Asynchronous Transfer Mode (ATM) Testing

Definition

Testing asynchronous transfer mode (ATM) communications and network equipment is the function of performing the three primary testing phases required for complete evaluation of ATM products:

1. conformance verification
2. interoperability testing
3. performance benchmarking

These test phases measure and analyze all aspects of ATM—from the characteristics of lower-layer cell transmission through to the complex ATM services (i.e., available bit rate [ABR], undefined bit rate [UBR], etc.) used to transmit multimedia over ATM networks.

Overview

The term "ATM technology" has become inextricably linked to promises of a global communications infrastructure. The expectation is that seamless integration of voice data and video across high-speed ATM links will provide universal access to multimedia services.

ATM equipment developers, service providers, and end users are all faced with these same challenges when testing ATM products. ATM technology is now in a period of dynamic growth. Standards groups (i.e., the International Telecommunications Union [ITU]) are challenged to keep up with this fast-paced development, and their publications do not always correspond to specifications issued by other organizations (i.e., the ATM Forum).

How can ATM technology users define their testing requirements and focus on product release and deployment? This tutorial by is intended to provide the reader with an overview of the main issues encountered when testing ATM products.

Topics

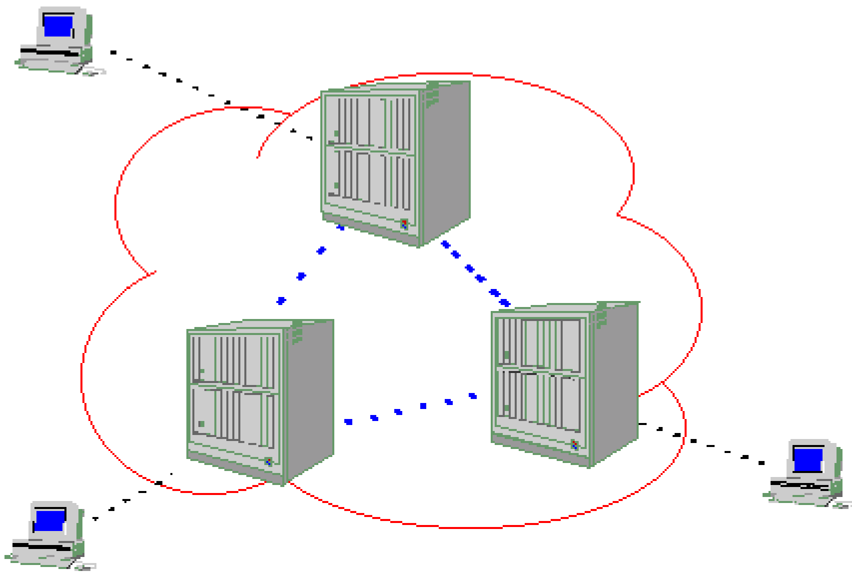
1. ATM Layer Testing

ATM is primarily a transport-level protocol. ATM systems operate by establishing a connection between two users and then sending data using the unique ATM cell format. The primary issues for ATM layer testing are to test the equipment function and measure system performance when transporting ATM cells between any two points across a network connection.

An ATM Network Contains Buffers

Each ATM cell can pass through one or several ATM switches during end-to-end transmission (shown in *Figure 1*). Cells can be processed through buffers (queues) in ATM switches introducing variable delays to the ATM cell traffic throughout the entire ATM network. The cell delay through switch buffers is dependent on the aggregate traffic loading on the network. Switch buffers can also become overloaded and cause a loss of cells.

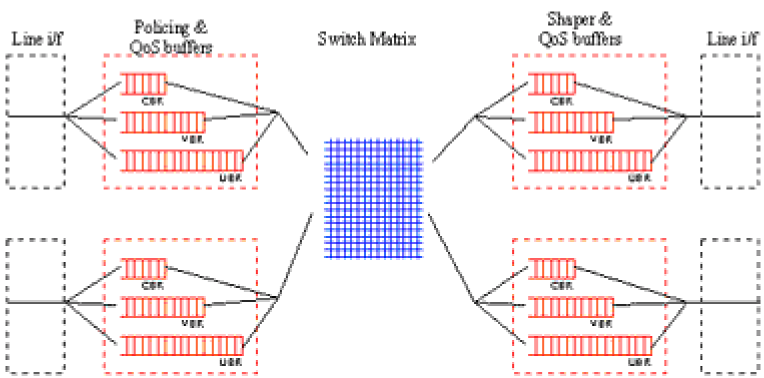
Figure 1. All ATM Switches in the Network Can Buffer Cells



Different Queues for Each ATM Service Category

Each ATM switch may implement a different queuing mechanism. The queuing mechanism may be simple or extremely complex depending on the types of ATM service categories supported by the switch (i.e., UBR or ABR). This design may cause cells belonging to different ATM service categories to be processed through different queues in the ATM switch. Even within a single ATM service category (i.e., UBR), different virtual channel connections (VCCs) may be processed through separate queues. These advanced cell scheduling mechanisms introduce a high degree of complexity to the ATM switches and require extensive testing.

Figure 2. An ATM Switch May Have Queues, Shapers, and Complex Scheduling Mechanisms



ATM switches may also perform shaping of its output cell traffic. This introduces another form of cell delay called jitter. The switch matrix design may include several layers (one for each ATM service category) and this delay may result in cell loss or cell misinsertion (in rare cases).

Switch to VCI/VPI Translation

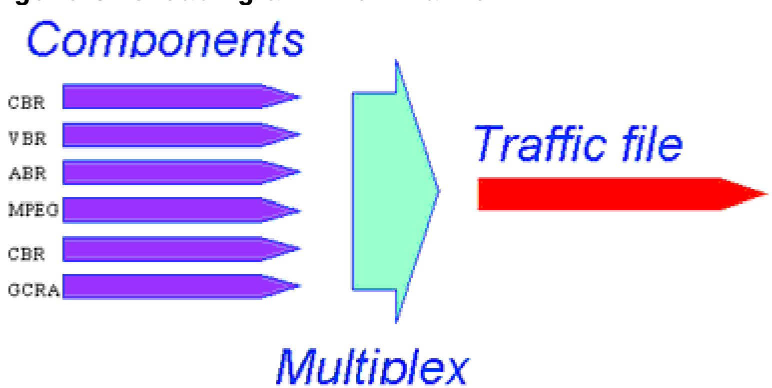
One of the major ATM layer functions of an ATM switch is to perform virtual channel identifier (VCI)/virtual path identifier (VPI) translation from the input to the output. This function is achieved using an address lookup table that is programmable through signaling set-up messages or via network management. Cell misrouting and cell misinsertion can occur if the address translation function does not operate correctly.

