Measuring Real-time QoS Using the E6270A OAM Protocol Tester

Agilent Technologies Broadband Series Test System
Application Note

Introduction

This product note explains how to use the Agilent Technologies Broadband Series Test System (BSTS) to perform real-time QoS measurements using the Agilent Technologies E6720A OAM Protocol Test (OPT) module.

Tutorial

- How and why OAM PM cells can be used to measure QoS

Demo guides

- Out-of-service and in-service QoS testing

Reference

- Definitions of E6270A QoS measurements

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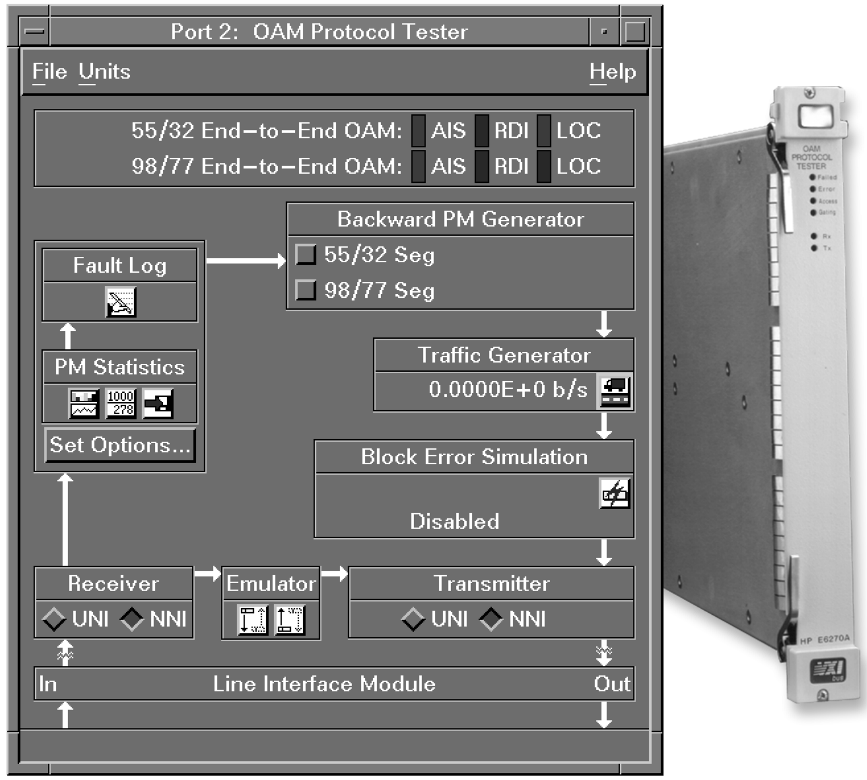
Overview of the E6270A OAM Protocol Tester

The Agilent E6270A OPT module is the industry's first real-time test solution that helps manufacturers and service providers incorporate Operations, Administration, and Maintenance (OAM) capabilities into their ATM equipment and networks.



- Conforms to ITU-T I.610 specification for OAM.
- Offers test features for the Bellcore GR-1248-CORE recommendations for OAM, including:
  - generation of CBR and VBR user traffic on 124 channels
  - generation of all OAM cell types on 124 channels
  - full emulation of OAM source requests and destination responses on 124 channels, including AIS states, loopbacks, and activation/deactivation
  - real-time statistics on two channels for OAM fault management, forward monitoring performance management, and backward reporting performance management

The E6270A helps ensure correct implementation of all aspects of OAM.

Benefits of using the E6270A OPT for QoS

In addition to its comprehensive OAM test capability, the OPT module offers features suited to traffic, policing, and Quality of Service (QoS) testing.

- **Standards-compliant**
  Sends and receives ITU-T I.610 OAM Performance Management (PM) cells for QoS and policing measurements on blocks of user cells.
- **Real-time QoS measurements**
  Monitors OAM PM cells continuously at rates up to 155 Mb/s to provide QoS and cell-tagging measurements.
- **Powerful traffic source**
  Generates CBR or VBR user traffic on up to 124 independent traffic streams.
- **Out-of-service QoS**
  Generates OAM PM cells for each stream of user cells. The OPT is a powerful traffic source for performing out-of-service QoS measurements.
- **In-service QoS**
  ITU-T I.610 OAM PM cells can be generated by ATM network equipment. The benefit of standards conformance is that QoS monitoring on live user traffic (in-service QoS) is made possible.

Tutorial

Background information on OAM and QoS

Before discussing QoS test procedures in detail, we will review the ITU-T standards related to QoS and OAM:

- I.356
- I.610
- I.191

What is QoS and what are I.356 QoS parameters?

The ITU-T I.356 standard specifies which parameters should be measured to determine ATM-layer Quality of Service (QoS).

- **Cell error ratio**
  A cell is errored if it arrives within the required time and has either different payload contents than when it was transmitted, or an invalid cell header.
  - cell error ratio = errored cells / (successfully transferred cells + errored cells) *
- **Cell loss ratio**
  A cell is lost if it does not arrive at a specified point within the required time after leaving a previous point.
  - cell loss ratio = lost cells / number of transmitted cells *
- **Cell misinsertion rate**
  A cell is misinserted if it is received at the destination but was not part of the original transmission.
  - cell misinsertion rate = misinserted cells / time interval*

* Note: Excludes cells in SECBs

I.356 Cell blocks and SECBs

A cell block is a consecutive sequence of cells on a given virtual channel or virtual path connection. A cell block is counted as severely errored when more than the specified number of cells in the cell block are errored, lost or misinserted.

The Severely Errored Cell Block Ratio (SECBR) is the ratio of severely errored cell blocks to the total number of transmitted cell blocks.

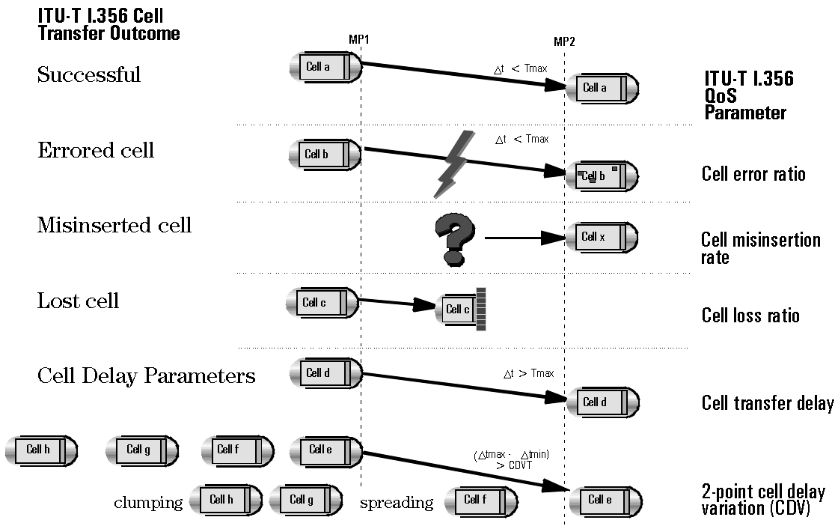
The SECBR indicates the availability and reliability of the network or ATM equipment. It provides a measure of the amount of time the connection is unavailable due to excessive errors.

