A Heuristic for Interoperability Assurance in ATM Networks

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ABSTRACT

The Army Research Laboratory (ARL)'s Advanced Telecommunication/Information Distribution Research Program (ATIRP) is a vehicle for extending advanced commercial communication technologies to battlefield environment, and ensuring seamless interoperability among these technologies within the Warfighter Information Network (WIN). As ATM products/systems of different vendors are deployed in WIN, it is essential to develop necessary guidelines for fostering interoperability among these systems/products, and ensuring end-to-end interoperability across WIN.

The objective of this paper is to propose and develop a heuristic for interoperability assurance in a multi-vendor ATM environment. It specifically builds upon the definition of interoperability to propose an interoperability assurance heuristic that comprises two main sets of tests, interworking tests and end-to-end quality of service (QOS) tests. The former attempts to ensure that ATM systems of different vendors interwork within the ATM environment. While the latter mostly focuses on ensuring that the ATM environment satisfies the QOS requirements of its applications. We present the generic templates of these tests as well as an overview of the required capabilities and tools (e.g., an ATM monitoring system) that are implemented for executing the proposed heuristic. A network operator can execute this heuristic with the current version of our ATM monitoring tools. However, further work is required to completely automate the execution of the heuristic.*

Key words: Interoperability Assurance, ATM Networks

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1. Introduction

The Warfighter Information Network (WIN) is an evolving, integrated C4 Network of Communications that is comprised of evolving, commercially based, high technology information and communications systems. It is designed to increase the capacity and velocity of information distribution throughout the battlespace in order to gain Information Dominance. It will maximize Information Services for the Warfighter and support the Power Projection Force of the 21st Century from sustaining base to foxhole.

The Asynchronous Transfer Mode (ATM) is expected to be a key transport technology of the National Information Infrastructure (NII) and the information infrastructure of Department of Defense (DoD) for supporting voice, video, data, and multimedia services. ATM provides a sound commercially accepted infrastructure for the information support architecture since it allows us to leverage developments in commercial technology and the warfighter can use the same telephone or personal computer in the field that he uses in garrison[1].

WIN will very likely be a multi-vendor ATM environment. Thus, it is essential to develop necessary guidelines that i): foster interoperability among commercial ATM products of different vendors deployed in WIN, and ensure its end-to-end interoperability.

The objective of this paper is to propose and develop a heuristic for ensuring interoperability among ATM products of different vendors within WIN. Building upon the concept and criteria for interoperability [2], we

- develop a heuristic comprising of two sets of tests, interworking and end-to-end QOS tests for interoperability testing/assurance in ATM internets, and

1. Commercial ATM products needs to be enhanced in order to be used in WIN. For instance, core components of WIN ATM hub (nodal) switches, and extension switches include embedded multilevel security and other network services.

- present the generic templates of these tests, as well as an overview of the required ATM monitoring system/ tool that is developed for performing these tests.

This ATM monitoring system is used to set up an interoperability testbed between Bellcore (Red Bank, NJ) and Joint Interoperability Test Center (JITC) in Ft. Huachuca, Az.

This paper is organized as follows: Section 2 covers the definition and requirements for interoperability. Section 3 contains an overview of the ATM monitoring system and its capabilities. In Section 4, we describe the proposed interoperability testing/assurance heuristic, and present generic templates of its tests. Finally, Section 5 concludes the paper with a few open issues that require further work.

2. Interoperability: The Concept and Requirements

In principle, two systems[2] (*e.g.,* subnets, products, etc.) are said to be interoperable if their end-to-end internet resembles (or be made to resemble[3]) an unbounded buffer process whose performance satisfies the QOS requirements of the applications [1][2]. In other words, their end-to-end internet shall deliver a copy of the sender's message to the receiver after some delay, and ensure that the QOS requirements of the applications are satisfied. This simple concept has several theoretical and practical implications/ interpretations. In a nutshell, key theoretical implications of this concept are that i): in principle, two distinct subnets/ systems with correct protocols can be interworked, and ii): the protocols of different subnets/systems of an internet should at least have a common part (*i.e.*, a layer or more). On the other hand, this statement practically implies that the two systems/subnets a): shall interwork, and b): their internet[4] shall satisfy the QOS requirements of applications. These practical requirements serve as a basis for developing the proposed heuristic for interoperability assurance among different systems/subnets of an internet.

