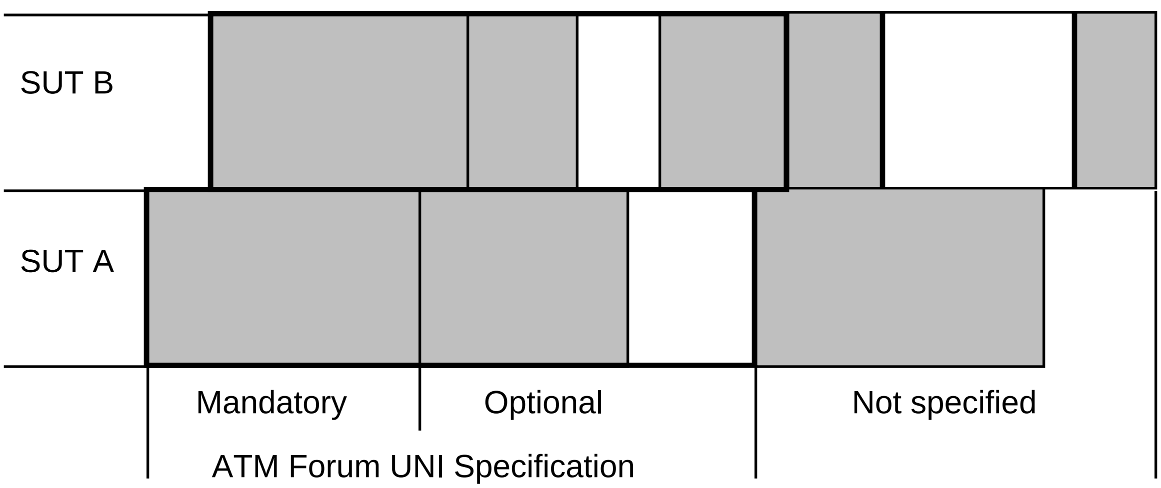

Figure 6.3: Two SUTs with Different Mandatory Features/Functions Implemented

Protocol specifications may contain areas of ambiguities that are more likely to be subjected to different interpretations and thus implementations. Examples of this include things like supporting optional procedures and parameters, different ranges of parameter and timer values. While these areas may be addressed during conformance testing, it may be necessary to highlight them in an interoperability test.

It is possible for different implementations not to meet the standard specifications but still to interoperate. These deviations from the standards need to be identified before interoperability testing begins. It may be necessary to generate additional test cases to test these unspecified features and/or functions. These additional test cases are beyond the scope of the test specifications of the ATM Forum.

Therefore, interoperability testing is used to measure the condition under which two or more systems with separate and different implementations will interoperate and produce the expected behavior. Interoperability testing can be bound to specific protocols within the stack. It involves testing both the capabilities and the behavior of an implementation in an interconnected environment and checking whether an implementation can communicate with another implementation of the same or of a different type.

In the case where the SUT is an ATM terminal equipment, the SUT has to interoperate and should be tested to interoperate with (see Figure 6.4):

1) the ATM network (as represented by its local switch);
2) one or more peer ATM implementations across the ATM network;
3) hardware or software that performs a higher-layer function over ATM.