I.356 SECB QoS parameters

The SECB measurement is also designed to prevent bursts of errors from inappropriately affecting the cell transfer measurements. SECB measurements are not included in cell error ratio, cell loss ratio, or cell misinsertion rate.

- Severely errored cell block (SECB) ratio A block of cells which exceeds contract-defined thresholds for either cell error count, cell loss count, or cell misinsertion count is an SECB. *
  - SECBR = SECB count / total number of blocks

* Note: SECB threshold values are not specified in the ITU-T standards. Bellcore makes some recommendations. For example, refer to GR-1248-CORE Generic Requirements for Operations of ATM Network Elements.



ITU-T I.356 QoS Parameters.

I.356 Delay QoS parameters

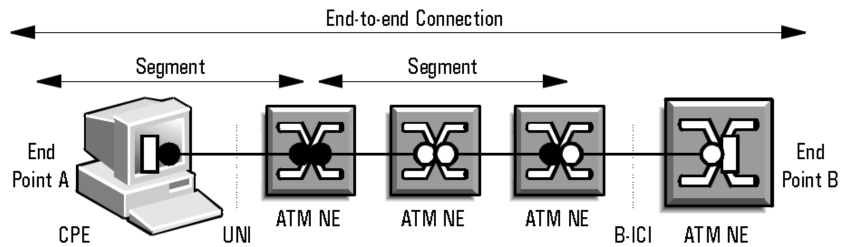
- **Mean cell cell transfer delay**
  This is the length of time it takes for a cell to travel between two measurement points (MPx). T1 is the arrival time at MP1, T2 is the arrival time at MP2.
  - cell transfer delay = T2 - T1
- **2-point cell delay variation (CDV)**
  2-point CDV is the variation in cell transfer delay relative to the reference cell. The reference cell can be any cell in the stream.
  - peak-to-peak 2-point CDV = maximum cell transfer delay - minimum cell transfer delay
- **1-point cell delay variation (CDV)**
  1-point CDV is the variation in cell arrival time at a single measurement point relative to the expected arrival time. The expected arrival time is derived from the negotiated peak cell rate (PCR).
  - ΔT arrival = 1/PCR

2-point CDV measures only the delay variation added between the two measurement points. 1-point CDV measures the total delay variation relative to an ideal CBR traffic stream.

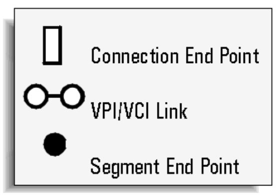
I.610 OAM functions

OAM (Operations, Administration, and Maintenance) is defined by the ITU-T I.610 standard. There are different types of OAM cells for different functions:

- **Fault Management**
  Forward and backward alarms (AIS and RDI) indicate that a fault has occurred. Continuity check and loopback OAM cells enable the fault location to be determined.
- **Performance Management (PM)**
  Forward monitoring enables QoS measurements to be made at the destination. Backward reporting cells communicate the results back to the source.
- **Activation/Deactivation**
  These OAM cells instruct the ATM equipment to turn on or off features such as continuity check, loopback, and performance management.



	End-to-end	Segment
F5 OAM Flow Cells	PTI=5	PTI=4
F4 OAM Flow Cells	VCI=4	VCI=3



ATM OAM Flows F4 and F5, Segment and End-to-end.

OAM Flows

There are two types of OAM flows:

- **F5** is for virtual channel connections. The payload type indicator is used to distinguish between user data and F5-OAM cells. The F5-OAM cells have the VPI/VCI as the channel being managed.
- **F4** is for virtual path connections. There are pre-defined VCIs which identify F4-OAM cells. The F4-OAM cells have the same VPI as the path being managed.

OAM flows can be:

- **end-to-end:** terminate at the end of a connection. A connection is from end-point to end-point.
- **segment:** terminate at the end of a segment A segment is any part of a connection.

QoS testing tip

Use end-to-end F5-OAM PM cells to monitor QoS on a particular VPI/VCI channel.

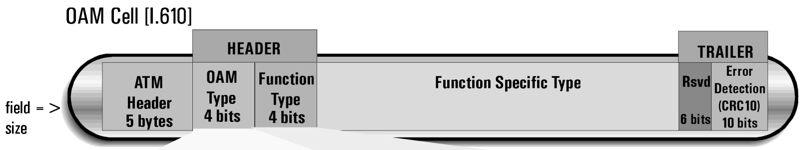
About the OAM PM cell

QoS capability The OAM PM cell has all the features required (sequence number, timestamp, error checking field) to measure I.356 QoS parameters.

Policing capability It can also perform cell tagging (policing) measurements because it provides measurements for high priority (CLP=0) cells.

Block statistics OAM PM cells are inserted into blocks of user cells. They provide QoS measurements (cell error, loss, misinsertion, and SECB) on blocks of user cells. I.610 specifies a block size of 128 user cells, while Bellcore recommends larger block sizes.

Sampled delay measurements Cell delay and CDV is measured on the OAM PM cells themselves, not the user cells. OAM PM cells therefore provide an estimate of the delay and CDV of the user cells.



OAM Type and function type identifiers

OAM Type	Coding	Function Type	Coding
Fault management	0001	AIS	0000
	0001	RDI	0001
	0001	Continuity check	0100
	0001	Loopback	1000
Performance management	0010	Forward monitoring	0000
	0010	Backward reporting	0001
Activation/deactivation	1000	Performance monitoring	0000
	1000	Continuity check	0001
System management	1111	(Note)	(Note)

Note: Not to be standardized by ITU-T I.610.

Operations, Administration and Maintenance: the I.610 OAM cell

O.191 or I.610 for measuring QoS?

ITU-T O.191 defines the characteristics of ATM measuring equipment for both out-of-service and in-service QoS.

Out-of-service QoS

The O.191 test cell is a user cell with the features required (sequence number, timestamp, error checking field) to measure I.356 QoS parameters. It provides out-of-service QoS measurements on individual user cells.

The I.610 OAM PM cell provides coarser-resolution QoS measurements on blocks of 128 cells.

In-service QoS

Because I.610 OAM PM cells can be distinguished from user cells, they can be inserted into a live traffic stream and used for in-service QoS measurements.

The O.191 standard specifies in-service QoS measurements using OAM PM cells. In other words, the O.191 in-service test cell = the I.610 OAM PM cell.

Limitations of OAM PM cell QoS measurements

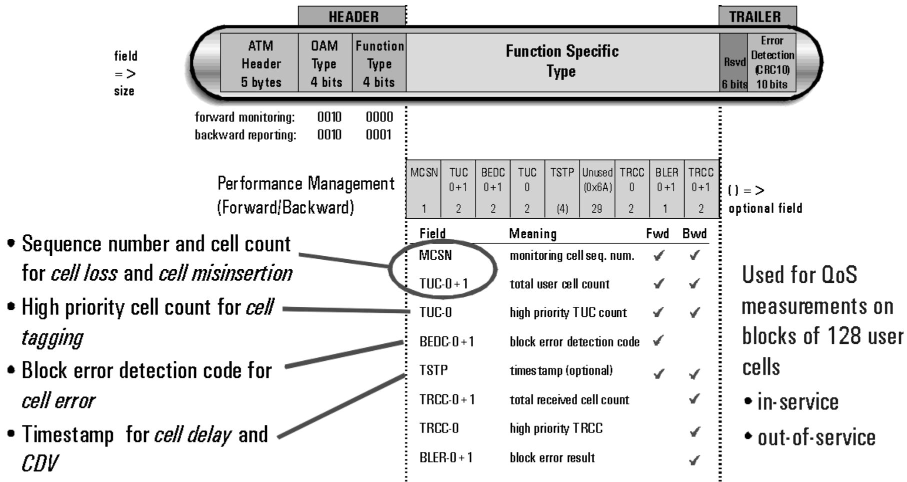
The I. 610 QoS measurement technique has certain accuracy limitations because the measurements are performed on blocks of cells rather than on individual cells. The following notes describe these limitations.