In order to determine whether two systems are interoperable, we connect them in tandem either directly or via an interworking unit (IWU) to set up a testing internet. Since we are testing interoperability of different implementations of the same technology, *i.e.*, ATM, there will be no need for interworking unit. As shown in **Figure 2-1**, the ATM systems under test are connected directly to set up the testing internet. We will hereafter refer to this configuration as the interoperability testing internet.

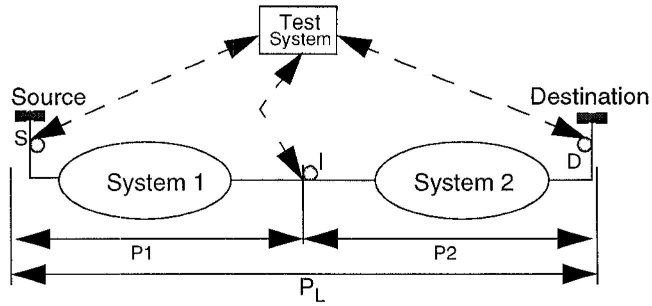

Figure 2-1. The ATM Interoperability Testing internet

The proposed interoperability assurance heuristic essentially comprises two sets of tests, the interworking tests and the end-to-end QOS tests, on the ATM and AAL layers which are common layers of the systems under test. The interworking tests attempt to verify whether the two systems interwork, *i.e.*, whether end-to-end connections on the testing internet correctly replicate the source (*i.e.,* point S) information at the destination (*i.e.,* point D). The aims of the end-to-end QOS tests are to determine whether end-to-end connections across the interoperability testing internet satisfy the performance objectives of their applications, and isolate the cause of failure when they do not satisfy the performance objectives.

An ATM monitoring system is required to carry out the heuristic and perform the interworking and end-to-end QOS tests. The required ATM monitoring system should enable the tester/operator to measure the performance metrics of connections, and capture both the contents and statistical behaviors of their cell streams at the source (*i.e.*, point S), the intermediate (*i.e.*, point I), and the destination (*i.e.*, point D) interfaces (as shown in **Figure 2-1**).

3. The ATM Monitoring System: An Overview

Bellcore and Tektronix have been jointly developing such an ATM monitoring system under a grant from DARPA (Defense Advanced Project Research Agency) and NSF (National Science Foundations) since 1995 [3]. This monitoring system was used to deploy an ATM interoperability testbed between JITC and Bellcore at the end of 1997. This testbed can serve as a field laboratory for

2. We use the word "system" to refer to either a subnet or a network element/product (*e.g.,* a switch).
3. They are made to resemble a buffer through the use of an appropriate interworking unit (IWU).
4. This internet is created by connecting the two systems either directly or via an interworking unit (IWU).

interoperability among different ATM products and networks. The ATM monitoring system is depicted in **Figure 3-1**.

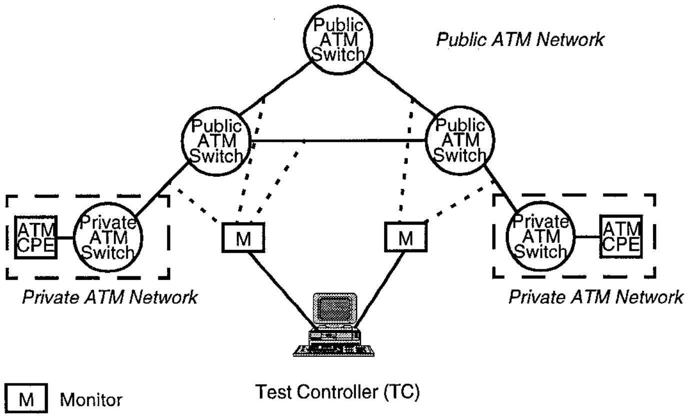

Figure 3-1. The ATM Monitoring System

The ATM monitoring system has a client-server architecture. It consists of several monitors which collect information about the state of the network/system under test, and a test controller (TC) which essentially serves as a test control and management center. The ATM monitoring system enables the tester/operator at the TC to obtain and display on demand the necessary statistics about the behavior of a VP, VC, or an interface at the ATM and AAL layers on the Graphic User Interface (GUI) of the TC. In principle, each monitor can measure the performance (and capture the contents, if necessary) of one or more traffic streams (*e.g.*, the traffic on a VC, VP, or an interface) and obtain its relevant statistics for the management information base (MIB) of the monitor. Moreover, the monitors also serve as traffic generators that can transmit/feed a user specified traffic stream into the interoperability testing internet. The TC uses the standard simple network management protocol (*i.e.*, SNMP) to retrieve the desired data from the MIB.