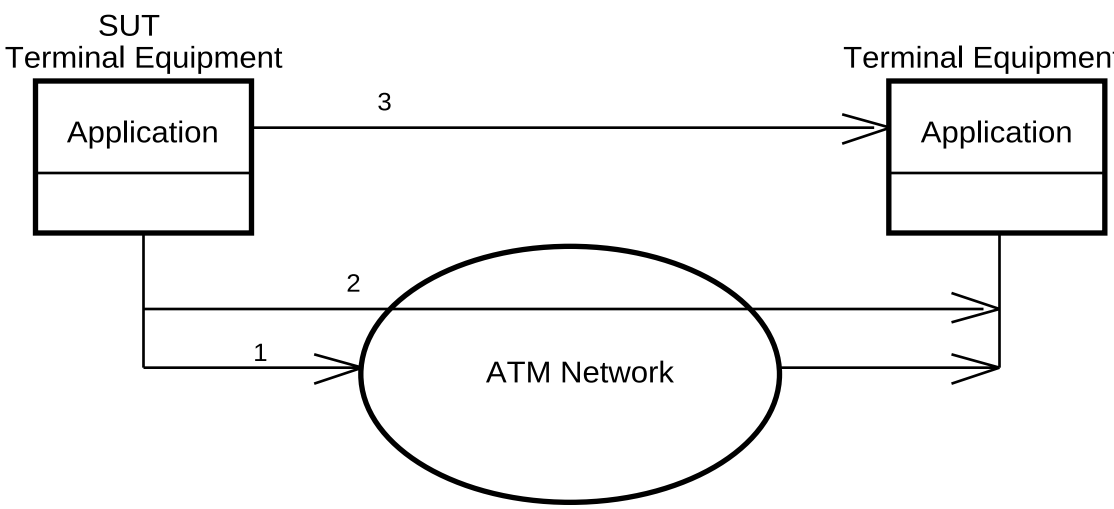

Figure 6.4: Three Kinds of Interoperability

Interoperability testing should include at the minimum:

1) **Static Conformance Testing** achieved through PICS and/or PIXITs ensures that the different IUTs are based on standard specifications. This will increase the likelihood that they will also interoperate with other implementations. Interoperability does not replace dynamic conformance testing.

2) **Interoperability Performance Testing** is needed to measure the joint performance of IUTs over an appropriate range of operating parameters. The set of operating parameters and ranges over which they are varied is dependent upon a number of factors including the features, services and/or applications being tested and the operating conditions under which the IUTs are expected to be used.

Interoperability testing does not include assessment of the performance, robustness, or reliability of an implementation. The determination of the above properties are left to the results of the performance test. However, a joint performance evaluation of both SUTs is required for interoperability performance testing.

Interoperability testing does not measure the conformance of an implementation relative to the standards since two implementations can be “non-standard” but still interoperate.

Neither does interoperability testing test each mandatory feature defined in the standard against the implementation of the tested IUT; this is left for conformance testing.