Cell loss and misinsertion

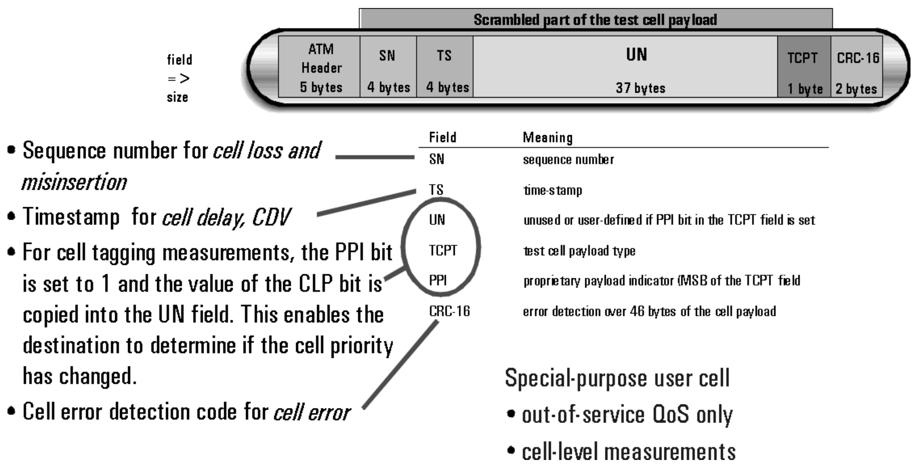
Cell loss and misinsertion are detected by checking the user cell count (TUC field of the OAM PM cell). If a cell loss and a cell misinsertion occur in the same block, they will cancel each other out.

Justification for using this measurement technique:

- Cell misinsertion is very rare, so it will generally have very little effect on the accuracy of the cell loss measurement.



Structure of the I.610 OAM Performance Management cell.



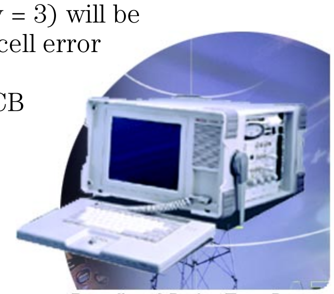
Structure of the O.191 out-of-service test cell.

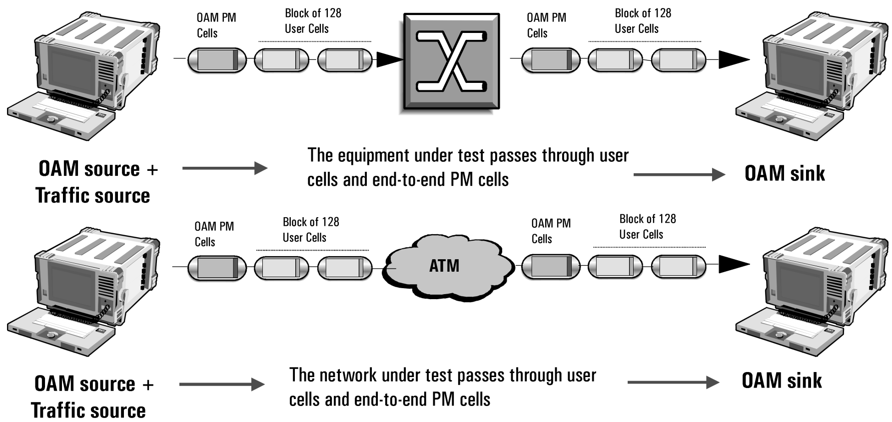
Cell errors

The CRC-16 block error detection code enables the number of errored bits within the cell block to be counted. An assumption is made that there is no more than one errored bit per cell. The cell error rate calculation therefore equates the number of errored bits to the number of errored cells.

Justification for using this measurement technique:

- This assumption is valid at low error rates.
- At moderate error rates, multiple bit-errors per cell will produce a conservative (high) estimate of the cell error ratio.
- At high error rates, bursts of errors exceeding the SECB cell error threshold (typically = 3) will be excluded from the cell error ratio. They will be included in the SECB ratio instead.





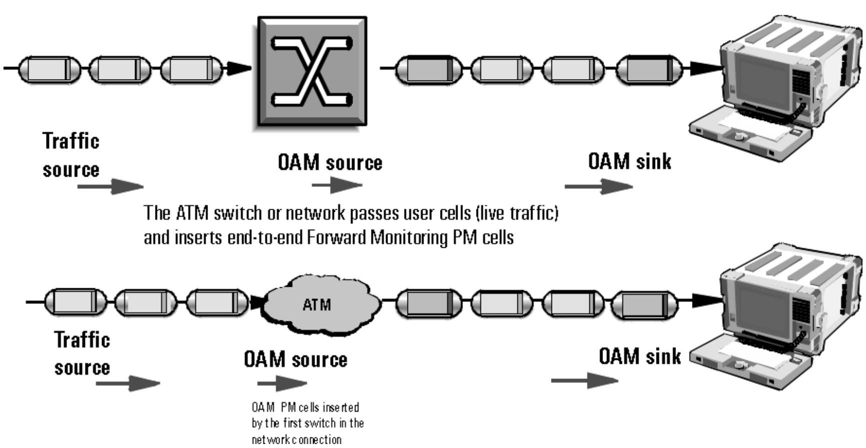
Measuring out-of-service QoS.

Cell delay and CDV

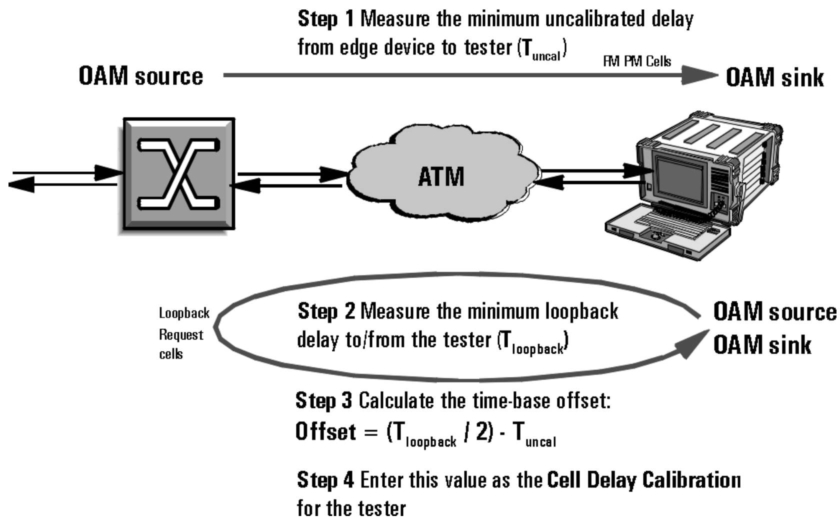
Delay measurements are carried out on the OAM PM cells themselves and not the user cells. They provide a sampled estimate of the user cell delay and CDV. It is possible that the sampling rate will be too low to accurately detect periodic variations in cell delay.