This monitoring system is a real-time ATM network observer that enables the operator to obtain the performance metrics (*e.g.*, cell loss, cell delay, PDU loss, PDU delay, *etc.*) of the connections across the internet. Furthermore, it permits the operator to obtain and visualize the statistical behavior (*e.g.*, load spectrum, load histogram, .., *etc.*) of connections on different interfaces across the network dynamically.

4. The Interoperability Assurance Heuristic

Let us consider the ATM interoperability testing internet of **Figure 2-1**, and explain the proposed heuristic for testing the end-to-end interoperability of systems that constitute this internet and summarize them in generic templates. This heuristic can serve as a blueprint for interoperability testing in ATM internets regardless of their applications. It can be performed

- on an operational (in service) internet with its own service scenario to verify its "correct" operation, and/or
- on an internet under construction with a test traffic scenario selected from a reference load menu to ensure proper design of the internet under construction.

In principle, the network operator/tester can perform all of these tests on the GUI of the current version of the ATM monitoring system. However, further work is required to develop the necessary test scripts for complete automatic execution of this heuristic.

4.1 The Interworking Tests

The tenet of interworking of two communication systems is that their protocols share a common part (a layer or layers). This common part is the narrow point of their internet "hourglass". For instance, the ATM and AAL layers will serve as the narrow point of the "hourglass" in an ATM internet. The aim of the interworking tests is to ensure that the source information is correctly received at the destination. It attempts to verify that the ATM cells (or AAL PDUs) are correctly transferred among different systems that constitute the interoperability testing internet. These tests essentially consist of a): conformance testing of the common layer/layers on both systems, and b): frequent file transfers on their end-to-end internet under different load scenarios. As summarized in **Table 4-1**, the interworking testing menu is as follows:

— Determine whether the ATM systems conform to the standard specifications of ATM. These tests are performed according to ATM forum specifications, Bellcore generic requirements (GRs), and the DoD standards for tactical ATM. They are necessary for ensuring interworking among different ATM systems but are not sufficient.

— Transfer test files correctly from the source to destination and vice-versa across connections which pass through the ATM systems under test. Traffic monitors are used to capture the cell stream generated by the file transfer at the S, I, and D interfaces. The captured copies of the cell stream at these points shall be identical.

— Browse into different web sites (*e.g.,* http://cnn.com/, or http://www.pbs.org/) from the source and destination via the interoperability testing internet, and capture the resulting cell streams at interfaces S, I, and D. The captured copies of the cell at these interfaces shall be identical. In the third step, the browsing path on the interoperability testing internet should include the ATM systems under test. These tests ensure the spontaneity of the source files and improve the reliability of the tests.

Table 4-1. Generic template of ATM interworking tests

Tests	Description	Procedures	Criteria
Conformance	Perform ATM Forum Specs & PICS Performa, Bellcore GRs, and DoD ATM standards.	As defined in the Forum Specs & PICS performa, and Bellcore GRs.	As Defined in the Corresponding Specs
FTP	Transfer a set of known files from S to D and *vice-versa.*	Capture the cell streams on the VC at S, I, and D simultaneously.	These streams shall be identical, otherwise, the subnets, systems, or products do not interwork.
Web Browsing	Browse into different web sites one the Internet from the source via the destination, and *vice-versa.*	Capture the cell streams on the VC at S, I, and D simultaneously.	These streams shall be identical, otherwise, the subnets, systems, or products do not interwork.