Methods to Test the ATM Layer

Quality of service (QoS) tests are performed under out-of-service conditions. Testing of the ATM layer requires an ATM analyzer capable of generating ATM traffic and then monitoring the same traffic to make specific measurements.

The ATM analyzer traffic generator must be capable of transmitting cell streams at full line rate to stress test ATM switches and devices. It should also allow selection of channels from a range of available virtual channels (VCs) on the link under test and adjustment of the cell transmission rate and background traffic conditions. These different channels are then mixed together to emulate real-world traffic to ensure that the switch can simultaneously process traffic for different ATM service categories.

Figure 3. Creating a Mix of Traffic

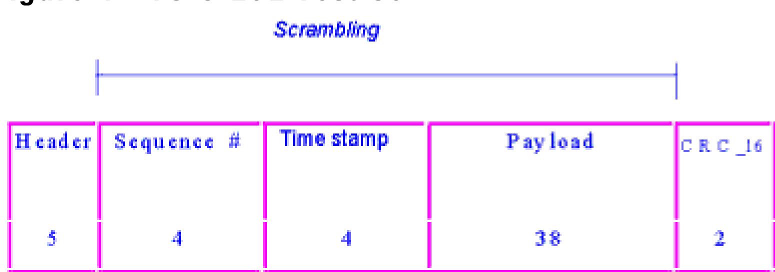


QoS Parameters

Use of the ITU defined O.191 test cell (*Figure 4*) provides the most accurate method to calculate ATM–layer performance parameters. The primary advantage of using the O.191 test cell is that measurements are interpreted in a consistent manner:

- Standardized format enables monitors to distinguish between cell errors and cell misinsertions.
- 10–ns time stamp resolution in the O.191 test cell allows accurate timing for existing rates and migration to very high bandwidths (OC–12 and higher).
- Scrambling of the test cell payload effectively alters the bit patterns so that the O.191 cell stream acts like a pseudo-random bit stream (PRBS).
- The large test cell sequence number allows cell loss measurements to be taken over extended periods of testing. This is of particular importance when testing for large bursts of cell losses as often occurs in real-life networks.

Figure 4. ITU O.191 Test Cell



The following ATM layer statistics are significant for measuring ATM QoS:

- **minimum cell transfer delay (CTD)**—minimum round-trip time for transmitted (foreground) test cells
- **maximum CTD**—maximum round-trip time for transmitted (foreground) test cells
- **mean CTD**—average round-trip time for transmitted (foreground) test cells
- **peak-to-peak cell delay variation (CDV)**—difference between maximum and minimum (foreground) test cell delay; this is generally a

good first estimate of the cell delay variation tolerance (CDVT) for the network

- **CDV distribution**—histogram indicating the number of foreground test cells detected having a CTD within a specified range, monitored over specified sampling time intervals during the test period

- **cell loss and cell loss ratio (CLR)**—measurement of the difference between the number of foreground test cells transmitted and the number of test cells received

- **cell sequence integrity**—identifies any out-of-sequence cells by comparing the sequence of received foreground test cells with the transmitted test cells. This is a severe error that should cause immediate notification to the user

- **cell error and cell error ratio (CER)**—the number of foreground test cells received with single or multiple payload bit errors divided by the total number of transmitted test cells

- **cell misinsertion and cell misinsertion rate (CMR)**—CMR is the number of cells detected on one VC having payload information belonging to another VC. This test provides a good indication that network equipment is overloaded or is reconfiguring and is misrouting or mis-multicasting cells. Note that CMR is calculated as a rate (not a ratio) since CMR is independent of ATM traffic load.

Network Impairment

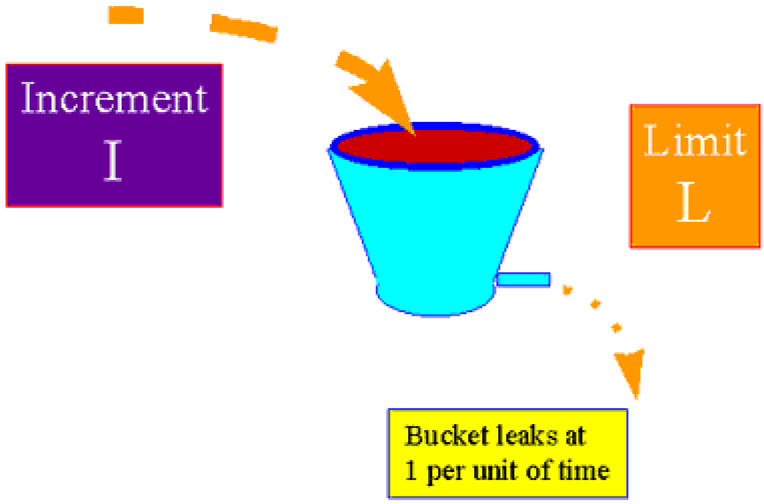
A valuable feature for ATM layer testing is the ability to introduce controlled impairments into a live ATM network—directly affecting the network QoS levels. This allows the ATM terminal vendors or ATM terminal purchasers to verify equipment operation under worst-case conditions (with cell losses, cell delays, bit errors, etc.).

GCRA Algorithm

All ATM switches perform user parameter control (UPC) verification on received traffic. The UPC function is based on the general cell rate algorithm (GCRA) (*i*, *l*)—algorithms defined in the ATM Forum and ITU standards. The UPC is a very critical function of switch behavior verifying that all sources obey their specific traffic contracts.

The UPC function in switches is performed primarily in hardware. Switch designers may implement hardware features that make assumptions about existing traffic conditions and implement shortcuts. For this reason, it is very important that the test equipment can verify the correct operation of the UPC function.