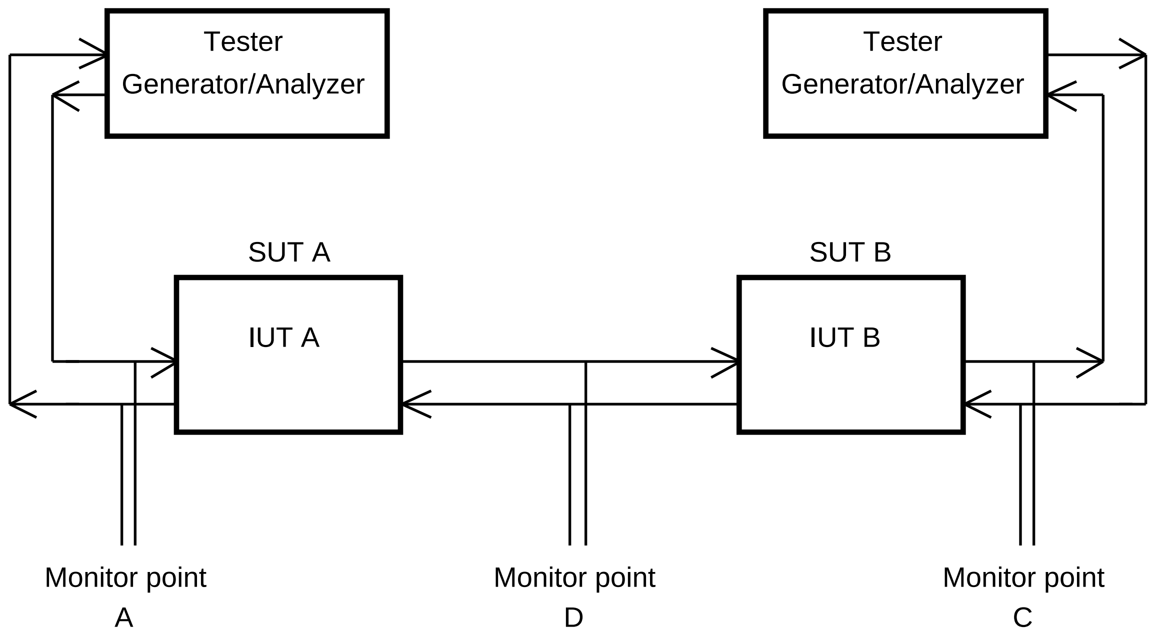

Figure 6.5: Generic Testing Configuration

Even though the goal of interoperability testing is to ensure that different implementations can interoperate, it should be borne in mind that the complexity of ATM and related protocols makes exhaustive testing impractical on both technical and economical grounds; therefore different tests should be designed to provide different levels of confidence that products will interoperate. Each test may require a unique configuration, however the generic configurations shown in Figure 6.5 can be used.

6.1 Interoperability Assessment Process Outline

The interoperability assessment process can be summarized in the flowchart shown in Figure 6.6. The test laboratory receives the PICS and PIXIT for IUTs of both manufacturers of equipment. After analyzing the PICS, a number of interoperability tests are selected for execution. These tests are chosen for IUTs that appear to follow a common standard (as claimed in the PICS). Interoperability tests are executed and results are analyzed. A final test report is prepared.

