

Can you be sure that there are no weak links?

Application Note 55



Advanced Broadband Testing:
ATM QoS
Traffic Contract
Signalling
Monitoring
ATM Service



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Communications Test Solutions



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Can you rely on your connection quality?

ATM offers many benefits over other network technologies:

- Diverse services possible in a single network
- Flexible bandwidth arrangements
- A single transport technology with different access rates
- Quality of service (QoS) can be varied
- Traffic management offers control mechanisms.

Within ATM networks, it is important to test and monitor the quality of service (QoS), in addition to testing and monitoring the various functions. QoS depends on the lines used, the network elements, the switches and their instantaneous utilization.

ATM service providers must be able to offer proof of QoS to their customers. Fortunately, the latest test equipment can provide such proof.

In the ATM world, an increasing number of services are offered using switched virtual circuits (SVCs). Due to the complexity of the ATM signaling involved, bugs in the signaling software can take quite some time to detect. Currently, SVC applications are being integrated into the test procedures. The latest ATM test sets use the signaling to automate QoS tests.

The ABT-20 Advanced Broadband Tester enables fast and effective testing of ATM SVC equipment in terms of the functionality and quality of service (QoS).

Turn-up: A fast test of UNI signaling

We begin by turning up and testing an ATM switch. With SVC services, it is important to have access to (at least) one signaling protocol. Using a single ABT-20, you can make a fast signaling check in *Self Call* mode. Here, the UNI 3.1 standard specified by the ATM Forum is tested.

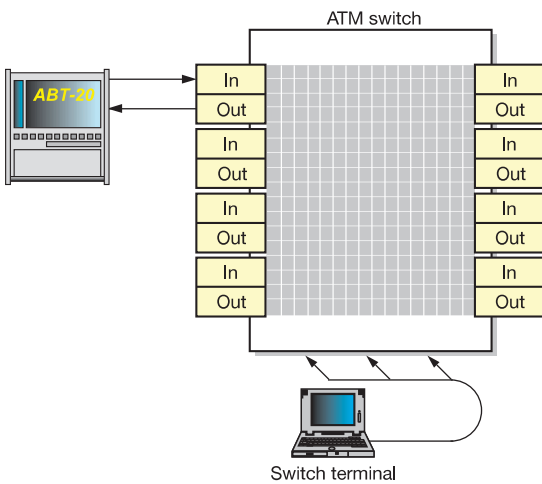


Fig. 1: Connecting the ABT-20 for a Self Call

Simply connect the ABT-20 as shown in Fig. 1 to a port on the switch. Set up a signaling channel on the switch port:

- Switch the chosen port to *Public UNI*
- Set the desired signaling protocol (here, UNI 3.1)
- Configure the ATM address of the port

The clearly arranged, interactive user interface makes it easy to configure the instrument. A few mouse-clicks are all it takes to set the essential

parameters (physical layer, signaling protocol, instrument address, *Self Call* mode, test channel usage). The settings are displayed immediately, as shown here:

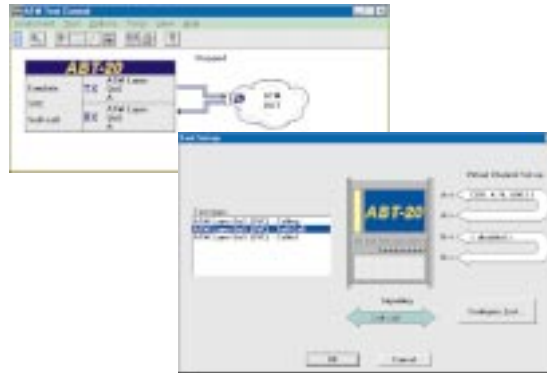


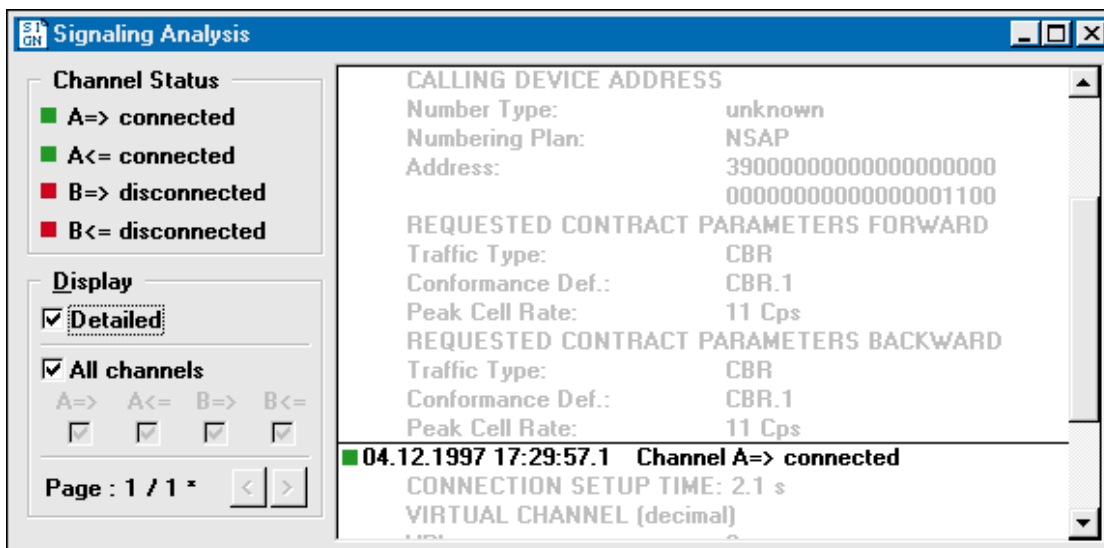
Fig. 2: Configuring Self Call mode

Now start the measurement. The signaling procedure is displayed in the *Signaling Analysis* window. Call setup can fail for a variety of reasons, including:

- No resources available
- No VCI/VPI available
- Requested QoS not available
- Called party does not answer
- Incorrect address format
- Improperly set protocol stack
- Service not available

In our case, however, call setup worked. The *Signaling Analysis* window provides some details.

Fig. 3: The Signaling Analysis window



Turn-up

SVCs – Switched
Virtual Circuits (p. 10)
→ Signaling
→ Addressing in ATM networks
Quality of Service (QoS)
(p. 12)

Acceptance

- Traffic management (p. 14)
- Traffic management functions (p. 14)
 - UPC
 - Policing
 - Traffic shaping
- Traffic contract (p. 13)
 - Source parameters
- GCRA or the "leaky bucket" algorithm (p. 14)
 - Tagging
 - Dropping

Acceptance: Does the UPC monitor all the parameters?

Usage Parameter Control (UPC) functions are designed to prevent non-conforming ATM traffic from one subscriber from disrupting other subscribers. The availability and quality of UPC functions are important considerations when selecting a switch. UPC – also known as policing – is an important part of traffic management. During acceptance, we test how well a switch supports policing functions. The ABT-20 is optimized for such work. This test is simplest in *Self Call* mode. It involves two steps: An ATM test channel is first specified with all of its parameters (traffic contract, connection type, etc.). After the call is set up, the response of the UPC is tested during the second step by intentionally manipulating the transmit behavior of the instrument (conforming/non-conforming traffic).

Sample case: Testing the UPC functions with an nrt-VBR connection in *Self Call* mode

We proceed as follows: First, the traffic contract is negotiated between the test instrument and the switch, then it is tested with conforming (Case 1) and non-conforming traffic (Case 2).

Traffic contract:

- Select the contract parameters for an nrt-VBR connection:
- | | |
|-----------------|-----------|
| PCR: | 15 Mbit/s |
| CDVT peak: | 60 μs |
| SCR: | 4 Mbit/s |
| BT: | 800 μs |
| CDVT sustained: | 120 μs |

These settings are easy to make in the *Traffic Contract* input field.