Figure 5. Illustration of the GCRA (*i*,*l*) Algorithm as Leaky Bucket



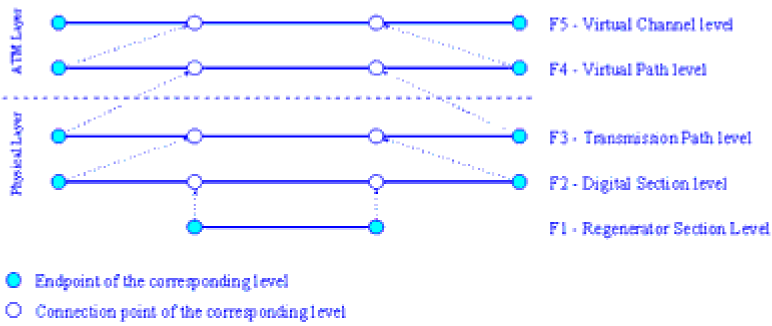
The ATM test analyzer should be capable of generating traffic that obeys source description as well as introducing violations to the negotiated GCRA contract.

OAM Parameters

Operation and maintenance (OAM) cells are used for alarm surveillance, performance monitoring, and troubleshooting. The OAM cells consist of five flow levels (F1–F5) where the highest (F4–F5) are dedicated to the ATM layer. All layers are interrelated as shown in *Figure 6*. Alarms in the lower layer move upwards to the higher layers.

The OAM cell traffic is transmitted intermixed with the user cells on each channel. An ATM test analyzer should be capable of sending and receiving OAM cells as well as generating the lower-layer OAM signals to properly test the complete OAM functionality.

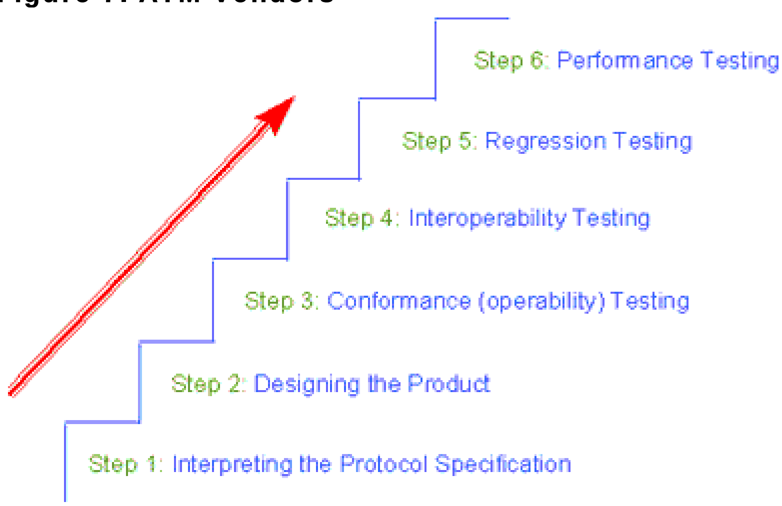
Figure 6. OAM Hierarchy



2. Stages of Testing ATM Products

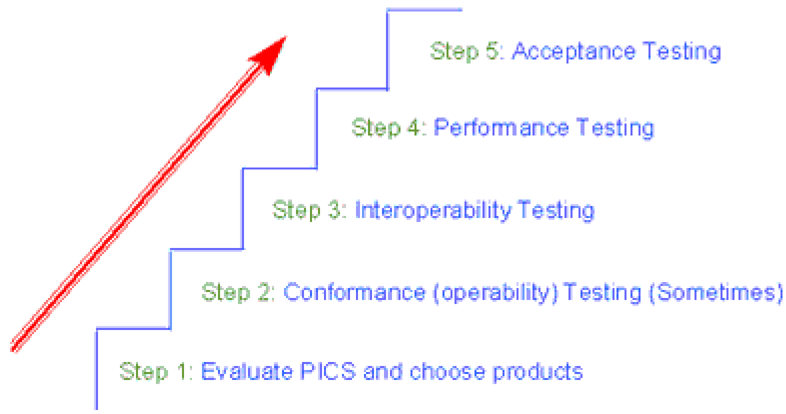
ATM technology is being designed to perform a complex set of functions. The rapid pace of ATM development has resulted in publication of specifications that are indefinite, subject to interpretation, not always backwards compatible, and, in some cases, prove to be impractical to implement. Regardless of these difficulties, manufacturers are meeting these challenges by proceeding with product development—often by making assumptions about future ATM services.

Figure 7. ATM Vendors



This challenge extends to testing ATM products and ATM networks. Initially, conformance testing must be performed to verify that new ATM equipment works according to a given specification. Following this demonstration, the equipment must be proven to interoperate with other equipment in an ATM network. Finally, performance testing is required to establish product benchmarks such as throughput and latency.

Figure 8. ATM Service Providers

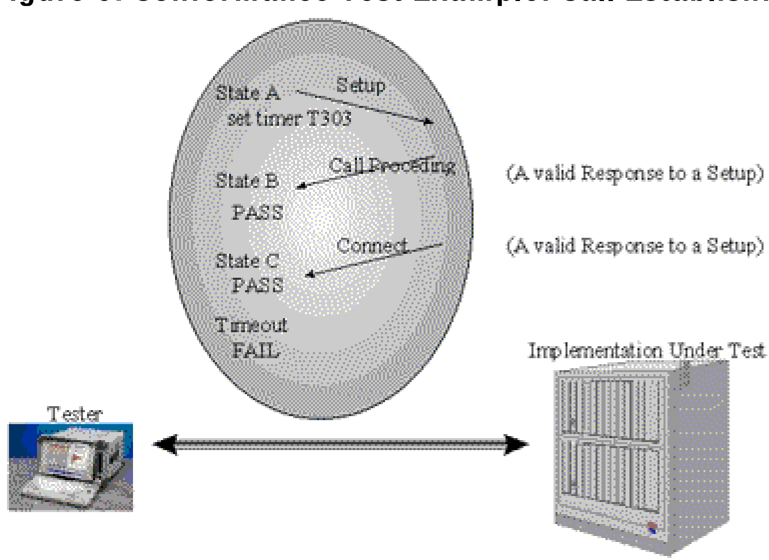


Conformance Testing

Conformance testing is used to validate a specific product according to a standard or specification. The equipment is always tested under out-of-service conditions. The ATM test technician must simulate an operating environment by generating traffic flows or emulating specific protocols. This should include simulating valid traffic flows and network errors to ensure that the device functions correctly under a range of operating conditions.

