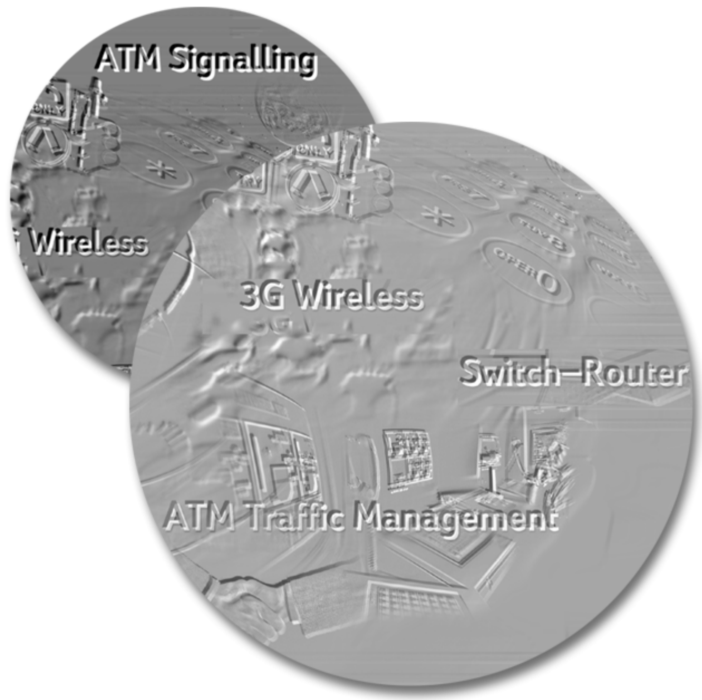
ATM Switch Characterization Test Plan



This test plan suggests test cases for categorizing ATM switch functionality and performance using the Agilent E4200/E4210 Broadband Series Test System (BSTS).

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Agilent Broadband Series Test System

The BSTS is a modular UNIX-based test system. Flexible architecture allows you to start with a basic, cost-effective configuration. The line interfaces test the physical, convergence and ATM layers. Adding the Agilent E4209B Cell Protocol Processor (CPP), allows ATM and AAL layers to be tested in real-time. You can add higher layer protocol test software, such as ILMI, and UNI signaling emulation, and the tester will behave as an active device in the network.

- Specialized test modules for ATM traffic management testing are also available:
- The E1607A/1609A ATM stream processors brings real-time QoS traffic management test capabilities to the BSTS.
- The E6270A OAM Protocol Test module provides real-time in-service and out-of-service testing and emulation capabilities for all aspects of OAM.
- The E6287A ABR Emulator Module is a dedicated module for testing functional ABR compliance of ATM switches
- The E4219A Network Impairment Emulator generates real-world network impairments.

There are two base systems to choose from. The Agilent E4210B Form-13 mainframe is a rack mounted chassis with 11 open slots for modules. The Agilent E4200B Form-7 transportable base, with 5 open slots and a built-in monitor and keyboard is ideal for field trials. Agilent BSTS modules and software applications are the same for both systems.

X-windows networking via TCP/IP at the Ethernet port is supported, which means that you can use the BSTS to solve problems remotely, or multiple users can share the same BSTS.

You can use the C function libraries or the TCL Tool Kit to build customized test scripts. This makes it simple to perform repeatable tests during regression testing, system verification, or manufacturing testing.

Introduction

This test plan suggests test cases for categorizing ATM switch functionality and performance using the Agilent Broadband Series Test System. The test plan captures an in-depth understanding of ATM traffic specifications and test methods. Network equipment manufacturers and Service Providers new to ATM testing can use the test plan as a starting point and guide to what needs to be tested, as well as how to test it. Experienced test engineers can also use this test plan to augment existing test suites.

Accompanying test software that automates the test plan is readily available for the BSTS. The software can be used "as is" to implement all the test cases specified in this test plan. Engineers can go beyond the test cases specified in this test plan by modifying test parameters like number of ports, channels, bandwidths, background loading, and error injection. This allows test engineers to immediately start testing without having to invest weeks of development time required to automate the test plan.

The industry-standard Agilent BSTS is a modular system, available in two models to suit your needs — the E4200B transportable chassis and the E4210B mainframe chassis.

Test Plan Overview

The test plan is divided into nine test groups representing 36 test cases.

1. GCRA (1 test case)
2. CBR Throughput (8 test cases)
3. VBR Throughput (11 test cases)
4. Port Fairness (1 test case)
5. Port Starvation (2 tests cases)
6. Cell Loss Priority (2 test cases)
7. Tail Packet Discard (1 test case)
8. Multicast Throughput (8 test cases)
9. Head of Line Blocking (2 test cases)

Definitions

No drop throughput - The maximum rate at which no cells are dropped by the DUT.

Peak throughput - The maximum rate at which the DUT operates, regardless of cells dropped.

Full-load throughput - The rate at which the DUT operates when input ports are at 100% loading.

Note: In the case where all links operate at full line rate under all conditions, with no lost cells, then:
No drop throughput = Peak throughput = Full-load throughput

Equipment Requirements

The minimum configuration for the ATM Switch Characterization Test Plan is a single port system comprising:

- Agilent E4210B Broadband Series Test System Form-13 Mainframe Base (or Form-7)
- One CPP/LIF pair for bi-directional traffic generation and monitoring

A CPP/LIF pair consists of:

- Agilent E4209B Cell Protocol Processor (CPP) Module
- Agilent E1697A OC-3/STM-1 Line Interface Module

This system configuration will only permit a subset of the test cases to be implemented. Multi-port test cases will require multiple CPP/LIF pairs.

Version 1.0 of the accompanying automated test software provides a full implementation of the test plan. Equipment requirements are:

- Agilent E4210B Broadband Series Test System Form-13 Mainframe Base
- Four CPP/LIF pairs
- Agilent E1696A Optical Load Generator (OLG)

Note: The optical load generator has been used to provide multi-port background load generation. Background loading can also be implemented via existing CPP/LIF pairs, though this is not supported in the current version of the automated test software.

The test case matrix below details equipment requirements for each test case.

		1 CPP/LIF	2 CPP/LIF	3 CPP/LIF *	4 CPP/LIF *	3 CPP/LIF + OLG *	4 CPP/LIF + OLG *
Test Group 1: GCRA Baseline	1.1				✓		
Test Group 2: CBR Throughput	2.1	✓					
	2.2				✓		
	2.3						✓
	2.4						✓
	2.5						✓
	2.6						✓
	2.7						✓
	2.8						✓
Test Group 3: VBR Throughput	3.1	✓					
	3.2					✓	
	3.3						✓
	3.4				✓		
	3.5						✓
	3.6				✓		
	3.7						✓
	3.8						✓
	3.9						✓
	3.10						✓
	3.11						✓
Test Group 4: Port Fairness	4.1					✓	
Test Group 5: Port Starvation	5.1			✓			
	5.2					✓	
Test Group 6: Cell Loss Priority	6.1						✓
	6.2						✓
Test Group 7: Tail Packet Discard	7.1					✓	
Test Group 8: Multicast Throughput	8.1				✓		
	8.2				✓		
	8.3						✓
	8.4						✓
	8.5				✓		
	8.6				✓		
	8.7						✓
	8.8						✓
Test Group 9: Head of Line Blocking	9.1		✓				
	9.2		✓				

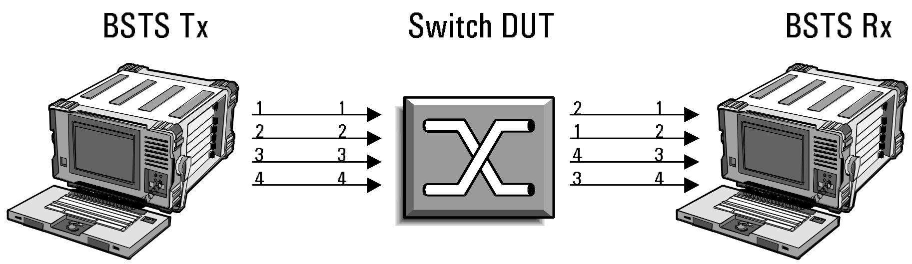
* Applicable for the Agilent E4210 only

Test Group 1 GCRA

Test Purpose

To validate the policing function of an ATM switch by generating VBR traffic and measuring conformance with the policer both enabled and then disabled.