Justification for using this measurement technique:

- OAM PM cells are inserted every 128 user cells. Most equipment buffers are much larger than this (thousands of cells), so the delay variation period is usually much slower than the OAM PM sampling rate.
- The E6270A module can generate OAM PM cells with either constant and variable block sizes. By varying the block size, sampling effects of periodic patterns are minimized.



Measuring in-service QoS



Calibrating for time-base offset.

Demo guide

Measuring out-of-service QoS using the E6270A OPT module

The tester generates user cells and end-to-end forward monitoring PM cells. At the far end, the test equipment monitors blocks of user cells and forward monitoring PM cells. It calculates QoS parameters in real time.

- Use F5-OAM cells to measure QoS on a Virtual Channel Connection (VCC). Use F4-OAM cells to measure QoS on a Virtual Path Connection (VPC).
- The equipment or network under test should regenerate segment-flow OAM cells. Use end-to-end OAM cells to ensure that end-to-end QoS measurements are performed.
- If the same tester is used to generate and monitor OAM PM cells, then departure and arrival time-bases will be automatically synchronized. If two remote testers are used, then a calibration procedure will be required to calculate the time-base offset.

Measuring in-service QoS using the E6270A OPT module

The ATM switch or network entry point inserts end-to-end forward monitoring PM cells into the stream of user cells from the live traffic source. At the far end, the test equipment monitors blocks of user cells and forward monitoring PM cells. It calculates QoS Parameters in real time.

- Use F5 end-to-end OAM cells to measure QoS on a Virtual Channel Connection (VCC).
- The time-base of the equipment which generates the PM cells is not synchronized with the time-base on the test equipment. A calibration procedure is required to calculate the time-base offset.

System requirements for QoS measurements

To perform the tests covered in this guide, you will need an Agilent E4200B BSTS Form 7 Transportable Base or Agilent E4210B BSTS Form 13 Mainframe Base with:

- one OAM Protocol Test (OPT) module (E6270A)
- one Line Interface Module (LIF)
- V743 HP-UX controller

and the following software applications:

- Version 3.08 or later base software and on-line help (installed from the A.12 CD-ROM set or later).

Out-of-service QoS procedure

Step 1: Start a test session with the E6270A OPT module and a line interface module.

Step 2: Configure the line interface module (for example, turn on the laser).

Step 3: On the OPT, set up user cell traffic generation for a single VPI/VCI.

Step 4: Turn on end-to-end F5-OAM PM cell generation for the same VPI/VCI.

Step 5: Set up the channel to monitor. Set error thresholds for SECB statistics.

Step 6: Select performance management statistics from these categories: Cell Errors, Cell Counts, Severely Errored Cell Blocks, Delays.

Step 7: Start measurements.

In-service QoS procedure

Step 1: Start a test session with the E6270A OPT module and a line interface module.

Step 2: Configure the line interface module (for example, turn on the laser).

Step 3a: Set up a live traffic stream from some user equipment.

Step 4a: Configure the VPI/VCI through the ATM switch and set up end-to-end F5-OAM PM cell insertion for the same VPI/VCI.

Step 5: Set up the channel to monitor. Set error thresholds for SECB statistics.

Step 6: Select performance management statistics from these categories: Cell Errors, Cell Counts, Severely Errored Cell Blocks, Delays.

Step 7a: Calibrate for time-base offset.

Calibrating for time-base offset

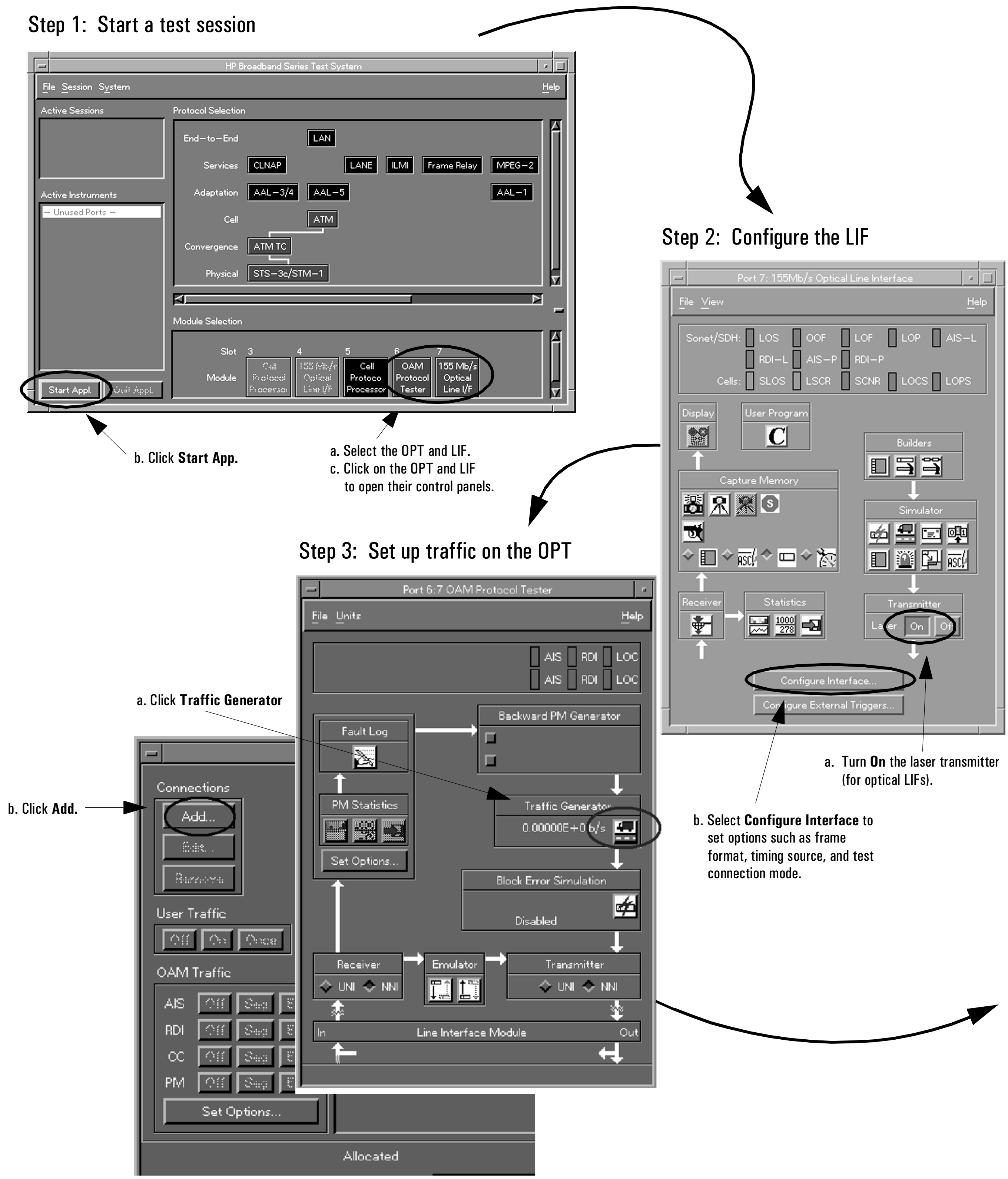
Step 1: Measure the one-way cell delay using OAM PM cells. The value obtained is equal to the true delay plus the time-base offset.