Figure 9 describes a conformance test case for a signaling protocol to establish a call.

Figure 9. Conformance Test Example: Call Establishment



Interoperability Testing

Interoperability testing must be performed to ensure that products from multiple vendors will function properly together in a network. With ATM specifications being constantly updated to meet the increasing demands of users, interoperability testing is the most critical phase of ATM system verification.

Performance Testing

Performance testing provides essential measurement criteria for evaluating ATM switch operation. Conformance verification alone does not guarantee that the same equipment will operate satisfactorily under all anticipated network conditions.

Testing Challenges

There are three main reasons why ATM technology is currently very difficult to test:

- **ATM is an emerging technology**—Products are being developed based on specifications that may have been drafted based only on theoretical projections. As actual working models are produced, the specifications must be modified to match the realities of contemporary production methods. It is expected to take a number of years before ATM reaches a stable state comparable to today's local-area network (LAN) technology.

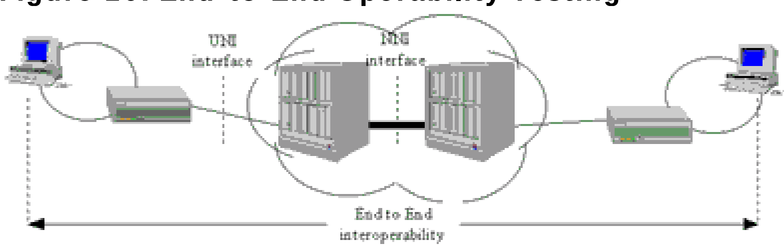
- **complexity of the standards and specifications**—The concept of ATM appears relatively simple: a protocol designed to provide high data throughput at negotiated rates (services). The primary function of an ATM switch is to receive a 53-byte (ATM) cell on an input port and then retransmit the same cell on a second port based on the VPI and the VCI. The high degree of complexity is introduced from the numerous control protocols required to set up and maintain these VPI/VCI pairs. Many interoperability problems are caused by timing relationships between these signaling protocols. Another factor is support for multiple priority levels for different traffic types based on service classes (i.e., UBR or ABR).

- **optional parameters**—Since ATM has widespread appeal for many diverse traffic types and applications, the specifications contain many optional parameters. If switches are connected together which support different optional features, they may have problems working together despite the fact they both pass complete conformance tests.

Migration of the Standards

Interoperability testing is critical for ATM because of this extensive migration of the standards (see *Figure 10*). The perceived slow pace of activities at the international standards bodies (i.e., International Telecommunications Union–Telecommunications Standardization Sector [ITU–T]) has prompted companies anxious to develop cutting-edge ATM products to create the ATM Forum. The purpose of the ATM Forum is to expedite development and deployment of ATM products and services. The ATM Forum has developed an aggressive schedule for the rapid development of ATM specifications (not standards) based on a two-thirds (members) majority rule for approval. These specifications are often treated as de facto standards even though all issues are not yet resolved.

Figure 10. End-to-End Operability Testing



However, the ATM Forum is not a standards body—it only issues specifications. These specifications are supplied both for implementing products and to influence the ITU–T. The ITU–T is under no obligation to implement standards that are compatible with any specification issued by the ATM Forum. The migration of user network interface (UNI) 3.0 signaling to UNI 3.1 is one example where the specifications were not made backwards compatible (i.e., UNI 3.0 equipment will not interoperate with UNI 3.1 equipment).

Summary

1. Conformance testing provides assurance that the product adheres to the specifications.

2. Interoperability testing verifies that the product will function when installed in a network.

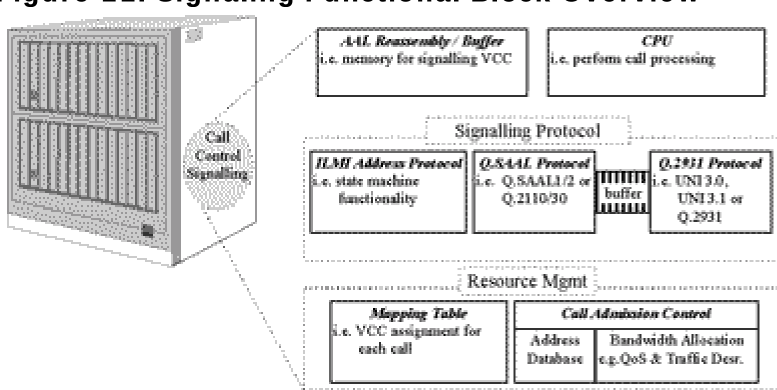
3. Performance testing provides a benchmark of product efficiency.

3. Signaling over ATM

The critical requirement for wide deployment of ATM networking equipment is the ability to dynamically establish switched virtual circuits (SVCs). It is impossible to support the growing number of users with the current method of cross-connecting using permanent virtual circuits (PVCs).

The function of establishing SVCs across an ATM network is called signaling. To fully test the signaling features utilized in an ATM switch, both the signaling equipment and the network over which the equipment will operate should be tested together (see *Figure 11*).

Figure 11. Signaling Functional Block Overview



The signaling function of an ATM switch includes establishing, maintaining, and clearing VCs. These switch operations must conform to the industry standards for network signaling. When the signaling equipment is part of a network, the signaling equipment and the network over which the equipment will operate must both be certified to the same operating specifications.

Conformance testing involves applying a series of predefined tests to the equipment based on the matching specification. These tests are generally applied under ideal conditions and are intended to demonstrate conformance (of supported function) to the detailed specification. Conformance tests usually verify only the base (minimum) set of functions for the equipment and do not include any dynamic stress test or error recovery or demonstrate interoperability of the equipment.

Interoperability

Interoperability testing verifies compatibility between two or more products intended to function in a network environment. With many differences in features and supported functions in vendor's products, it is difficult to develop general specifications for interoperability testing.