Test Configuration



Test matrix

	BSTS	ATM Switch (Input)	Results (Non-conforming cell ratio)
Traffic Shaping	OFF (Ports1)	OFF (Ports1)	Same as BSTS
	ON (Ports 2)	OFF (Ports 2)	0
	OFF (Ports 3)	ON (Ports 3)	0
	ON (Ports 4)	ON (Ports 4)	0

ATM switch configuration

- Configure VBR PVCs from each of the input ports to a single output port (1-2, 2-1, 3-4, 4-3).
- Optimize the buffer queue size on the output ports for VBR traffic.
- Turn on GCRA on ports 3 and 4 on the ATM switch.

BSTS configuration:

- Build upc test cells with the appropriate VPI/VCI on port 1.
- Build upc test cells with the appropriate VPI/VCI on port 2.
- Build upc test cells with the appropriate VPI/VCI on port 3.
- Build upc test cells with the appropriate VPI/VCI on port 4.
- Configure the BSTS to analyze traffic on port 1,2,3 and 4.
- Enable traffic shaping on BSTS transmitting ports 2 and 4 and traffic shaping off on transmitting ports 1 and 3.

Test 1.1 GCRA baseline

Test Purpose

To characterize an ATM switch's GCRA capability.

Methodology

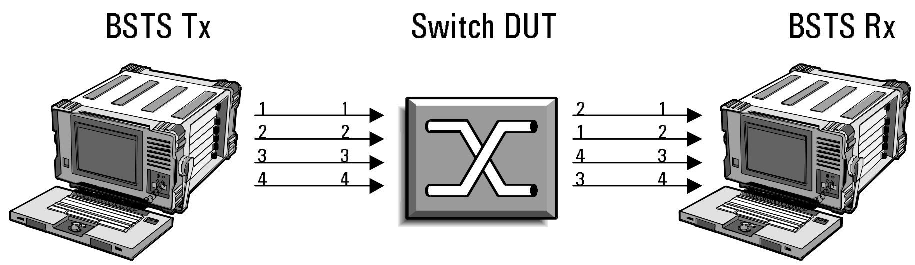
1. Configure traffic stream 1 with UPC test cells encoded with the appropriate options on all ports, including VPI/VCI.
2. Select a stream distribution (Constant, Sawtooth, Bursty, GCRA or Poisson).
3. Enter valid GCRA parameters on the traffic-shaping menu.
4. Disable traffic shaping on port 1 and 3 and enable traffic shaping on ports 2 and 4.
5. Log the Non-Conforming cell ratio on each port.
6. Enable background traffic loading.
7. Enable cell generation on all input ports at 50% line rate for 5 minutes.
8. Measure and log the total of cells to be transmitted in these 5minutes. Denote this measurement as value "X".
9. Capture data every 1-minute on all the receivers.
10. Measure and log the GCRA parameters for each receiving port on the analyzer.
11. Measure and log the UPC measurements for each receiving port on the analyzer. Expected Result: The Non-Conforming cell ratio should be zero for all cases where the shaping was turned on either on the tester or on the DUT. It should also be equal to the Non-Conforming cell ratio calculated by the tester for the case when traffic shaping is turned off both on the tester and the DUT.
12. Measure and log the total cells received in the 5 minutes (real time measurement). Denote this measurement as value "Y".
13. Measure and log the total cell loss = X - Y.
14. Increase the input traffic rate by 5% until 100% line rate is reached and repeat the test.

Test Group 2 CBR Throughput

Test Purpose

To characterize an ATM switch's handling of CBR traffic under a variety of conditions by measuring throughput, cell loss, cell delay and cell delay variation.

Test Configuration



ATM switch configuration

- Configure a CBR PVC from the source ports to the destination ports.

BSTS Configuration

- Configure test cells with the appropriate VPIs/VCIs.
- Configure the BSTS receive ports to monitor the cell latency for traffic on the appropriate VPIs/VCIs.

Test Methodology

The throughput of the ATM switch can be characterized by comparing the received test traffic to what was generated. By tuning generated percentage load against cell loss detected at the receive port, no drop, peak and full load throughput can be measured. Cell latency on the other hand, can be measured by calculating the difference in cell arrival and departure times from the destination and source ports respectively. To properly characterize the switch's CBR throughput behavior, the above measurements should be taken under a variety of load conditions.

These conditions could include:

- Multiple-ports
- Multiple-streams
- Varying background load
- Background load with errors

The following eight test cases are suggested.

Test 2.1 CBR throughput baseline

Test Purpose

Characterize CBR throughput behavior with a single VCC at 5% load. Measurements made include throughput, cell loss, cell delay and CDV, and provide a baseline for CBR Throughput.

Methodology

1. Configure one stream of the LIF traffic generator with a single VCC at 5% line rate. Use "timestamp data" as the payload to ensure that cell delay can be measured. Also use "AAL-1" encapsulation type so that cell loss can be detected.
2. Select the appropriate VCC such that the DUT switches the test stream from one input port to one output port.
3. Start the cell generator on the input port and enable the receive monitor on the output port.
4. Enable statistics on the LIF to monitor cell loss.
5. Observe and log the following:
   - cell loss
   - cell delay and
   - cell delay variation

Test 2.2 Multi-port (up to 4x4) CBR throughput

Test Purpose

Characterize CBR throughput behavior for multi-port configuration while sweeping from 80%-100% input load. Measurements made include throughput, cell loss, cell delay and CDV.

Methodology

1. Configure traffic generation and receive monitors for all 4 input and corresponding output ports. Specify traffic profiles at 80% of the line rate across each PVC.
2. Log the traffic rate.
3. Measure and log the following:
   - cell loss
   - cell delay
   - cell delay variation.
4. If there cell loss is detected, decrease the traffic by 5% and repeat the test.
5. If there no cell loss is detected, increase the traffic by 1% and repeat the test.

6. Log the traffic rate.
7. Measure and log the no drop throughput and the corresponding cell delay and cell delay variation.
8. Increase the load by 1% and measure the throughput of the switch until 100% of the load is reached.
9. Log the traffic rate.
10. Measure and log the following:
    - peak throughput,
    - full-load throughput
    - the cell loss ratio at full-load
    - the corresponding cell delay and
    - the corresponding cell delay variation.

Test 2.3 Constant background load

Test Purpose

Characterize CBR throughput behavior for a multi-port configuration while sweeping from 80%-100% input load with additional constant background loading. Measurements made include throughput, cell loss, cell delay and CDV.

Methodology

1. Repeat Test 2.2 with 100% background traffic.

Test 2.4 Single VC and varying background load

Test Purpose

Characterize CBR throughput behavior for a multi-port switch configuration with a single stream at 100% line rate at each input port and varying background traffic load. Measurements made include cell loss, cell delay and CDV.

Methodology

1. Start the background traffic at 5% load.
2. Configure each of the input ports to generate a single stream of traffic at 100% load. Ensure that each stream of traffic is destined to a single (unique) output port.
3. Configure the receive monitors at each of the output ports.
4. Observe and log the following:
    - cell loss
    - cell delay
    - cell delay variation.

5. Increase the background load in increments of 5% until 100% background load is attained.
6. Log the traffic rate.
7. Observe and log the following:
   - cell loss
   - cell delay
   - cell delay variation.

Test 2.5 Multiple VCs (4) and constant background load

Test Purpose

Characterize CBR throughput behavior for a multi-port configuration with multiple (four) streams while sweeping from 80%-100% input load with additional constant background loading. Measurements made include throughput, cell loss, cell delay and CDV.

Methodology

1. Repeat Test 2.3 with four VCCs per port with constant background traffic.

Test 2.6 Multiple VCs (1024) and varying background load

Test Purpose

Characterize CBR throughput behavior for a multi-port switch configuration with many streams (1024), occupying 100% of the line rate at each input port and varying background traffic load. Measurements made include cell loss, cell delay and CDV.