Step 2: Measure the loopback cell delay, using OAM fault management loopback cells from the tester. The value obtained is equal to approximately twice the true delay.

Step 3: The time-base offset is approximately equal to half the loopback delay minus the one-way (uncalibrated) delay.

Step 4: Once the time-base offset calibration value has been estimated, it can be entered into the OAM PM measurement setup screen for the E6270A module.

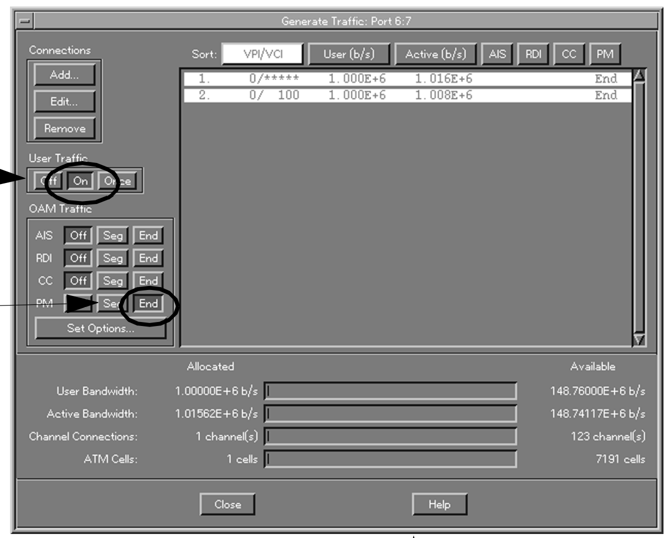
Out-of-Service QoS Procedure (Steps 1, 2, 3, 4, 5, 6,7)
In-Service QoS Procedure (Steps 1, 2, 3a, 4a, 5, 6, 7a)



Step 4a: Set up OAM PM cell generation in the ATM switch (*for in-service QoS*)

a. Connect the user traffic to the input port of the ATM switch.
b. Configure the VPI/VCI through the ATM switch from the input port to the output port.
c. Set up end-to-end F5-OAM PM cell insertion for the same VPI/VCI as the user traffic on the output port.

Step 4: Set up OAM PM cell generation

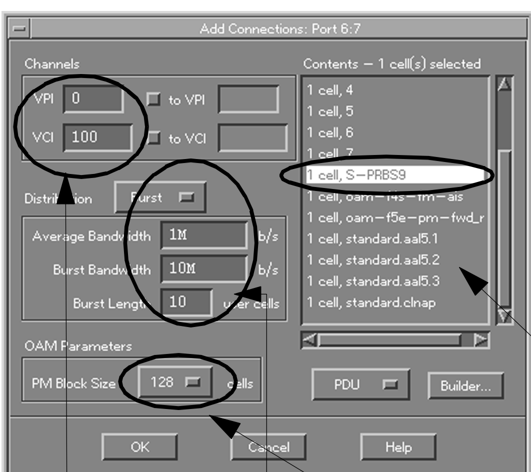


a. Turn user traffic **On**.

b. Select **End** (end-to-end) PM cell generation.

Note: The tester is now generating F5 (on channel 0/100) and F4 (on path 0) OAM PM cells.

Step 3 (cont.): Set up traffic on the OPT



e. Select a PDU or Sequence for the user cells (e.g. ATM S-PRBS9).

c. Enter the **VPI** and **VCI** values for the VCC.

d. Select a traffic distribution (constant or burst) and enter the **Bandwidth** parameters.

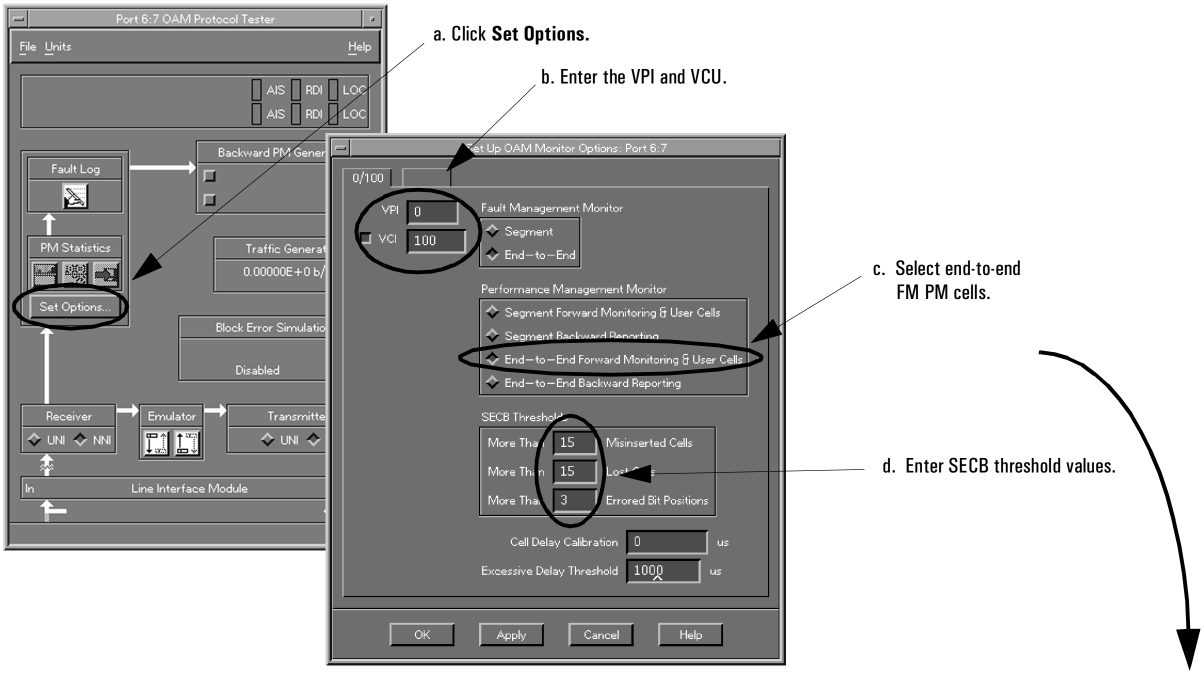
f. Select the minimum PM Block Size of 128 cells.