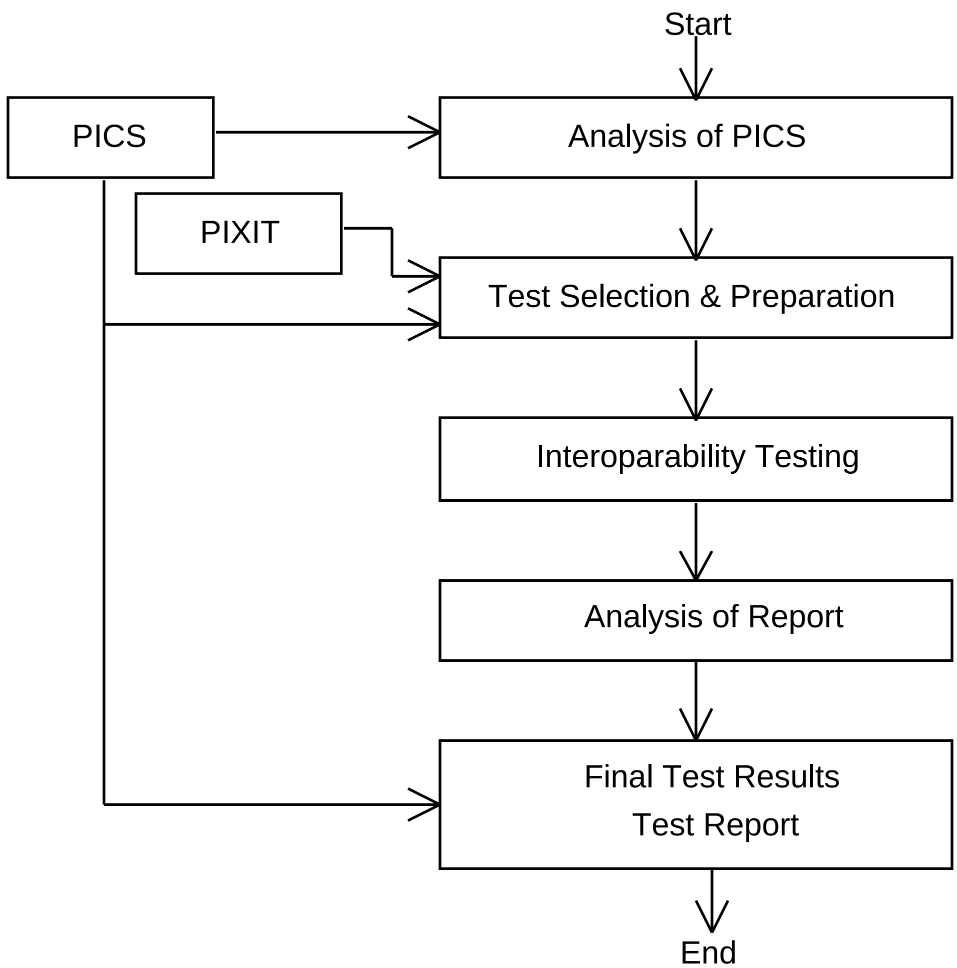

Figure 6.6: Interoperability Testing Process Outline

7. Status and Conclusion

This document has summarized each of the different testing areas. As stated earlier, each area serves its own purposes and only a combination of the three will give the end-user the highest level of confidence that the equipment meets the specification and will interoperate.

The testing documents like PICS and Test Suites that have been developed by the ATM Forum can be found via the master index [3].

Appendix:

A. Out-of-service Measurement of QoS Parameters

A.1 Test Configuration

Since QoS parameters are defined as parameters that can directly be observed by the users, the following definitions can be given:

- System under Test (SUT) is an ATM network or an ATM switch.
- Access for QoS measurement is the T or S reference point at the UNI

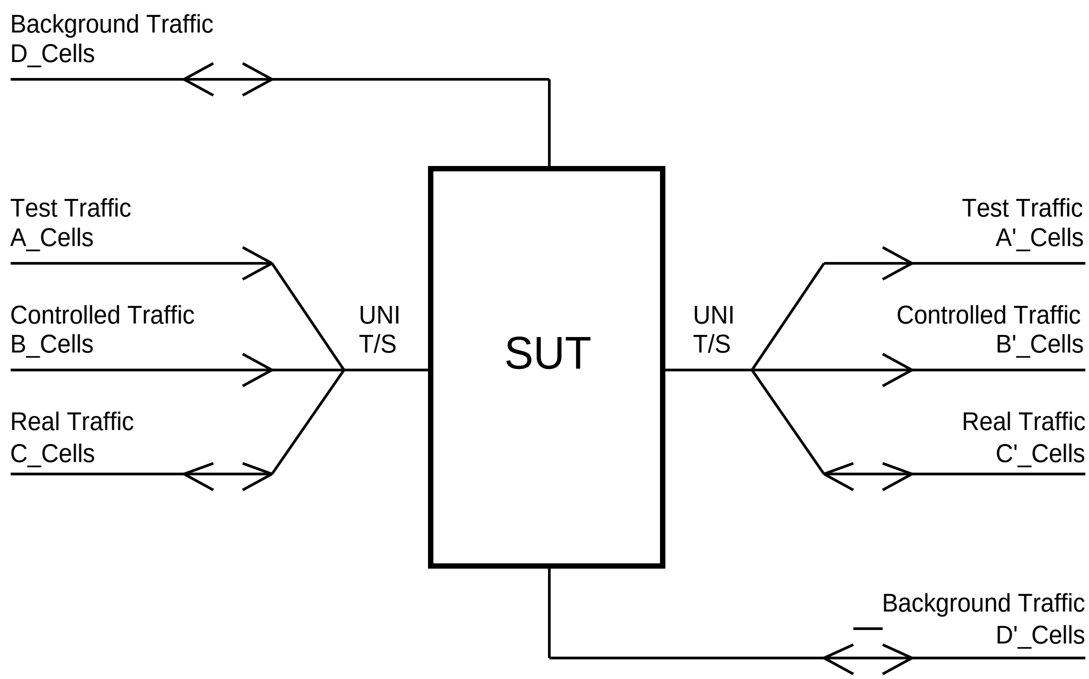

Figure A.1: QoS Measurement Arrangement

The SUT is loaded by the following cell traffic:

- Traffic at the Test Cell Input:
  - -- Test Traffic (A_Cells, unidirectional, called test cell stream) generated by the test equipment for the VP and/or VC used for testing purposes
  - -- Controlled Traffic (B_Cells, unidirectional) generated by the test equipment but for VPs/VCs not used for testing.
  - -- Real Traffic (C_Cells, bi-directional) generated/terminated by real subscribers connected to the UNI used for testing.