4.2 The End-to-End QOS Tests

These tests comprise the end-to-end performance measurement tests and diagnostic tests. The former focus on determining whether the end-to-end connections on the interoperability testing internet satisfy the QOS requirements of their applications. While the latter attempts to identify the cause(s) of failure when they do not meet the performance objectives. In order to perform the end-to-end QOS tests, we

1. translate the QOS requirements of applications into a set of end-to-end performance objectives for ATM and AAL layers of the interoperability testing internet that can be measured by the ATM monitoring system (e.g. cell loss ratio, PDU loss ratio, .., *etc.*),
2. allocate/partition the end-to-end ATM and AAL performance objectives among different systems across the interoperability internet, and
3. test to see whether the ATM and AAL layers of each system satisfy their allocated performance objectives.

Let us consider the testing internet shown in **Figure 2-1** to explain the performance measurement tests in more detail. This internet consists of two ATM systems where each of these systems essentially perceives the other as its customer/user and ensures that its QOS requirements are satisfied (*i.e.,* each system meets its share of the performance allocation). For instance, suppose that the packet loss ratio objective of connections on the internet of **Figure 2-1** is P_L, and P1, and P2 are the allocated shares of packet loss ratio to system 1, and system 2, respectively, we have

$$P_L = P1 + P2 \ .$$

Note that we have neglected the higher order terms in the above equation. Having assigned the performance objectives of each system, the last step is to measure the relevant metrics on the ATM and AAL layers of each system to see whether each system meets/supports its performance objectives. As shown in **Figure 2-1**, in order to perform this last step, the monitoring system shall monitor/measure the performance of connections at the source (*i.e.,* S), the intermediate interface (*i.e.,* I), and the destination (*i.e.,* D) in both directions.

The diagnostic tests are performed when the end-to-end performance measurements indicate that the testing internet does not satisfy its performance objectives. The aim of diagnostics tests is to help the operator/tester to determine why the internet performance objectives are not satisfied, and to identify the cause of the failure. In the diagnostic tests, we obtain the statistical behavior (*e.g.,* load histogram, load spectrum, ..., *etc.*) of the internet traffic on one (or more) VC(s) at the source (*i.e.,* point S), the intermediate (*i.e.,* point I), and the destination (*i.e.,* point D) interfaces on both ATM and AAL layers. These statistics can assist the operator to detect and isolate faults within the internet. The end-to-end QOS tests are summarized in **Table 4-2.**

Table 4-2. Generic template of the end-to-end QOS tests

Test	Objective	Procedures	Criteria
End-to-End performance measurements	Verify that the testing internet satisfies the end-to-end performance objectives.	Obtain the performance metrics (e.g., cell loss, error, jitter, etc.) on the ATM layer at points I and D, and PDU loss and error, etc. on the AAL layer at point D.	None of the measured metrics shall exceed its bound.
Diagnostic through traffic observations on the testing internet	When the testing internet fails to support its QOS objectives, the operator invokes these tests to assist him/her to identify the cause.	Obtain the statistical behavior of ATM traffic on a VC (or more) at points S, I, & D (e.g., cell delay histogram, load spectrum, etc.), and the statistical behavior of AAL traffic on one or more VCs at points S & D.	Beyond the scope of this paper. For instance, the tail of the cell & PDU delay distributions shall meet applications' requirements.

The detailed description of the procedures and criteria for the end-to-end tests, particularly, those of diagnostic tests are beyond the scope of this paper.

5. Summary and Conclusions

This paper proposes and develops a heuristic that can be used to foster interoperability among commercial ATM systems of different vendors deployed in WIN, and to ensure its end-to-end interoperability. Our discussions indicate that two systems are said to be interoperable, if they interwork and their end-to-end internet satisfies the end-to-end QOS requirements of its applications. Building upon this proposition, we have proposed and developed a heuristic for interoperability assurance among different ATM systems. This heuristic comprises interworking tests and end-to-end QOS tests. The aim of the interworking tests is to ensure that the source information is correctly received at the destination, while the end-to-end QOS tests focus on whether the end-to-end connections satisfy the QOS requirements of their applications. We have described these tests as well as the architecture and capabilities of an ATM monitoring system which is built for performing this heuristic. Finally, an open issue for further work is to develop the necessary test scripts that completely automate the execution of the proposed ATM interoperability assurance heuristic.

Disclaimer

The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the official policies, either expressed or implied, of the Army Research Laboratory or the U.S. Government.

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