Methodology

1. Repeat Test 2.4 with multiple (1024) virtual circuits per port with varying background traffic.

   (The 1024 VPI/VCI test for CBR traffic can be done using the UPC test cells as a special test case under VBR traffic throughput test).

Test 2.7 Errored test traffic (1-bit HEC error)

Test Purpose

Characterize CBR throughput behavior for a multi-port configuration with a single VCC while sweeping from 80%-100% input load. Simultaneously, additional constant background loading and 1-bit HEC error injection are enabled. Measurements made include throughput, cell loss, cell delay and CDV.

Methodology

1. Repeat Test 2.3 injecting 1 bit error in the HEC.

Test 2.8 Errored test traffic (2-bit HEC error)

Test Purpose

Characterize CBR throughput behavior for a multi-port configuration with a single VCC while sweeping from 80%-100% input load. Simultaneously, additional constant background loading and HEC error injection are enabled.

The output stream is corrupted by inserting a:

- 2-bit error in the HEC field for 50% of the traffic and
- 1-bit error in the HEC field for the remaining 50% of the traffic.

Measurements made include throughput, cell loss, cell delay and CDV.

Methodology

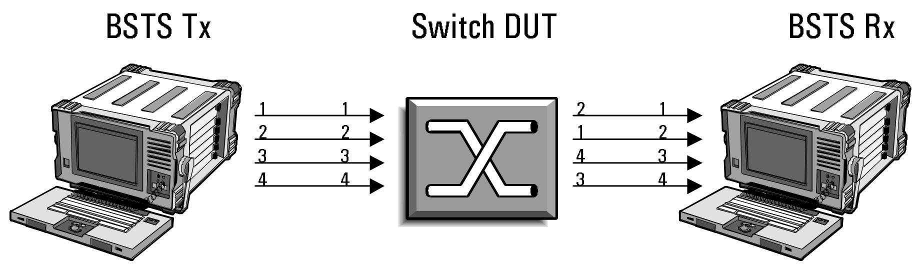
1. Repeat Test 2.3 injecting 2 bit error in the HEC for 50% of the traffic and 1 bit error in the HEC for the remaining 50% of the traffic.

Test Group 3 VBR Throughput

Test Purpose

To characterize an ATM switch's handling of VBR traffic under a variety of conditions by measuring throughput, cell loss, cell delay and cell delay variation.

Test Configuration



ATM Switch Configuration

- Configure VBR PVCs, which connect one input port to one output port (full duplex - NOT fully meshed).
- Configure the buffer queue size on the output port for VBR traffic.

BSTS Configuration

- Build ATM cells with the appropriate VPI/VCIs. The PDU sequence "correct" can be used for traffic on a single VPI/VCI. This sequence contains 8 AAL-1 PDUs, with correct sequence numbering from 0 through to 7. Loading the same sequence on different streams in the CPP traffic generator while encoding the ATM options with a unique VPI/VCI, can generate traffic on multiple VPI/VCIs.
- Define the traffic pattern for the PVCs configured on the DUT for full duplex operation.
- Configure the ports to generate and analyze traffic. Configure LIF statistics to measure cell loss in real-time.
- Configure optical load generators for background traffic.
- Duration for each iteration of traffic generation = 60 seconds.

Note:

The DUT typically contains many tens of ports. Since only 4 OC3 LIFs are available, the remaining ports from the DUT can be filled with traffic generated by the Agilent E1696A (4-port optical load generator).

Test Methodology

As with the CBR throughput test method, except now we deal with VBR traffic profiles.

Test 3.1 1x1 VBR throughput baseline

Test Purpose

Characterize VBR throughput behavior with a single VCC at 80% SCR load.

Measurements made include cell loss and throughput, which provide a baseline for VBR throughput.

Methodology

1. Generate a single stream at 80% line rate (PVC=SCR=80%), across a single PVC for a 1x1-switch configuration. Traffic is generated by the CPP, using different traffic profiles such as Poisson, Sawtooth, Burst etc. to generate VBR traffic with a sustained cell rate of 80% load. Send the pre-defined AAL-1 sequence "correct", containing 8 PDUs with sequence number 0 through 7.
2. Measure and log the following:
   - throughput of the switch,
   - cell loss (on the LIF) and
   - cell loss ratio (on the LIF).
3. If cell loss is detected, perform a capture using the CPP to test for cell mis-insertion. This requires the use of the "UPC Test Cells" sequences.
4. If there is cell loss, decrease the traffic by 5% and repeat the test.
5. If there is no cell loss, increase the traffic by 1% and repeat the test.
6. Measure and log the no drop throughput.
7. Increase the load by 1% and measure the throughput of the switch until 100% of the load is reached.
8. Measure and log the following:
   - peak throughput,
   - full-load throughput and
   - the cell loss ratio at full-load.

Test 3.2 Multi-port (up to 4x4) VBR throughput

Test Purpose

Characterize VBR throughput behavior with multiple VCCs originating from different ports. Real-time cell loss measurements are made.

Methodology

1. Configure a single PVC between each input and output port.
2. Transmit a valid AAL-1 sequence from each of the LIFs on a different VCC (the PDU sequence "correct" can be used).
3. Configure the receiver of each LIF to measure cell loss in real-time using statistics.

Test 3.3 Constant background load

Test Purpose

Characterize VBR throughput behavior with multiple VCCs originating from different ports and with additional background load. Real-time cell loss measurements are made.

Methodology

1. Repeat test 3.2 for multiple input ports and multiple output ports with background traffic.

Test 3.4 Multi-port meshed VCCs

Test Purpose

Characterize VBR throughput behavior with a meshed multi-port topology. Real-time cell loss measurements are made.

Methodology

1. For a 4x4 port configuration, configure each CPP/LIF pair to generate 4 VCC streams. This can be achieved by loading the PDU sequence "correct" and specifying a unique VPI/VCI value for each stream.
2. Monitor cell loss for each VPI/VCI. Each CPP/LIF will be receiving traffic on 4 different VPI/VCI combinations. This can be achieved by sequentially monitoring cell loss for a 20 second duration per each VPI/VCI.

Test 3.5 Multi-port meshed VCCs and background load

Test Purpose

Characterize VBR throughput behavior with a meshed multi-port topology with background loading. Real-time cell loss measurements are made.

Methodology

1. Repeat test 3.4 with background traffic and multiple PVCs between input and output port.

Test 3.6 Multi-port with AAL-3/4 and AAL-5 traffic bursts

Test Purpose

Characterize VBR throughput behavior with multiple VCCs originating from different ports with AAL-3/4, 5 frames. Measurements made include reassembled PDUs, errored PDUs and cell counts.

Methodology

1. Repeat Test 3.2 with an AAL-3/4 and then an AAL-5 test frame. The sequence should contain a range of valid frames ranging the min to max allowable sizes.
2. Generate a burst of AAL-5 traffic from the CPP.
3. Verify that the correct number of PDUs get through the switch using the statistics from the CPP:
   - Virtual Channel 1: Total AAL-5 PDUs
   - Virtual Channel 1: Total Cells
   - Virtual Channel 1: Total Errored AAL-5 PDUs
4. Generate a burst of AAL-3/4 traffic from the CPP
5. Verify that the correct number of PDUs get through the switch using the statistics from the CPP:
   - Virtual Channel 1: Reassembled PDUs
   - Virtual Channel 1: SAR Errored Cells
   - Virtual Channel 1: Total Cells
6. Measure and log the following (for both AAL types):
   - Frame Loss
   - Frame Loss Ratio = (Input frame count - output frame count)/(input frame count)

Test 3.7 AAL-3/4 and AAL-5 traffic bursts with background

Test Purpose

Characterize VBR throughput behavior with multiple VCCs originating from different ports with AAL4/3, 5 frames and additional background load. Measurements made include reassembled PDUs, errored PDUs and cell counts.