Step 3a: Set up live user traffic (*for in-service QoS*)

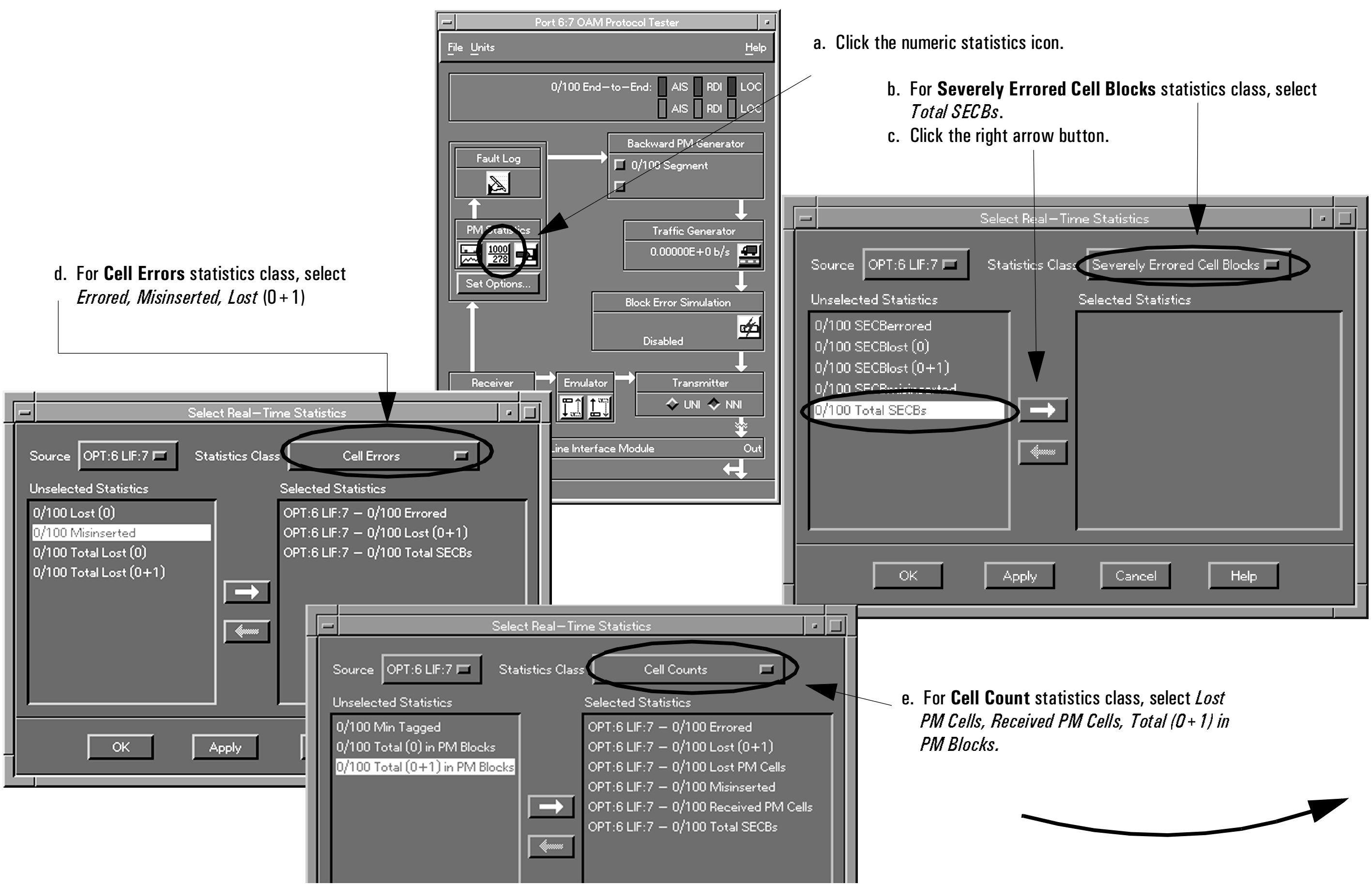
a. Set up a live traffic stream from some user equipment (for example, the traffic could be: LAN, LANE, Frame Relay, SMDS, or MPEG-2 video over AAL-1, AAL-2, AAL-3/4, AAL-5 or over ATM)

Note: At the far end, the E6270A OPT module can pass all received cells to the E4209A/B CPP module for further analysis. All of the above protocols can be decoded. To do this, you must first select the CPP + OPT + LIF module and the required protocols in the Test Session Manager before starting the application.

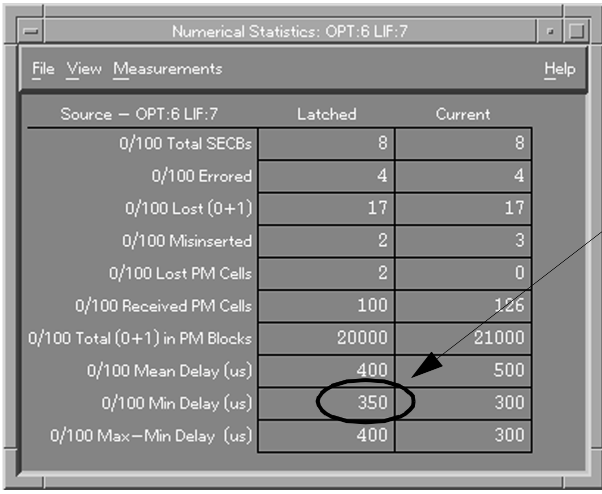
Step 5: Set measurement options



Step 6: Select PM statistics



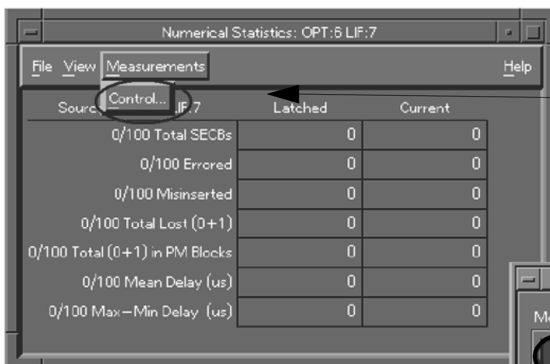
Step 7a: Determine the cell delay calibration value



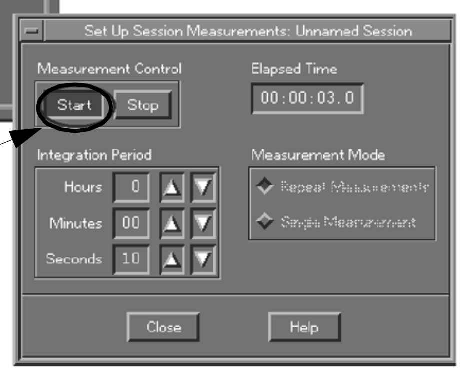
For in-service measurements, or out-of-service measurements where the generator time-base is not synchronized with the receiver time-base.

a. Record the *Latched* **Min Delay** value (e.g. T_{uncal} = 350 μs).

Step 7: Start measurements



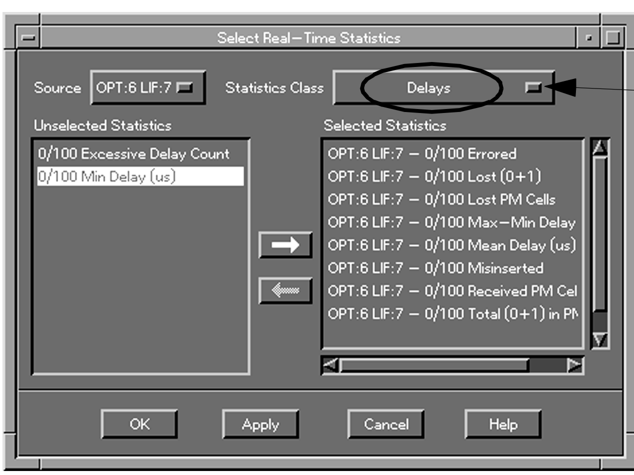
a. Select **Measurements > Control**.



b. Select the integration period and click **Start**.