Interoperability testing procedures are designed to exercise a specific set of signaling functions across a network of two or more switches. Two key areas to be tested are QoS–based routing and the scalability (i.e., reachability information). Interoperability testing should be performed for all signaling protocols to be used with the equipment.

The private network-network interface (PNNI) signaling protocol provides a particular challenge for interoperability testing. The routing components, adopted from existing packet routing protocols (i.e., used on the Internet) are the most complex routing protocols in current use. Specifically, portions of the PNNI signaling protocol using the ATM routing and signaling combinations should be tested.

Signaling Performance Testing

When assessing ATM switch performance, or the ability of a network to transfer cells, most switch vendors and network designers focus on the cell relay component (i.e., switch fabric and cell transmission rate). Most ATM interworking protocols rely implicitly on the use of signaling to establish SVCs that will be used to transfer data between users. Signaling performance is a measurement of the efficiency of this function.

The ability to transfer data through an ATM network is restricted by the following:

- the rate at which SVC connections can be set up through an ATM switch
- the aggregate latency for an SVC connection setup request to be propagated through a network

In many ATM transactions, the amount of time to establish the SVC connection may be many times greater than the time to transfer the data. It is important that signaling performance be measured to establish operational benchmarks.

The methods for measuring signaling performance are influenced by the architectural design of the ATM switch. Switch design issues that effect signaling protocol performance include the following:

- processor type
- depth of memory to buffer signaling messages
- sharing processor(s) between multiple ports
- structured design of the signaling software

Performance Testing is Necessary

The operating characteristics and the function of an ATM switch during signaling operations often varies widely for different manufacturers and models. These variations in performance can be the result of choices in the following:

- **architecture (hardware)—**the operating characteristics of the switch change under different loading conditions depending on the switch architecture (cell relay components) and type of microprocessor(s)

- **programming (software)—**The signaling operations of switches are usually performed under software control.

Testing routines should include point-to-point and point-to-multipoint calls as well as support for all signaling protocols used. Automated signaling performance testing is preferred for maintaining consistent testing methodology and results. This benchmark provides a relative measurement, not a pass and fail result (as with conformance testing).

Signaling Performance Analysis

Performance testing establishes benchmarks by measuring the operational characteristics of the signaling protocol state machine under different loading conditions. Signaling performance testing measurements and analysis should focus on four main areas:

1. **latency**—Latency measurements establish the processing time required for signaling messages to be processed (e.g., set up) through the switch. Varying the call-loading rate applied to the switch allows measurements to be taken under a variety of conditions. These signaling functions exercised should include processing of the following:

    - setup messages

    - connect messages

    - release messages

2. **burst**—These tests focus on measuring the time required to establish a number of calls. Network managers must know how long it will take to establish a burst of calls when networks are initialized or during cut-over periods (i.e., after catastrophic failure). This testing focuses on measuring the amount of time needed to establish a number of calls. A

specific number of calls are transmitting to the system under test during a limited period of time. The amount of time to release a number of calls can also be analyzed. Short-term burst analysis is not sufficient to confirm full functional operation of a switch signaling performance. Switch performance tends to degrade over time for the following reasons:

- **memory fragmentation**—As blocks of memory are reserved and then released there is a resulting loss of contiguous free space. This can have a severe impact on performance.

- **status message traffic**—Although status messages only constitute low bandwidth traffic they affect overall performance for the following reasons: status messages are continually being transmitted and received; they require high priority processing; and processing of messages may require or result in rescheduling or retransmission of data messages.

- **protocol complexity**—The signaling protocol requires a significant amount of processing to maintain databases for tracking message transaction information.

Delays in switch operations above may result in increased buffering of new signaling messages. Increased buffering may cause overflow (message loss) of the call queue resulting in message retransmission that will increase the switch loading levels.

3. **throughput**—Signaling performance testing must include long-term conditions to identify the effects of large number of network calls being established and then released.

4. **limits**—identifies the maximum ranges of settings supported by the switch; as an example, tests could include determining the maximum number of concurrent point-to-point calls that a device under test can establish and actively maintain

4. Automated Testing

To ensure the highest quality product, complete system verification must be performed many times before a product can be released to manufacturing for delivery to customers. Quality assurance teams must quickly detect the existence of any problems and ensure that corrective measures are taken. The efficiency of this process can have a dramatic influence on time to market.

The increasing complexity of communications standards (i.e., ATM service classes) now greatly exceeds the capacity for manually performing comprehensive product and systems testing. New testing standards are published on a regular basis, and only the most experienced ATM designers and software engineers are capable of conducting these tests and correctly interpreting the results.

Drawbacks to Manual Testing

The traditional method of question-and-answer (QA) testing is for a team to manually verify each step of an approved step-by-step test procedure. This method of manual testing is insufficient for the following reasons:

- The best resources in a corporation should be responsible for the product quality. However, these same resources are typically also required for product design and development and troubleshooting complex problems that are detected during testing.

- Regression test phases must be efficient to quickly discover any problems to be fixed and retested before release. Each testing cycle for complex test phases manually may take weeks or more—introducing a corresponding delay in the final product release date.

- Each regression test phase must retest all product functions—not just those functions identified to have been affected by the most recent product software and hardware modifications. Quality assurance groups may reduce the scope of testing in later phases to reduce the time required for testing. Reduced testing results in missed defects and lower product quality.

- Testing technicians become distracted while repeating the same actions many times during successive test phases. This results in missed defects and lower product quality.

- Testing technicians and test authors understand what input is logical and will perform tests accordingly. These actions will miss many defects caused by illogical input that will be entered by mistake or by less knowledgeable users.

Automated Testing Solutions

Automated testing offers solutions to these and other problems:

- Automated test suites operate with minimum manual intervention, allowing expert resources time to build test procedures that verify all necessary functions that the product should perform.

- Automated tests are proven to reduce the time required for testing. New tools are constantly being introduced to author and manage automated test platforms.

- Once an automated test suite is written, the entire test cycle can be repeated in a fraction of the time required for manual testing. This will ensure that important tests are not skipped due to time constraints.