Methodology

1. Repeat Test 3.6 with background traffic.

Test 3.8 Errored test traffic (1-bit HEC error)

Test Purpose

Characterize VBR throughput behavior with multiple VCCs originating from different ports and with additional background load. Simultaneously enable 1-bit HEC error injection. Real-time cell loss measurements are made.

Methodology

1. Repeat Test 3.3 and corrupt the output stream ATM cells' HEC field with a 1-bit error.
2. Generate traffic using the PDU sequence "correct".
3. For each ATM cell, configure the error generator to insert a 1-bit error in the HEC field.

Test 3.9 Errored test traffic (2-bit HEC error)

Test Purpose

Characterize VBR throughput behavior with multiple VCCs originating from different ports and with additional background load. Simultaneously enable 2-bit HEC error injection. Real-time cell loss measurements are made.

Methodology

1. Repeat Test 3.3, but this time injecting 2-bit HEC error for 50% of the traffic and 1-bit HEC error for the remaining 50% of the traffic.
2. Generate traffic using the PDU sequence "correct".
3. Insert a 1-bit error in the HEC field for 50% of the ATM cells.
4. Insert a 2-bit error in the HEC field for the remaining ATM cells.

Test 3.10 Multi-port with varying traffic profiles

Test Purpose

Characterize VBR throughput behavior with multiple VCCs originating from different ports with additional background load, using UPC test cells. Real-time cell loss measurements are made.

Methodology

1. Repeat Test 3.3 with UPC test cells.
2. Generate random VCI numbers for VPI = m, VCI = x to y, traffic type = Constant, Poisson, Burst OR Sawtooth PT = 0, 1, 2, 3, 4, 5, 6, OR 7 CLP = 0 traffic = A% and CLP =1 traffic = B%. Total traffic = line rate.
3. Test duration = 10 minutes (to test the set of random VPI/VCI).
4. Start the test, log the input parameters and the number of cells to be transmitted in 10 minutes = X.
5. Measure and log the following parameters every m=30 seconds:
   - VP/VC Usage
   - Cell Arrival Time
   - Cell InterArrival Time
   - CLP Count
   - CLP=0 count
   - CLP=0 loss count
   - CLP=1 count
   - Cell loss count
   - Tagged cell count
   - Tagging violation count
   - Cell Misinsertion rate
   - MisInsertion Cells
   - Cell MisInsertion count
   - Errored cells
   - 1 Point CDV
6. After 10 minutes, measure the total cells received from the LIF and measure and log total cell loss = X - total cells received.

Test 3.11 Multi-port with constant traffic profiles

Test Purpose

Characterize VBR throughput behavior with multiple VCCs originating from different ports with additional background load, using UPC test cells and multiple streams. Real-time cell loss measurements are made.

Methodology

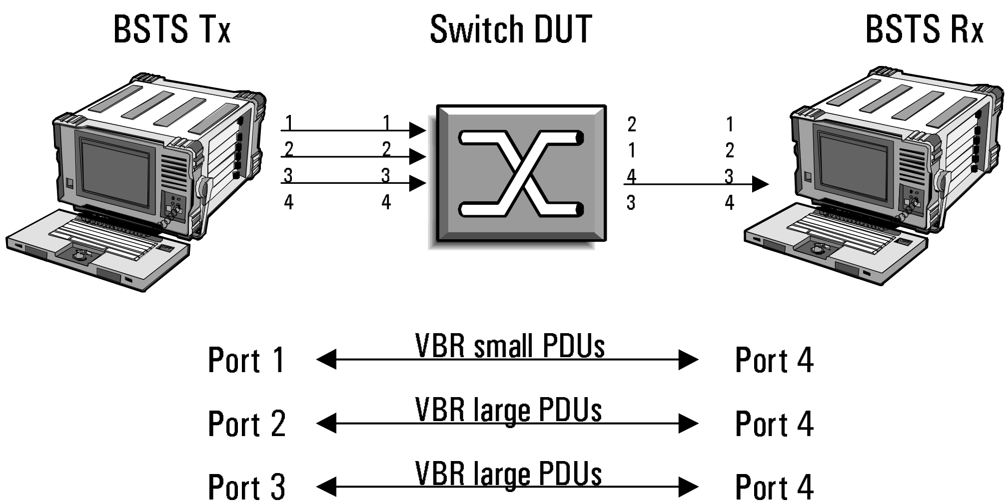
1. Repeat 3.10 with 8 streams of constant traffic.
2. Parameters same as test 3.10 except:
   - traffic type = Constant
   - Use 8 streams on each CPP. The first 7 uses 1024 UPC test cells and the last one uses 512 UPC test cells.

Test Group 4 Port Fairness

Test Purpose

To characterize an ATM switch's ability of fairly dropping cells under port overload conditions

Test Configuration



ATM Configuration

- Configure VBR PVCs from multiple input ports to a single output port.
- Optimize the buffer queue size on the output port for VBR traffic.

BSTS Configuration

- Build 2 cells with the appropriate VPI/VCI.
- Build 2 large PDUs (10,000 bytes) using multiple instances of these cells.
- Build 1 cell with the appropriate VPI/VCI.
- Build 1 small PDUs (128 bytes) using multiple instances of this cell.
- Define the number of PDUs to send periodically.
- Configure a port to monitor the received PDUs on the appropriate VPI/VCI.

Test Methodology

Port overload may occur when multiple channels from various input ports converge onto a single output port. This may result in the aggregate cell stream overloading the output ports capacity. In such a situation, cells from the various channels must be dropped in a fair manner.

Port fairness under congestion can be tested by:

- generating bursts of long packets (AAL-5 PDUs) on multiple input ports and
- a periodic stream of short packets (AAL-5 PDUs) on another port all destined for the same output port.

The latency of the short PDU traffic stream is measured while varying the load on the congested port with multiple bulk data streams.

The following test case describes an exhaustive test for port fairness, while Test 4.2 describes a cut-down, shorter version.

Test 4.1 Port fairness - extensive test

Test Purpose

Characterize port fairness of an ATM switch through an extensive test.

Methodology

1. Log the input port number and the input traffic rate.
2. Start tests on Port 1 at the 10% traffic allowed on output port 4 for 5 minutes using the small PDU.
3. After 5 minutes, measure and log:
   - cell loss
   - number of AAL-5 small PDUs received
   - number of AAL-5 small PDUs errored and cell delay variation along with the port on which the PDUs were received and the port from which they were sent.
4. Log the input traffic rate on all input ports along with their port numbers.
5. Configure the traffic generator on all input ports, and the monitor/analyzer on the output port for Multiple Burst, Poisson and Sawtooth traffic.
6. Start tests on Port 1 at the 10% traffic allowed on output port 4 for 5 minutes using the short PDU. At the same time, start traffic on Ports 2 and 3 at 70% total load (35% each) using the long PDU.

7. After 5 minutes, measure and log:
   - cell loss
   - number of AAL-5 small PDUs received
   - number of AAL-5 small PDUs errored and cell delay variation along with the port on which the PDUs were received and the port from which they were sent.
   - number of AAL-5 large PDUs received
   - number of AAL-5 large PDUs errored and cell delay variation along with the port on which the PDUs were received and the port from which they were sent.

   Cell loss will be calculated by measuring the total cells received and the program keeping track of how many cells it sent.
   Total Cell Loss = Total Cells Send - Total Cells Received.
   Cell delay variation will be calculated using one capture made towards the end of the 5 minute test cycle.
   Total number of AAL-5 PDUs received and errored can be calculated using the real-time measurements on the CPP.