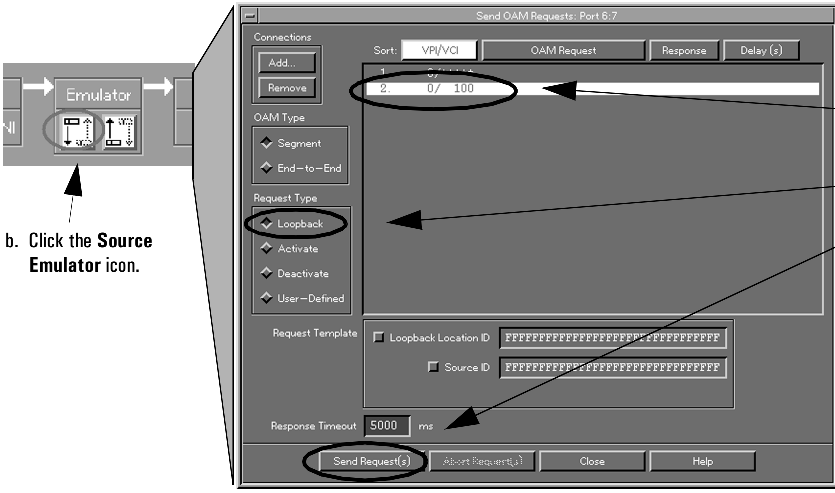
Note: With the integration period shown here, *Current* measurements will accumulate and then be *Latched* every 10 seconds.

Step 6 (cont.): Select PM statistics



f. For **Delays** statistics class, select *Mean Delay, Max-Min Delay, Min Delay*.

Step 7a (cont.): Determine the cell delay calibration value



b. Click the **Source Emulator** icon.

c. Select the VPI/VCI (or **Add**...a new connection and then select it).

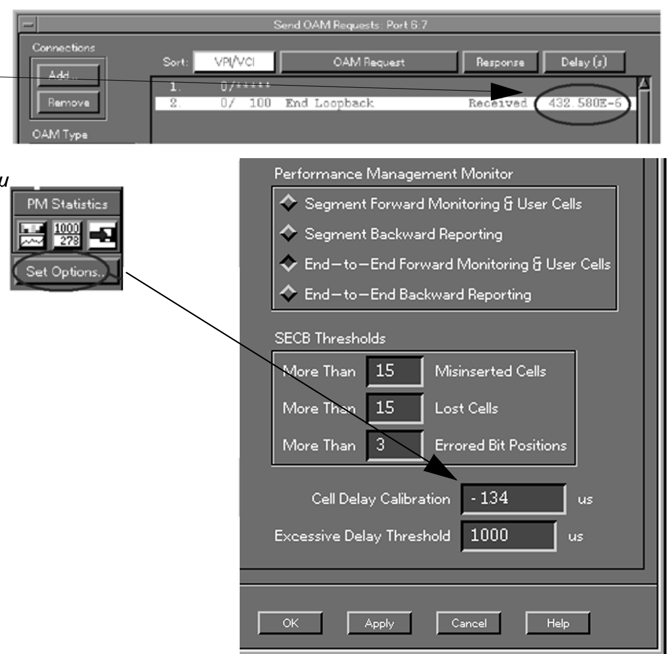
d. Select **Loopback** request type.

e. Click **Send Request(s)** a few times.

Step 7a (cont.): Determine the cell delay calibration value

f. Record the minimum **Delay(s)** value (e.g. $T_{Loopback}$ = 433 μs)

g. In the measurement **Set Options** window, enter the **Cell Delay Calibration** value (eg. $T_{Loopback}$ / 2 - T_{Uncal} = 433/2 - 350 = -134 μ



QoS Measurements Example

Numerical Statistics: OPT:6 LIF:7

File View Measurements Help

Source – OPT:6 LIF:7		Latched	Current
0/100 Total SECBs	a)	8	8
0/100 Errored	b)	4	4
0/100 Lost (0+1)	c)	17	17
0/100 Misinserted	d)	2	3
0/100 Lost PM Cells	e)	2	0
0/100 Received PM Cells	f)	100	126
0/100 Total (0+1) in PM Blocks	g)	20000	21000
0/100 Mean Delay (us)	h)	400	500
0/100 Min Delay (us)	i)	350	300
0/100 Max–Min Delay (us)	j)	400	300

k) In this example, measurement integration period = 10 seconds

Calculation based on values latched at the end of the integration period

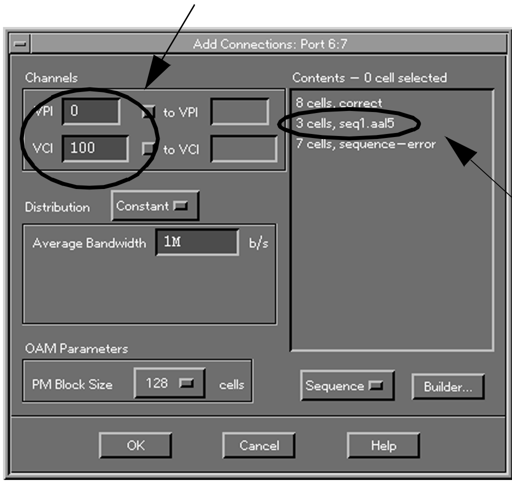
- **Cell error ratio** = b/g = 8/20,000 = 4E-4
- **Cell misinsertion rate** = d/k = 2/10 = 0.2 per second
- **Cell loss ratio** = c/g = 17/20,000 = 8.5E-4
- **SECB ratio** = a/(f+e) = 8/120 = 7.8E-3
- **Mean cell transfer delay** = h = 400 us
- **2-point CDVp-p** = j = 400 us

Note: These are not realistic values! See reference section for derivation of QoS parameters.