- Automated tests run every test—every time—in a predictable manner. Automated tests do not become distracted or inconsistent.

- Automated tests can be programmed to test using inconsistent/illogical input values or selection sequences triggering the system error conditions. This will test the operator-tolerance level of the system.

The prime advantages for product developers using automated testing is that it becomes practical to develop and perform adequate and accurate regression testing throughout the entire product development phase.

5. Testing Deployment of ATM Services

As ATM technology matures, turnkey ATM solutions will be required to meet the growing demands of a global telecommunications marketplace. The testing requirements to support this increased level of deployment will soon exceed the supply of experienced ATM technicians. What options will companies have to meet these needs?

The first step is an analysis of the testing requirements for deployment of ATM equipment and services.

Testing Requirements

The activities of ATM test technicians are quite different from those in a research laboratory. In system deployment testing, the fundamental precept is that the system should work as installed. This axiom is based on the assumption that comprehensive product tests (conformance, interoperability, and performance) have been performed by the equipment manufacturers. With new ATM technology, there is an area of uncertainty about product behavior.

The field deployment sector has a specific set of functions to perform. This includes the following:

- deployment of physical medium and equipment to construct a defined network configuration

- performing adequate testing to guarantee that the specified level of services are available

ATM field technicians are generally working with a defined set of parameters, and the system being installed is designed to operate within these boundaries. Deployment testing is primarily a methodology to isolate and correct faults. This involves the following primary areas:

- **connectivity (network architecture and interconnection)—**A large percentage of the problems encountered during installation will be due to faults in the physical medium. Fortunately, the technology for testing physical layer connectivity in ATM compatible mediums (i.e., fiber-optic cable) is maturing more rapidly than the rate of ATM services, and a number of reliable products are available.

- **parameterization (setup/programming of equipment)—**Incorrect parameterization will typically account for over 90 percent of problems experienced by ATM technicians during network installation. This same percentage will probably also apply to the time to solve these problems. This will be due largely to the complexity of the ATM network architecture—with multiple protocol layers and levels of service—coupled with the relative inexperience of field technicians new to the area of ATM testing. During the early deployment phases, product manufacturers will be obliged to expend a large effort on product support to demonstrate that their products are performing as specified. This effort will also include adequate training service technicians and system users new to ATM technology.

- **equipment failure (damaged or defective components)—**In mature technologies (i.e., LAN or wide-area network [WAN]), it is now relatively easy to identify the symptoms of various hardware failures. In new ATM technology, there are many issues, including conformance and interoperability, that will not have been fully explored during the production phase. This will make it difficult to identify defective components within large complex equipment such as ATM switches.

Testing Solutions

ATM is more dynamic than any previous technology. There is no method to sit on a fault channel—VCs are established, used, and cleared within milliseconds. Single VCCs may simultaneously carry multiple protocol signals.

The key to reliable product deployment is to transfer testing knowledge from the experienced ATM designers to technicians and field engineers. The most effective tools available to address the deployment sector are automated test suites designed to measure and analyze activity between network devices. These tests transfer the application knowledge of engineers specialized in each area of ATM development by leading the test technician through the most logical methodology to test and verify system operation (i.e., physical layer tests first, then specific ATM adaptation layer [AAL] tests, etc.) Test data can be recorded, correlated, and significant results displayed in a manner to present obvious courses of action to the tester.

6. LANE over ATM

The Issues

Testing LAN interconnections over ATM continues to provide many difficulties. These problems are the result of a number of contributing factors including:

- **multiple product specifications**—the ATM Forum, Internet Engineering Task Force (IETF), and a number of networking companies (including Cisco, IBM, 3Com, and Ipsilon) have each proposed different models for LANE, multiprotocol over ATM (MPOA), Classical Internet protocol (IP), and additional variations based on the concepts of intelligent switching.

- **protocol decoding**—ATM is primarily a transport level protocol. To provide a communications link between two (2) existing LAN systems, all of the native protocols must be encapsulated before transmission over the ATM portion of the network. When monitoring an ATM network, it is often necessary to detect protocol encapsulations prior to performing protocol decoding.

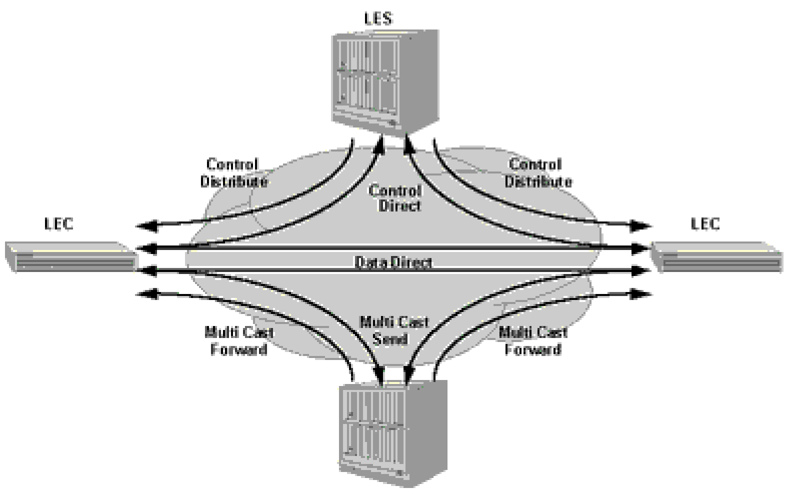
Encapsulation standards are the rules observed by networking equipment to insert and extract the protocol information for any payload portion of any packet. Each encapsulation method describes the location within the packet (at what offset) of the unique identifier to specify the higher layer protocol (i.e., IP or Internet packet exchange [IPX]).

The use of protocol encapsulation process requires prior agreement between any end-systems involved in communication. Most protocol encapsulation methods do not directly identify the encapsulation method or the identity of the encapsulated protocol.

- **multiple encapsulations**—The use of multiple encapsulations is one of the most common causes of networking problems on LANs. The use of multiple encapsulations is relatively common in both LAN and WAN networks. Router vendors have developed products supporting both standards-based and proprietary WAN encapsulations. The proprietary versions are often driven by the need for efficient use of bandwidth while standards-based solutions trade off efficiency for multivendor compatibility.