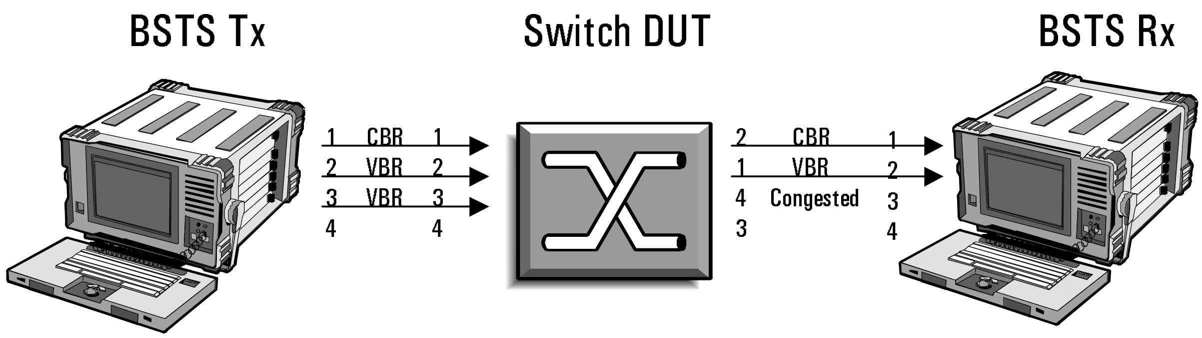
8. Increase the traffic on Ports 2 and 3 by 4% total (2% each) until the theoretical total traffic on the output port is 180% of the line rate and repeat the test.
9. Repeat the test with background traffic.

Test Group 5 Port Starvation

Test Purpose

To characterize an ATM switch’s handling of port starvation.

Test Configuration



ATM Switch Configuration

- Configure CBR PVC from one input port to a single output port.
- Optimize the buffer queue size on the output port for CBR traffic.
- Configure 2 VBR PVCs from 2 other input ports to a common output port, which is different from the output port for the CBR traffic.
- Optimize the buffer queue size on the output port for VBR traffic.

BSTS Configuration

- Build the CBR and VBR cells with the appropriate VPI/VCI.
- Configure a port to monitor the received CBR cells on the appropriate VPI/VCI.
- Configure another port to monitor the received VBR cells on the appropriate VPI/VCI.

Test Methodology

Port starvation/congestion control tests measure an ATM switch's ability to minimize loss when output port contention occurs. Output port contention arises when multiple input ports are sending traffic simultaneously to a common output port. If congestion at this port affects traffic flow on another port, port starvation results.

Port starvation is tested by measuring traffic flow through an output port, while causing a second output port to be congested. Congestion is established by generating periodic cell bursts (VBR streams) from multiple input ports, which are all destined for the same target output port. This can be achieved with two input ports with an average aggregate cell rate exceeding the line rate of the output port by 50%. A third CBR stream should be unaffected by the congestion the VBR traffic streams are experiencing at the other output port.

The following test cases are suggested.

Test 5.1 Port starvation baseline

Test Purpose

Characterize port starvation behavior using a 100% CBR stream and two VBR streams with SCR load of 40%-80%. Measurements made include cell loss, delay and CDV, which provide a baseline for port starvation.

Methodology

1. Configure a CBR traffic stream at 100% line rate on one transmit port (1).
2. Configure the receive monitor on receive port (1) and measure and log the following:
   - cell loss
   - cell delay and
   - cell delay variation
3. Configure a VBR traffic stream on 2 other input ports (2 and 3) at 20% each of line rate (40% total). Also, configure the receive monitor at the receive port 2. The VBR traffic can be bursty, Sawtooth or Poisson. For bursty traffic, the burst should be on for 1 second and off for 10 seconds.
4. Monitor and log the VBR cell loss count on receive port 2.
5. Measure and log the following CBR statistics on receive port 1:
   - cell loss count
   - cell delay and
   - cell delay variation
6. Increase the rate of the VBR traffic by 5% each (10% total) until it oversubscribes the output port by up to 80% and repeat the test.

Test 5.2 Port starvation with background loading

Test Purpose

Characterize port starvation behavior using a 100% CBR stream and two VBR streams with SCR load of 40%-80%, plus additional background loading. Measurements made include cell loss, delay and CDV, which provide a baseline for port starvation.

Methodology

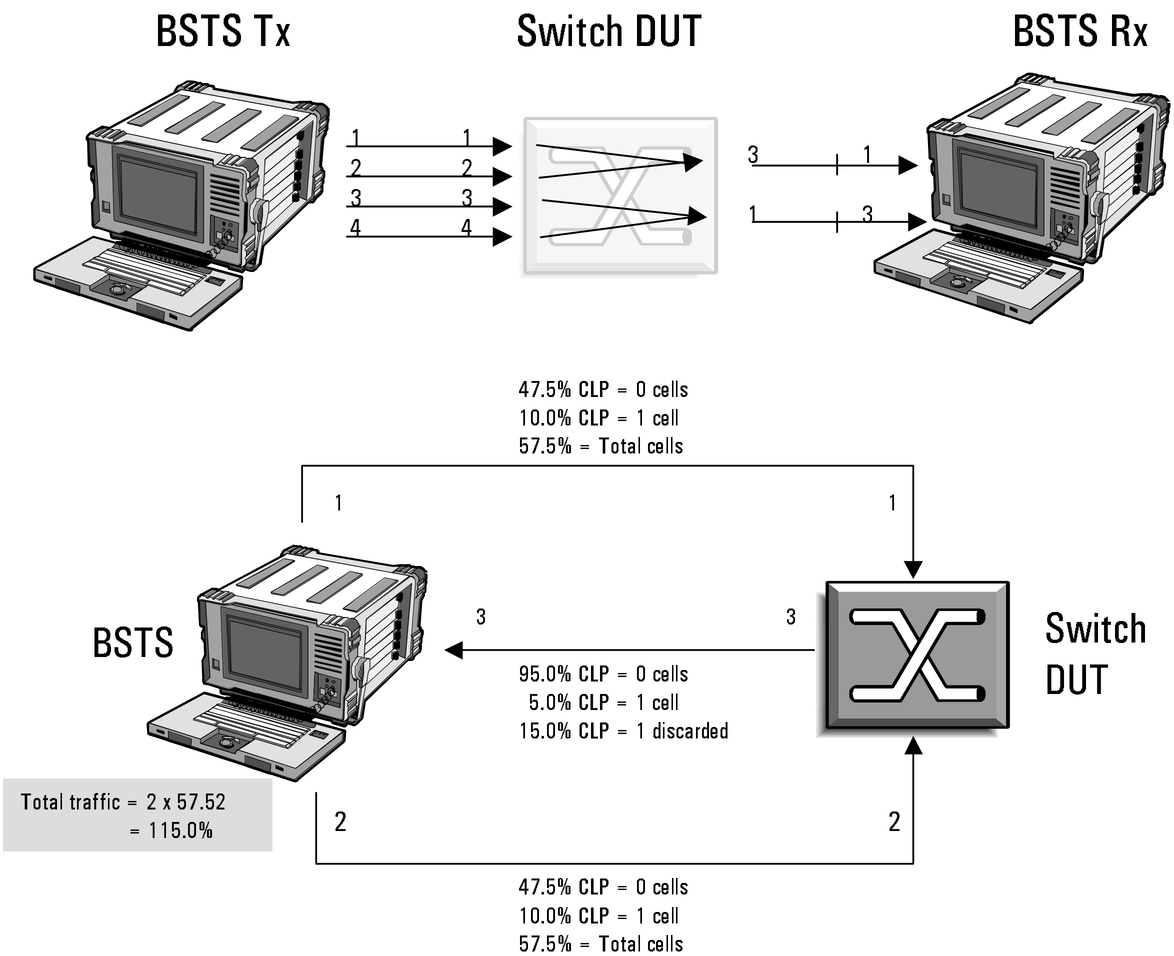
1. Repeat test 5.1 with background traffic.

Test Group 6 Cell Loss Priority

Test Purpose

To characterize an ATM switch's handling of the CLP bit.

Test Configuration



ATM switch configuration

- Configure VBR PVCs from 2 input ports 1 and 2 to a single output port 3.
- Optimize the buffer queue size on the output port for VBR traffic.
- Turn policing ON on port 3 and set it to drop CLP=1 cells on congestion.
- Configure VBR PVCs from 2 input ports 3 and 4 to a single output port 1.
- Optimize the buffer queue size on the output port for VBR traffic.
- Turn policing ON on port 3 and set it to drop CLP=1 cells on congestion.