Additional Test Capabilities

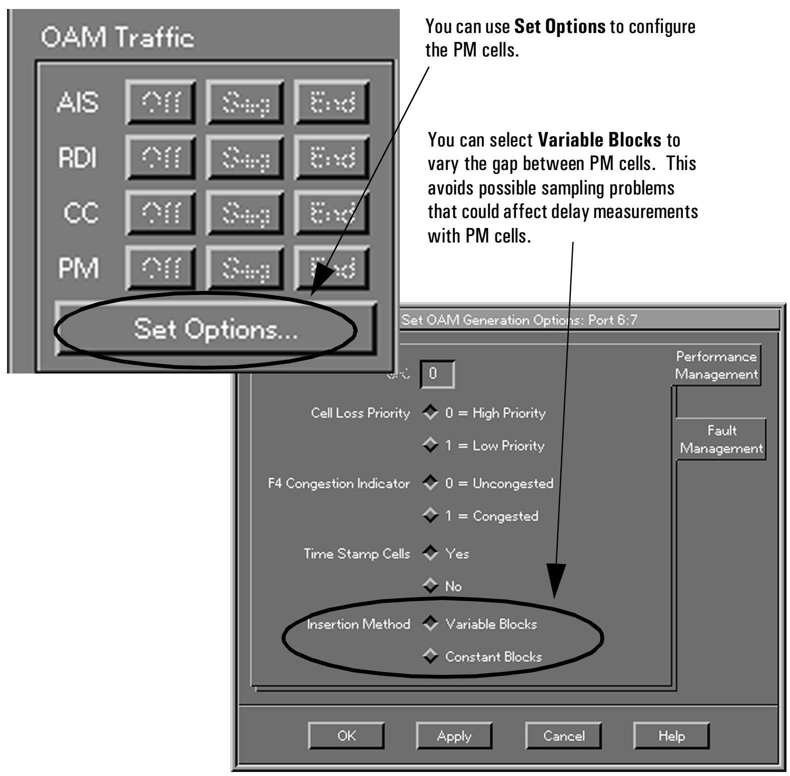
Setting up traffic on the OPT

You can generate up to 124 CBR/VBR channels of user traffic and OAM PM cells



You can send an AAL-5 PDU or any other type of higher layer PDU which has been encoded to the cell layer and saved as a sequence of ATM cells. (Use the CPP to build a higher layer PDU and encode to the cell layer.)

Traffic options



You can use **Set Options** to configure the PM cells.

You can select **Variable Blocks** to vary the gap between PM cells. This avoids possible sampling problems that could affect delay measurements with PM cells.

Configuring traffic parameters for policing traffic

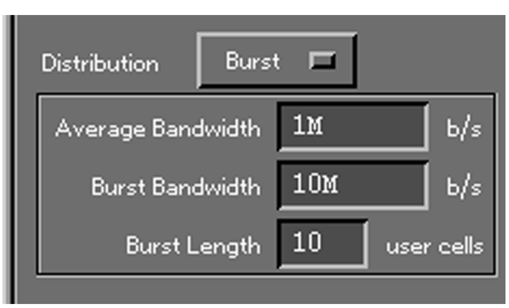
ITU-T O.191 addendum D.5 specifies that the user traffic should have a traffic profile with controllable peak cell rate (PCR), mean cell rate (MCR), and burst size (BS).

This enables policing tests to be carried out for a specified cell delay variation tolerance (CDVT). The 1-point CDV of the transmitted traffic can be calculated as follows:

CDV (1-point) = (BS - 1) * (1/MCR - 1/PCR)

In the example below:

CDV (1-point) = (10 -1) * (1/1E6 - 1/ 1E7) = 8.1 μs



Reference

In this section of the paper, we will provide information on the following items:

- definitions of E6270A (OPT) measurements and their use for both QoS and policing measurements
- more information about traffic generation capabilities of the OPT module
- where to look for more information about OAM and QoS

Definitions of E6270A OPT measurements

Cell errors

- **Errored**
  BIP-16 parity bit error count over block of user cells; does not include PM cells (Note: The errored statistic counts the number of errored bits within the cell block up to the SECB cell error threshold. The default is 3.)
- **Misinserted**
  Misinserted cell count
- **Lost (0)**
  Lost high priority user cells; does not include cells lost in SECBs
- **Total Lost (0)**
  Lost high priority user cells, including cells lost in SECBs
- **Total Lost (0+1)**
  Lost user cells, including cells lost in SECBs

Cell counts

- **Total (0) in PM Blocks**
  Number of high priority user cells transmitted between PM cells
- **Total (0+1) in PM Blocks**
  Number of user cells transmitted between PM cells
- **Min Tagged**
  Number of user cells tagged from high priority (CLP=0) to low priority (CLP=1)
- **Received PM Cells**
  PM cell count (also used as the cell block count); does not include the first PM cell which is used to initialize the statistics
- **Lost PM Cells**
  Number of lost PM cells

Severely Errored Cell Blocks

- **SECB Errored**
  Blocks exceeding BIP-16 parity bit error threshold
- **SECB Misinserted**
  Blocks exceeding misinserted cell threshold
- **SECB Lost (0)**
  Blocks exceeding high priority user cell loss threshold
- **SECB Lost (0+1)**
  Blocks exceeding user cell loss threshold

QoS Parameter	E6270A OPT Measurements
Cell error ratio	Errored / Total (0+1) in PM Block
Cell misinsertion rate	Misinserted / Measurement Interval
Cell loss ratio	Lost (0+1) / Total (0+1) in PM Block
Non-exclusive cell loss ratio	Total Lost (0+1) / Total (0+1) in PM Block
Severely errored cell block (SECB) ratio *	Total SECBs / Received PM cells + Lost PM Cells
Mean cell transfer delay	Mean Delay
Cell delay variation (CDVp-p)	Max-Min Delay

* Total number of cell blocks = received PM cells + lost PM cells

Policing Parameter	E6270A OPT Measurements
Cell tagging ratio (changed from high to low priority CLP=0 to CLP=1)	Min Tagged / Total (0) in PM Block
High priority (CLP=0) cell discard ratio	Lost (0) / Total (0) in PM Block

Using the OPT to monitor traffic policing

- **Total SECBs**
  Total number of blocks that exceed at least one of the above SECB thresholds

Delays

- **Mean Delay** Mean delay experienced by PM cells
- **Max-Min Delay**
  Delay variation experienced by PM cells
- **Min Delay**
  Minimum delay experienced by a PM cell
- **Excessive Delay Count**
  Number of PM cells that exceed the delay threshold

Choosing SECB thresholds

The ITU-T I.356 standard does not specify what the threshold levels for cell error ratio, cell loss ratio, and cell misinsertion rate should be. They need to be agreed upon between the service provider and the service user.

Bellcore GR-1248-CORE *Generic Requirements for Operations of ATM Network Elements* provides additional guidelines for implementing OAM, including SECB thresholds.

Bellcore GR-1110-CORE Broadband *Switching System (BSS) Generic Requirements* does not discuss SECBs, but provides guidelines to acceptable limits for other QoS parameters (for example, cell error, loss, and delay) for various types of services operating over ATM (cell relay service, SMDS, Frame Relay, DS1/DS3 circuit emulation)

Acronyms

AAL	ATM Adaptation Layer
AIS	Alarm Indication Signal
ATM	Asynchronous Transfer Mode
BIP	Bit Interleaved Parity
BSS	Broadband Switching System
BSTS	Agilent Broadband Series Test System
CBR	Constant Bit Rate
CDV	Cell Delay Variation
CLP	Cell Loss Priority
CPP	Agilent E4209B Cell Protocol Processor
ITU-T	International Telecommunications Union - Telecoms
LAN	Local Area Network
LANE	LAN Emulation
LIF	Line Interface
MP	Measurement Point
MPEG	Motion Pictures Expert Group
OAM	Operations, Administration and Maintenance
OPT	Agilent E6270A OAM Protocol Tester
PCR	Peak Cell Rate
PM	Performance Management
QoS	Quality of Service
RDI	Received Defect Indication
SECB	Severely Errored Cell Block
SECBR	Severlely Errored Cell Block Ratio
TUC	Total User Cell Count
VBR	Variable Bit Rate
VCC	Virtual Channel Connection
VCI	Virtual Channel Indicator
VPC	Virtual Path Connection

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