- **calls for standardization**—To promote compatibility for LAN over ATM the IETF's request for comment (RFC) 1490 (supersedes RFC 1294) recommends encapsulation be used for LAN data over a frame relay transport.

Figure 12. Typical LANE Network Architecture



The need for a common encapsulation for LAN traffic over ATM was recognized very early. IETF's RFC 1483 requested methods of encapsulating network interconnect traffic within an ATM adaptation Layer 5 (AAL5) protocol data unit (PDU). RFC 1483, published to define the recommended encapsulation, included six possible methods and resulted in introducing additional incompatibilities between devices that are 1483 compliant.

The six methods fall under two categories described as listed:

- **logical link control (LLC) encapsulation**—allows multiplexing of multiple protocols over a single VCC using 802.2 LLC/SNAP as the identifying prefix

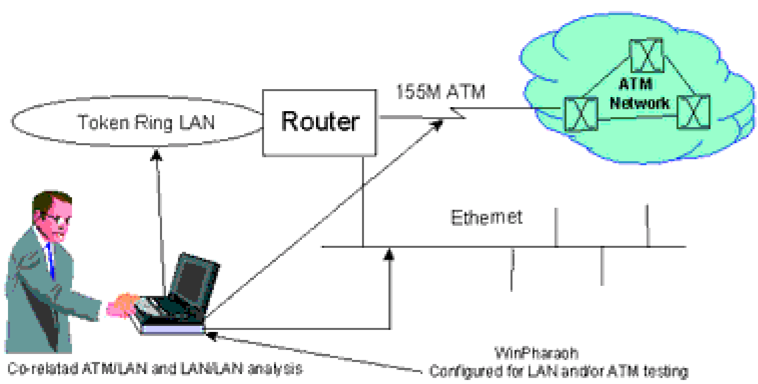
- **VC–based multiplexing**—implicitly defines a one-to-one protocol to VCC mapping

Will One Encapsulation Dominate?

Although it appears that standards are converging on LLC encapsulation, LANE v1.0 remains the most common implementation of LAN interconnect over ATM. Other popular methods include:

- LANE v1.0 uses the VC multiplexing bridged Ethernet/802.3 (for Ethernet LANs) or bridged 802.4/5/ fiber distributed data interface (FDDI) (for token-ring and FDDI LANs; see *Figure 13*).
- LANE v2.0 has specified the use of LLC encapsulation.
- RFC 1577 (classical IP over ATM) also uses the LLC encapsulation as does the MPOA specification.

Figure 13. Testing LAN of ATM



The ATM Forum has, to date, produced three separate specifications:

- LANE v1.0
- LANE v2.0
- MPOA

The IETF has published RFC1577, dealing specifically with transmission control protocol (TCP)/IP traffic. Most switch vendors today provide support for both LANE v1.0 and classical IP.

Many companies have recognized limitations in these standards (increased complexity and falling performance) and have responded by proposing their own proprietary solutions.

IETF—Next Hop Resolution Protocol

IETF's next hop resolution protocol (NHRP) was developed during an ATM Forum joint LANE/MPOA working group session. The LANE working group included support for the NHRP as a routing protocol in the LANE v2.0 specification. This feature enables users to employ short circuit direct VCC inter-emulated LAN (ELAN) connectivity similar to MPOA.

IBM—Multiprotocol Switched Services (MSS)

IBM adopted a modified version of LANE v1.0 with its announcement of MSS. This extends the LANE V1.0 specification by adding broadcast containment and allows LANE–based systems to route traffic based on the IETF's NHRP.

Ipsilon Networks—IP Switching

Ipsilon Networks was founded to promote a new standard called IP switching. This solution offers a proprietary hardware and software alternative to the use of UNI 3.1/4.0 signaling protocols. IP switching has demonstrated higher throughput levels at reduced cost and level of complexity. This technology, submitted to the IETF as RFC 1953/1954, is gaining market acceptance by the communications industry (i.e., FORE, GDC, Digital, and Ericcson).

Tag Switching

Cisco has also proposed a protocol switching method known as tag switching. This tag distribution protocol (TDP) has been submitted to the IETF as an RFC for adoption as a standard. TDP works by having edge devices numerically tag frames or cells based on routing table information. Once tagged, traffic is forwarded through the network solely on the basis of the tag rather than the more time-consuming route table look-up.

RFC 1577 Classical IP over ATM

IETF's RFC 1577 recommends an architecture for operating classical IP networks over an ATM transport. This RFC defines the operation and components (i.e., ATMARP server) and references the LLC method of encapsulation from RFC 1483 as the frame format to be used.

7. Summary

Advances in ATM technology provide the opportunity to create a global infrastructure providing high-speed data transmission integrated with voice and video services. To achieve this goal many new protocol specifications and standards have been developed to route data, emulate connectionless media, interwork ATM with existing LAN and WAN technologies, and guarantee the quality of service delivered across ATM backbones.

Construction of these large, scalable ATM networks presents a major challenge to ATM equipment developers, service providers, and end-users. Testing of ATM products must be performed in multiple stages:

- conformance verification (to specifications and standards)
- interoperability testing (match to other vendors' equipment)
- performance measurement (adequate throughput)

To adequately perform these types of tests on ATM equipment, the test engineers must use test equipment having the capability to do the following:

- analyze protocols on all seven layers of the protocol stack
- correlate data across ATM interworking boundaries (LAN–ATM, WAN–ATM)
- test all ATM service categories (i.e., ABR, UBR, etc.)
- QoS
- support complete automation of the test process

The complexity of ATM products will continue to increase as more networks are installed and additional services are introduced. For this reason, automation supporting all aspects of ATM testing is crucial for existing and future test equipment. Only automated test suites are capable of performing the variety and quantity of sophisticated testing sequences required to stress the operating limits of large high-speed ATM systems. These automated test suites will assist all classes of users to pinpoint ATM conformance and interoperability problems in addition to benchmarking and characterizing devices.