BSTS Configuration

- Build a cell with the appropriate VPI/VCI on port 1.
- Build a cell with the appropriate VPI/VCI on port 2.
- Setup the receiver to monitor the traffic on port 1.
- Build a cell with the appropriate VPI/VCI on port 3.
- Build a cell with the appropriate VPI/VCI on port 4.
- Setup the receiver to monitor the traffic on port 3.

Test Methodology

During heavy congestion periods, an ATM switch must discard first those cells with low priority (CLP=1). Low priority cells should be discarded in preference to those cells with a high priority (CLP=0). Only after all low priority cells have been discarded and congestion still exists, should high priority cells (CLP=0) be discarded.

Congestion on an output port can be caused by generating periodic bursts of cells from multiple input ports, which are all destined for the same target output port. By monitoring the traffic on the output port, we can confirm that the CLP=1 cells are discarded first.

Test 6.1 CLP baseline

Test Purpose

Characterize CLP handling behavior by loading an output port with 115% load consisting of 10% low priority cells. Measurements made include number of high and low priority cells received, and which provide a baseline for CLP characterization.

Methodology

1. Configure some background traffic loading.
2. Configure traffic generators on ports 1 and 2 to transmit an equivalent of 57.5% of the available line rate across each PVC. The traffic stream should contain:
   - 47.5% CLP = 0 cells and
   - 10% CLP =1 cells.

   The traffic generated on these ports will be analyzed on port 1.
3. Configure traffic generators on ports 3 and 4 to generate an equivalent of 57.5% of the available line rate bandwidth across each PVC. The traffic stream should contain:
   - 47.5% CLP = 0 cells and
   - 10% CLP =1 cells.

   The traffic generated on these ports will be analyzed on port 3. The total traffic flowing towards each output port is 115%.

4. Log the test parameters.
5. Configure the receive streams to monitor statistics on ports 1 and 3. Collect the following measurements:
   - number of cells received with CLP =0
   - number of cells received with CLP =1
   - total number of cells received.

   The expected results are:
   - 100% of the CLP =0 cells
   - 5% of the CLP=1 cells and
   - the switch should have discarded 10% CLP=1 cells.

Test 6.2 CLP enhanced

Test Purpose

Characterize CLP handling behavior by sweeping through multiple input loads from 40%-100%. Measurements made include number of high and low priority cells received and total cells received.

Methodology

1. Configure background traffic loading.
2. Configure traffic generators on ports 1 and 2 to transmit an equivalent of 40% of the available line rate across each PVC. The traffic stream should contain:
   - 30% CLP =1 cells and
   - the remaining CLP=0 cells.

   The traffic generated on these ports will be analyzed on port 1.
3. Configure traffic generators on ports 3 and 4 to transmit an equivalent of 40% of the available line rate across each PVC. The traffic stream should contain:
   - 30% CLP =1 cells and
   - the remaining CLP=0 cells.

   The traffic generated on these ports will be analyzed on port 3.
4. Log the test parameters.

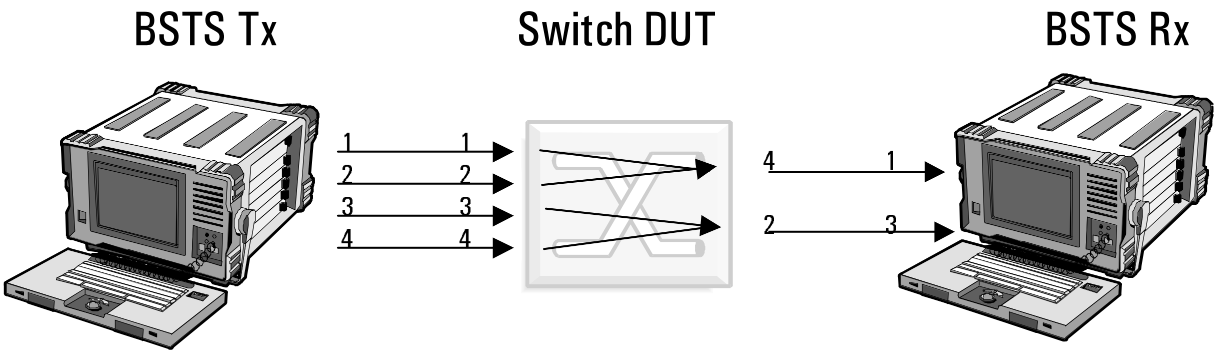
5. Configure the receive streams to monitor statistics on ports 1 and 3. Collect the following measurements:
   - Number of cells received with CLP =0
   - Number of cells received with CLP =1
   - Total number of cells received.
6. Increase the traffic by 5% until 100% load is reached and repeat the test.
7. Configure the receive streams to monitor statistics on ports 1 and 3. Collect the following measurements:
   - Number of cells received with CLP =0
   - Number of cells received with CLP =1
   - Total number of cells received.

Test Group 7 Tail Packet Discard

Test Purpose

To characterize an ATM switch's tail packet discard handling scheme.

Test Configuration



ATM switch configuration

- Configure 2 VBR PVCs from 2 input ports to a single output port.
- 1 PVC from input ports 1 and 2 to output port 4 and
- 1 PVC from input ports 3 and 4 to output port 2.
- Enable TPD on 1 PVC and Disable TPD on the other.

BSTS Configuration

- Build a cell with the appropriate VPI/VCI.
- Build multiple CPCS, AAL-5 and AAL-3/4 PDUs of length 64 bytes, 256 bytes, 1518 bytes, 4000 bytes and 64K (max length) bytes using multiple instances of the respective cell.
- Define the number of PDUs to send per second.
- Define the monitor/analyzer port to monitor the received PDUs on the appropriate VPI/VCI.

Test Methodology

When a cell of an AAL frame (e.g. AAL-5) is lost (due to congestion, for example), better throughput can be achieved by also discarding the remaining cells of the frame since the entire frame must be retransmitted anyway.

Testing a switch's ability to support tail packet discard is accomplished by creating a congestion situation, where multiple input ports are contending for a single output port. The aggregate traffic sent to the output port should exceed the capacity of the output port, thereby causing cell loss due to buffer overflow. The test is run with and without tail packet discard enabled, and the packet goodput/throughput monitored.

Test 7.1 TPD baseline

Test Purpose

Characterize TPD handling behavior by generating multiple streams of varying length AAL-3/4,5 PDUs. Throughput should be improved with TPD enabled on the ATM switch. Measurements include output rate, total valid PDUs received and sent, %Goodput, all which provide a baseline for TPD characterization.

Methodology

1. Configure the traffic generator with a CPCS PDU of 64 bytes in length.
2. Log the PDU type and the PDU length.
3. Configure background traffic loading.
4. Configure the traffic generator on all input ports at 10% of the output line rate.

   For example: for a 2 input test case, the total traffic on the output port is 10 x 2 = 20%).

5. Configure the receive monitor on the output port.
6. Execute the test for five minutes.
7. After five minutes, stop the generators and the analyzer, and record:
   - The total number of valid PDUs received on the output ports and
   - The total number of PDUs sent from all input ports.

   The total number of PDUs transmitted can be calculated as:
   - Total PDUs transmitted = Total PDUs received + Total errored PDUs received.

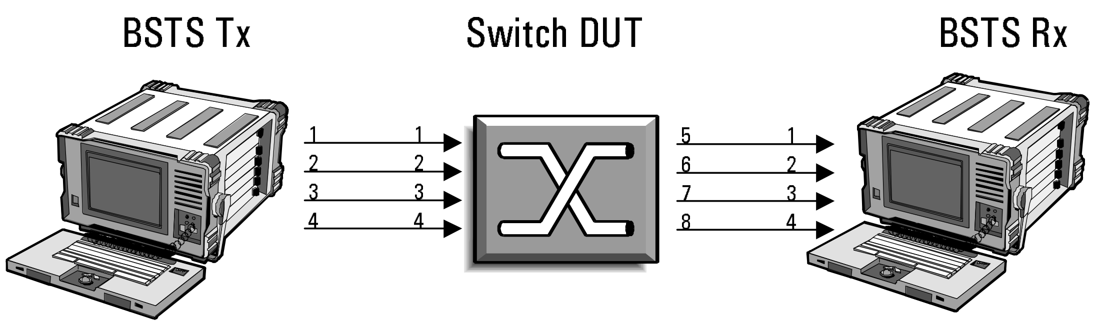
   Calculate the % PDU goodput as follows:
   - % Goodput = (total valid PDUs received / total PDUs sent) x 100
8. Record the following:
   - the output port
   - output rate
   - total valid PDUs received
   - total PDUs sent and
   - % Goodput.
9. Increase the traffic generated on each of the input ports by 10% until the theoretical output is 180% on the output ports and repeat the test.
10. Repeat the test for PDUs with length = 256 bytes, 1518 bytes, 4000 bytes and 64K (max length) bytes.
11. Repeat the test for AAL-3/4 and AAL-5 PDUs.
12. Stop the generator and the monitor/analyzer.
13. The PVC with TPD turned on should have a better goodput.