- Traffic at the Test Cell Output:
  - -- Test Traffic (A'_Cells, unidirectional) terminated at the test equipment for the VP and/or VC used for testing purposes
  - -- Controlled Traffic (B'_Cells, unidirectional) terminated at the test equipment but for VPs/VCs not used for testing.
  - -- Real Traffic (C'_Cells, bi-directional) generated/terminated by real subscribers connected to the UNI used for testing.
- Background Traffic (D_Cells and D'_Cells, bi-directional): traffic generated by real subscribers not connected at the Test Cell Input or Test Cell Output.

In general two types of test configurations exist:

1. SUT is fully under control by the tester. There is no real and no background traffic. Test traffic as well as the controlled traffic is generated by the test equipment. This configuration will allow reproducible test results to be obtained because the QoS parameters very much depend on the overall traffic in the SUT.

2. SUT is loaded with real as well as background traffic that is out of control of the tester. It is difficult to get reproducible test results mainly because the real and background traffic could lead to some overload conditions within the SUT. Therefore it is necessary to measure not only the QoS parameters but in parallel the load:
   - -- at the UNI of the Test Cell Input;
   - -- at the UNI of the Test Cell Output;
   - -- within the SUT

A.1.1 Test Cell Input

The Test Cell Input is a T or S reference point. Two categories of cells can be generated:

A_Cells that form the test traffic. Each cell contains
- VPI or VCI of a VP resp. VC established for testing purposes.
- Correct header (HEC)
- Cell payload containing an identification (e.g. a cell sequence number, a time stamp).
- Payload has to be guarded by a CRC. Form of the CRC: *for further study*.

Test traffic conforms to the negotiated traffic contract. It should be noted that any non-conformity could introduce cell loss and therefore a significant decrease of the QoS.

B_Cells which form controlled traffic. Each cell contains:
- VPI or VCI different from VP resp. VC used for testing purposes.
- Correct header (HEC)
- Cell payload: *for further study*.

A.1.2 Test Cell Output

The Test Cell Output is a T or S reference point. Since the QoS parameters are based on events of cells, therefore actual measurements can only be performed above the physical layer.

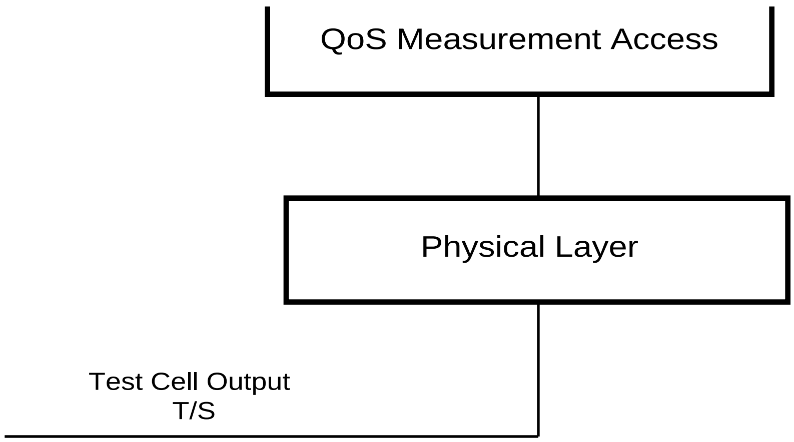

Figure A.2: QoS Measurement Access

The physical layer implemented in the test equipment may be considered as free of processing errors and without processing delay; or errors and delays in the physical layer should be taken into account in the calculation of the QoS parameter values.

QoS measurement access will get only valid cells from the physical layer because cells with a faulty HEC arriving at the Test Cell Output will get the header corrected or will be discarded. Therefore it will not be possible to analyze faulty cells with a HEC error in the ATM layer.