Self-Test

1. Conformance verification, interoperability testing, and performance benchmarking are the three primary testing phases required for complete evaluation of ATM products.

    a. true

    b. false

2. Cell delay can also be referred to as jitter.

    a. true

    b. false

3. One of the major ATM layer functions of an ATM switch is to perform ABR/UBR translation.

    a. true

    b. false

4. Testing of the ATM layer requires an ATM analyzer capable of generating ATM traffic and then monitoring the same traffic to make specific measurements.

    a. true

    b. false

5. The fact that ATM is still an emerging technology is one reason why it is a difficult technology to test.

    a. true

    b. false

6. _________________ testing must be performed to verify that new ATM equipment works according to a given standard or specification.

    a. Performance

    b. Conformance

    c. Interoperability

    d. Automated

7. __________________ testing verifies compatibility between two or more products in a network environment.

   a. Performance

   b. Conformance

   c. Interoperability

   d. Automated

8. __________________ testing provides a benchmark of product efficiency.

   a. Performance

   b. Conformance

   c. Interoperability

   d. Automated

9. This forum issues specifications in ATM testing.

   a. Frame Relay Forum

   b. ATM Forum

   c. The Network Professional Association Forum

   d. The One and Only Forum

10. The critical requirement for wide area deployment of ATM networking equipment is the ability to dynamically establish which of the following?

    a. SVCs

    b. ABR

    c. PVCs

    d. VBR

11. ___________________ measurements establish the processing time required for signaling messages to be processed.

    a. Burst

    b. Throughput

c. Limits

d. Latency

12. What testing method will ensure that a product of the highest quality will be manufactured?

    a. manual testing

    b. automated testing

    c. no testing

    d. all of the above

13. Which of the following is a drawback to manual testing?

    a. Repetitive, monotonous testing may lead engineers to make mistakes when performing certain tests.

    b. A corporation may have to utilize its best resources on testing when time could be better spent on design and development of new products.

    c. Increasing complexity of new standards greatly exceeds the capacity for manual testing.

    d. all the above

14. In order to provide a communications link between two existing LAN systems, all of the native protocols must be __________________ before transmission over the ATM portion of the network.

    a. formatted

    b. placed in packets

    c. encapsulated

    d. placed in cells

15. The most effective tools available to technicians responsible for the deployment of ATM are:

    a. automated test suites

    b. screw drivers

    c. hammers

d. pliers

Correct Answers

1. Conformance verification, interoperability testing, and performance benchmarking are the three primary testing phases required for complete evaluation of ATM products.

    a. true

    b. false

    See Definition and Overview.

2. Cell delay can also be referred to as jitter.

    a. true

    b. false

    See Topic 1.

3. One of the major ATM layer functions of an ATM switch is to perform ABR/UBR translation.

    a. true

    b. false

    See Topic 1.

4. Testing of the ATM layer requires an ATM analyzer capable of generating ATM traffic and then monitoring the same traffic to make specific measurements.

    a. true

    b. false

    See Topic 1.

5. The fact that ATM is still an emerging technology is one reason why it is a difficult technology to test.

    a. true

    b. false

See Topic 2.

6. _________________ testing must be performed to verify that new ATM equipment works according to a given standard or specification.

    a. Performance

    b. Conformance

    c. Interoperability

    d. Automated

    See Topic 2.

7. __________________ testing verifies compatibility between two or more products in a network environment.

    a. Performance

    b. Conformance

    c. Interoperability

    d. Automated

    See Topic 2.

8. __________________ testing provides a benchmark of product efficiency.

    a. Performance

    b. Conformance

    c. Interoperability

    d. Automated

    See Topic 2.

9. This forum issues specifications in ATM testing.

    a. Frame Relay Forum

    b. ATM Forum

    c. The Network Professional Association Forum

    d. The One and Only Forum

See Topic 2.

10. The critical requirement for wide area deployment of ATM networking equipment is the ability to dynamically establish which of the following?

    a. SVCs

    b. ABR

    c. PVCs

    d. VBR

    See Topic 3.

11. ___________________ measurements establish the processing time required for signaling messages to be processed.

    a. Burst

    b. Throughput

    c. Limits

    d. Latency

    See Topic 3.

12. What testing method will ensure that a product of the highest quality will be manufactured?

    a. manual testing

    b. automated testing

    c. no testing

    d. all of the above

    See Topic 4.

13. Which of the following is a drawback to manual testing?

    a. Repetitive, monotonous testing may lead engineers to make mistakes when performing certain tests.

    b. A corporation may have to utilize its best resources on testing when time could be better spent on design and development of new products.

c. Increasing complexity of new standards greatly exceeds the capacity for manual testing.

d. all the above

See Topic 4.

14. In order to provide a communications link between two existing LAN systems, all of the native protocols must be __________________ before transmission over the ATM portion of the network.

    a. formatted

    b. placed in packets

    c. encapsulated

    d. placed in cells

    See Topic 6.

15. The most effective tools available to technicians responsible for the deployment of ATM are _____________.

    a. automated test suites

    b. screw drivers

    c. hammers

    d. pliers

    See Topic 5.

Glossary

AAL
ATM adaption layer

ABR
available bit rate

ATM
asynchronous transfer mode

CDV
cell delay variation

CDVT
CDV tolerance

CER
cell error ratio

CLR
cell loss ratio

CMR
cell misinsertion rate

CTD
cell transfer delay

FDDI
fiber distributed data interface

GRCA
general cell rate algorithm

IETF
Internet Engineering Task Force

IP
Internet protocol

IPX
Internet package exchange

ITU–T
International Telecommunications Union–Telecommunications Standardization Sector

LAN
local-area network

LLC
logical link control

MPOA
multiprotocol over ATM

NHRP
next hop resolution protocol

OAM
operation and maintenance

PDU
protocol data unit

peak-to-peak CDV
peak-to-peak cell delay variation

PNNI
private network-network interface

PRBS
pseudo-random bit stream

PVC
permanent virtual circuit

QoS
quality of service

SVC
switched virtual circuit

TCP
transmission control protocol

TDP
tag distribution protocol

UBR
unspecified bit rate

UNI
user network interface

UPC
usage parameter control

VBR
variable bit rate

VC
virtual connection

VCC
virtual channel connection

VCI
virtual channel identifier

VPI
virtual path identifier

WAN
wide-area network