Test Group 8 Multicast Throughput

Test Purpose

To characterize an ATM switch's capability of handling multicast connections under a variety of conditions.

Test Configuration



ATM switch configuration

- Configure CBR multicast PVCs from single input port to 2 output ports. (fanout of 2)
- Configure CBR multicast PVCs from single input port to 3 output ports. (fanout of 3)
- Configure CBR multicast PVCs from single input port to 4 output ports. (fanout of 4)
- Configure CBR multicast PVCs from all 4 input ports to all 4 output ports.
- Optimize the buffer queue size on the output port for CBR traffic.

BSTS configuration

- Build a cell with the appropriate VPI/VCI to be transmitted from the input port
  - with a fanout of 2
  - with a fanout of 3
  - with a fanout of 4
- Build cells with the appropriate VPI/VCIs to be transmitted from all input ports to all the output ports.

Test Methodology

The ability of a switch to handle multicast connections can be tested by generating multiple ATM traffic streams on a single input port, destined for multiple output ports. As the multicast fanout increases, there should not be a significant degradation in throughput. Namely, increases in key metrics cell loss, cell delay and cell delay variation, should not be observed.

The following test cases are suggested.

Test 8.1 Multicast baseline

Test Purpose

Characterize multicast throughput for 2,3 and 4 port fanout, by sweeping through 50%-100% traffic loads. Measurements include peak throughput, full-load throughput, cell loss, delay and CDV, all which provide a baseline for multicast throughput characterization.

Methodology

1. Configure the traffic generator on the input port using the cells created for fanout of 2.
2. Configure and enable the receive monitor on the two output ports.
3. Configure traffic generation on the input port. Also, configure the receive monitor on the corresponding output ports at 50% of the maximum line rate.
4. Log the fanout number.
5. Log the traffic rate.
6. Measure and log the following statistics:
   - cell loss
   - cell delay
   - cell delay variation
7. If there is a cell loss, decrease the traffic by 5% and repeat.
8. If there is no cell loss, increase the traffic by 1% and repeat.
9. Log the traffic rate.
10. Measure and log the following:
    - no drop throughput
    - the corresponding cell delay
    - and cell delay variation.
11. Increase the load by 1% and measure the throughput of the switch until 100% of the load is reached.
12. Log the traffic rate.
13. Measure and log the following:
    - peak throughput
    - full-load throughput
    - cell loss ratio at full-load
    - the corresponding cell delay
    - cell delay variation.
14. Repeat test with fanout of 3.
15. Repeat test with fanout of 4.

Test 8.2 Multi-port multicast performance

Test Purpose

Characterize multicast throughput for 2,3 and 4 port fanout by sweeping through 50%-100% traffic loads on multiple input ports. Measurements include peak throughput, full-load throughput, cell loss, delay and CDV.

Methodology

1. Configure the traffic generator on all the input ports at 25% of the line rate (for a port test) using the cells created for this test. The amount of traffic to be generated on each port can be calculated as:

   X = 100/ (total number of input ports)

2. Configure all the receive monitors (4 in this case) to analyze the traffic from all the input ports (4 for this case).
3. Start the traffic generator on all the input ports at X = 100/total ports% (25% for this case where total ports = 4).
4. Configure the receive monitor on all the output ports to correspond to traffic from the appropriate input ports.
5. Monitor and log the following on all the output ports:
   - cell loss
   - cell delay
   - cell delay variation

Test 8.3 Multicast baseline with background load

Test Purpose

Characterize multicast throughput for 2,3 and 4 port fanout, by sweeping through 50%-100% traffic loads with the addition of background loading. Measurements include peak throughput, full-load throughput, cell loss, delay and CDV.

Methodology

1. Repeat Test 8.1 with background multicast traffic.

Test 8.4 Multicast performance with background load

Test Purpose

Characterize multicast throughput for 2,3 and 4 port fanout, by sweeping through 50%-100% traffic loads on multiple input ports with additional background load. Measurements include peak throughput, full-load throughput, cell loss, delay and CDV.

Methodology

1) Repeat Test 8.2 with background multicast traffic.

Test 8.5 Multicast baseline with VBR traffic

Test Purpose

Characterize multicast throughput for 2,3 and 4 port fanout, by sweeping through 50%-100% traffic loads with VBR traffic profiles. Measurements include peak throughput, full-load throughput, cell loss, delay and CDV.

Methodology

1. Repeat Test 8.1 for VBR traffic such as Poisson, Sawtooth or Multiple-Burst. The VBR traffic profile should be specified such that the sustained cell rate is 50% of the bandwidth (traffic rate mentioned in Test 8.1).
2. Measure and log the following:
   - throughput of the switch
   - cell loss
   - cell loss ratio.

Test 8.6 Multicast performance with VBR traffic

Test Purpose

Characterize multicast throughput for 2,3 and 4 port fanout, by sweeping through 50%-100% traffic loads on multiple input ports with VBR traffic profiles. Measurements include peak throughput, full-load throughput, cell loss, delay and CDV.

Methodology

1. Repeat Test 8.2 for VBR traffic

Test 8.7 Multicast VBR traffic and background load

Test Purpose

Characterize multicast throughput for 2,3 and 4 port fanout, by sweeping through 50%-100% traffic loads with VBR traffic profiles and additional background loading. Measurements include peak throughput, full-load throughput, cell loss, delay and CDV.

Methodology

1. Repeat Test 8.5 with background multicast traffic.

Test 8.8 Multicast VBR performance and background load

Test Purpose

Characterize multicast throughput for 2,3 and 4 port fanout, by sweeping through 50%-100% traffic loads on multiple input ports with VBR traffic profiles and additional background load. Measurements include peak throughput, full-load throughput, cell loss, delay and CDV.

Methodology

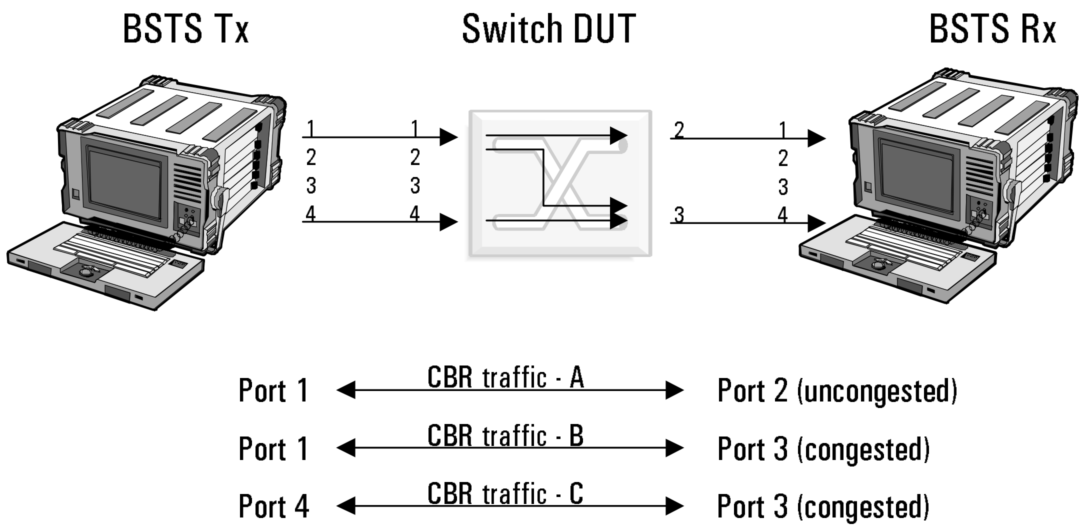
1. Repeat Test 8.6 with background multicast traffic.