At the QoS measurement access the cell stream will be divided into the following two types of cells:

A'_Cells belong to the test traffic identified by the VPI and/or VCI. The following analysis will be done:

- CRC of the payload:
  - If CRC is correct, the cell is assumed to be a valid test cell. In this case it is possible to analyze the cell identification in the payload. It shows that the cell is in the right sequence:
    - If yes, the cell is assumed to be a correct test cell (called a_cells).
    - If no, the cell is assumed to be a missequenced test cell (called b_cells).
  - If CRC is incorrect, the cell is assumed to be an errored test cell even if there is a possibility that the cell is a misinserted one (called c_cells).

B'_Cells do not belong to the test traffic but have to be taken into account (together with the real traffic) to calculate the total traffic at the Test Cell Output.

A.2 Analyzing of the test cell stream

A.2.1 Cell error ratio (CER)

A continuous test cell stream containing A_cells is sent at the Test Cell Input. At the Test Cell Output the A'_cells are analyzed during a time interval of t1 (service dependent, the value is for further study). CER is calculated as follows:

$$CER = c \ / \ A'$$

where

A': number of A'_cells (received test cells)

c: number of errored A'_cells (c_cells: payload CRC is faulty)

This method will lead to incorrect results if misinserted cells with payload bit errors are received (overcount of c and A').

A.2.2 Cell loss ratio (CLR)

A continuous test cell stream containing A_cells is sent at the Test Cell Input. At the Test Cell Output the A'_cells are analyzed during a time interval of t1 (service dependent, the value is for further study). CLR is calculated as follows:

$$CLR = (A - A') / A$$

where

A: number of sent A_cells (test cells)

A': number of received A'_cells (test cells)

This method will lead to incorrect results if misinserted cells with payload bit errors are received (overcount of A'). In case of misinserted cells > cell loss CLR will be negative.

A.2.3 Cell misinsertion rate (CMR)

A continuous test cell stream containing only B_cells is sent at the Test Cell Input. At the Test Cell Output no A'_cells should arrive otherwise they are misinserted. Therefore A'_cells are counted during a time interval of t2 (service dependent, the value is for further study). CMR is calculated as follows:

$$CMR = A' / t2$$

where

A': number of received A'_cells (test cells)

A.2.4 Cell missequenced ratio (CSR)

I.356 doesn't define a cell missequenced ratio (CSR) because AAL controls missequencing of cells. Nevertheless missequencing of cells is a faulty behavior of the ATM network that can be observed by the user. Therefore an appropriate measuring method is recommended.

A continuous test cell stream containing A_cells is sent at the Test Cell Input. At the Test Cell Output the A'_cells are analyzed during a time interval of t1 (service dependent, the value is for further study). CSR is calculated as follows:

$$CSR = b / A'$$

where

A': number of received A'_cells (test cells)

b: number of b_cells where the cell identification in the payload shows that the cell was overtaken by the previous cell (cell sequence error). Example:

Cell number :	1	3	4	2	5
Counter value b :	n	n	n	n+1	n+1

A.3 Measuring cell transfer times

At the Test Cell Output only correct A'_cells (a_cells and b_cells: no payload CRC fault) are analyzed. To be able to perform measurements of the cell transfer time, the equipment generating the test traffic and the equipment analyzing the received test traffic must have a synchronized time reference in the order of micro seconds. All of the parameters are evaluated from the measurement of the Cell Transfer Delay (CTD):

CTD = tr - ts

where

tr: receive time relative to the synchronized time reference when the cell reached the Test Cell Output side.

ts: transmit time relative to the synchronized time reference when the cell left the Test Cell Input side.

Note: CTD is one of the cell transfer performance parameter. It very much depends on the cell traffic in the test traffic, the controlled traffic and the real traffic as such, as well as on the background traffic.

A.3.1 Mean cell transfer delay (MCTD)

Is the arithmetic average (mean) of the CTD measured over the time period t1 (service dependent, the value is for further study).

MCTD(t1) = Scdt / a

where

a: number of received and correct A'_cells (no payload CRC fault: correct test cells)

Scdt: Summation of the CDT (tr - ts) of all correct A'_cells.

A.3.2 Cell delay variation

For further study.

A.3.3 Transfer delay jitter

For further study.