Test Group 9 Head of Line Blocking

Test Purpose

To characterize the switch's handling of HOL traffic under a variety of conditions.

Test Configuration



ATM switch configuration

- Configure CBR PVCs from input port 1 to output port 2 (stream A).
- Configure CBR PVCs from input port 1 to output port 3 (stream B).
- Configure CBR PVCs from input port 4 to output port 3 (stream C).
- Optimize the buffer queue size on the output ports 2 and 3 for CBR traffic.

BSTS Configuration

- Build a cell with the appropriate VPI/VCI to travel from port 1 to 2 (stream A).
- Build a cell with the appropriate VPI/VCI to travel from port 1 to 3 (stream B).
- Build a cell with the appropriate VPI/VCI to travel from port 4 to 3 (stream C).

Test Methodology

The ability of a switch to handle Head of Line blocking can be tested by generating two data streams from a single input source, each destined for a different output port. An additional background stream is then directed towards one of the output ports, which results in that port becoming congested.

Test 9.1 HOL blocking baseline with multi-flow CBR

Test Purpose

Characterize the DUT's HOL blocking handling using a multi-flow CBR stream. Measurements include cell loss, delay and CDV, all which provide a baseline for HOL blocking characterization.

Methodology

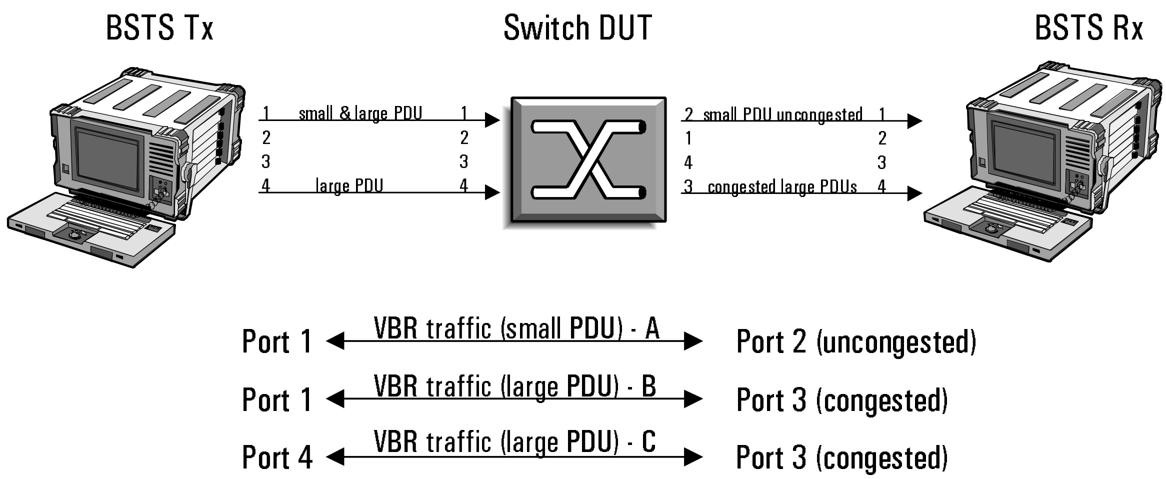
1. Start the two streams on input port 1 with each stream occupying 40% of the bandwidth. This can be done using two streams on the CPP by loading two individual cell sequences, which together form a single sequence.
2. Measure and log the following:
   - cell loss
   - cell delay (port 1 only)
   - cell delay variation on port 1 and 4 of streams A, B, and C.
3. Enable traffic generation from port 4 with it occupying 50% of the bandwidth that can be sustained by port 3.
4. Measure and log the following:
   - cell loss
   - cell delay (port 1 only)
   - cell delay variation on port 1 and 4 of streams A, B and C.
5. Increase the traffic generated on port 4 by 5% until the full line rate on port 4 is reached.
6. Measure and log the following:
   - cell loss
   - cell delay (port 1 only)
   - cell delay variation on port 1 and 4 of streams A, B and C.
7. Stop the test.

Test 9.2 HOL blocking with multi-length VBR streams

Test Purpose

Characterize the DUT's HOL blocking handling using a multi-flow, multi-length VBR stream. Measurements include cell loss, delay and CDV.

Methodology



1. Define a VBR AAL-5 PDU of length 64 bytes (payload) called small_pdu.
2. Define a VBR AAL-5 PDU of length 10000 bytes (payload) called large_pdu.
3. Configure background traffic loading.
4. Send 2 streams of data from port 1. Stream A at 20% line rate consisting of cells from small_pdu and stream B at 50% line rate consisting of cells from large_pdu for 2 minutes.
5. Capture stream A data at Port 1 every 15 seconds. (Repeat this for 3 cycles).
6. Measure and log the following:
   - port number
   - cell delay variation
   - intercell arrival time for all 3 captures and
   - calculate and log their average.
7. After two minutes, measure and log the following:
   - number of valid AAL-5 PDUs received
   - errored AAL-5 PDUs received on port 1 for stream A.
8. At the same time, measure and log the following:

- port number,
- the number of valid AAL-5 PDUs received from stream B
- the number of errored AAL-5 PDUs received from stream B on port port.

9. Send 2 streams of data from port 1.
   - Stream 1 at 20% line rate consisting of cells from small_pdu and
   - Stream 2 at 50% line rate consisting of cells from large_pdu for 2 minutes as before.
10. At the same time, enable traffic generation from port 4 to port 3 at 10% line rate of port 3 using large_pdu for 2 minutes (new).
11. Measure and log port number, cell delay variation, Intercell arrival time for all 3 captures and calculate and log their average (as before).
12. After two minutes, measure and log the following:
    - number of valid AAL-5 PDUs received
    - errored AAL-5 PDUs received on port 1 for stream A.
13. At the same time, measure and log the following:
    - port number,
    - the number of valid AAL-5 PDUs received from streams B and C and
    - the number of errored AAL-5 PDUs received from streams B and C on port 4.
14. Increase the percentage of traffic from port 4 to port 3 by 10%.
15. Repeat the test until the percentage of traffic from stream C reaches 100%.

Acronyms

AAL	ATM Adaptation Layer
ABR	Available Bit Rate
ATM	Asynchronous Transfer Mode
BSTS	Agilent Broadband Series Test System
CBR	Constant Bit Rate
CDV	Cell Delay Variation
CLP	Cell Loss Priority
CPCS	Common Part Convergence Sublayer
CPP	Agilent E4209 Cell Protocol Processor
DUT	Device Under Test
GCRA	Generic Cell Rate Algorithm
HEC	Header Error Check
HOL	Head of Line
ILMI	Interim Local Management Interface
IP	Internet Protocol
LIF	Line Interface module
OAM	Operations, Administration and Maintenance
OLG	E1696A Optical Load Generator
PDU	Protocol Data Unit
PVC	Permanent Virtual Channel
QoS	Quality of Service
Rx	Receive
SAR	Segmentation and Reassembly
SCR	Sustainable Cell Rate
TCL	Tool Command Language
TCP	Transmission Control Protocol
TPD	Tail Packet Discard
Tx	Transmit
UNI	User to Network Interface
UPC	Usage Parameter Control
VBR	Variable Bit Rate
VC	Virtual Channel
VCC	Virual Channel Connection
VCI	Virtual Channel Indicator
VP	Virtual Path
VPI	Virtual Path Indicator

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For more information

For an introduction to the modular Broadband Series Test System, please request the *BSTS Product Information & Technical Specifications*, publication 5966-0035E or visit the BSTS web pages at

www.Agilent.com/comms/BSTS

Technical specifications detailing other dedicated test modules and test software packages for the BSTS are also available.

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