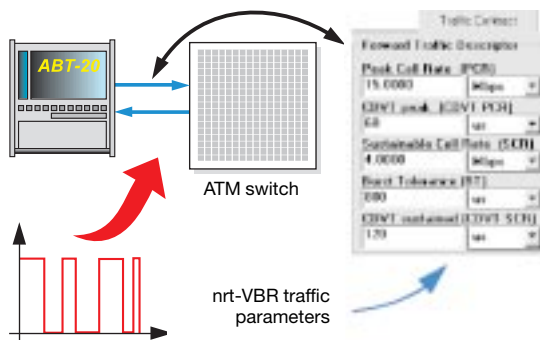


Fig. 4: Setting the traffic contract parameters

- Set the *Source Parameters* so that the traffic complies with the contract.
- Make sure that the addressing and signaling protocol are properly set on the switch and the instrument.
- Begin the measurement.

In the *Source Parameters* field, you can now intentionally manipulate the transmit behavior of the ABT-20:

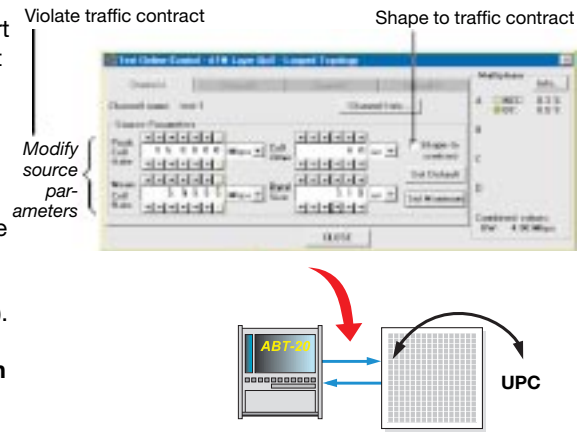


Fig. 5: Checking the source parameters in real-time

Case 1:

Generation of conforming ATM traffic

Check the contract settings of the switch again, particularly the CDVT value. By activating the *Shape to contract* button, you ensure that the instrument generates conforming traffic. In this case, the switch may not discard any cells.

Case 2:

Generation of non-conforming ATM traffic

Deactivate the *Traffic Shaper (Shape to Contract)* button). You can now violate the traffic contract with the source parameters. Use the following test strategy to check whether the switch monitors all source parameters.

Note: To be able to measure cell losses, the switch must be set to immediately discard non-conforming cells and not just tag them.

Use the *Set Maximum* button to set all source parameters to the maximum value at which the traffic is still conforming. Keep three of the four parameters constant (conforming values). Vary the fourth parameter and enter non-conforming ranges. The *Test Setup* window will show what % of the cells are non-conforming.

Here is an example based on values from the previous example:

Traffic (contract) parameter		Source parameter		
PCR:	15 Mbit/s	PCR	16 Mbit/s	Non-conforming Conforming Conforming Conforming
CDVT peak:	60 μs	Cell Jitter	60 μs	
SCR:	4 Mbit/s	MCR	3.9995 Mbit/s	
BT:	800 μs	Burst Size	319 μs	
CDVT sustained:	120 μs			

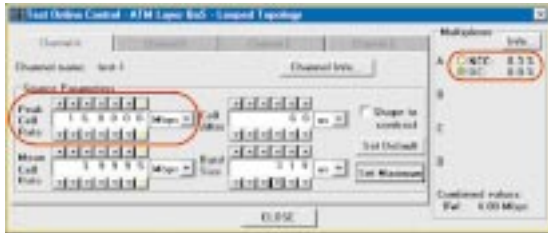


Fig. 6: Displaying non-conforming cells

Operation: Verifying end-to-end connection quality

ATM service providers have to provide proof of end-to-end quality of service to their customers. This is reflected in the QoS parameters. Using two ABT-20s, you can make an end-to-end measurement for determining the error-related QoS parameters (CLR, CMR, CER). Here, it is very useful to measure with the service category to be used later.

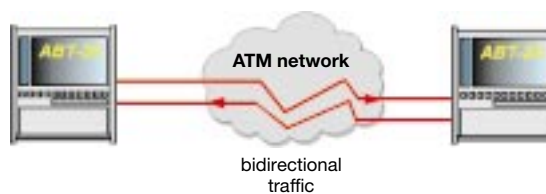


Fig. 7: Simulating bidirectional ATM traffic

Sample case: Simulating a link between two PBXs

We would like to connect two PBXs via a 2 Mbit/s leased line. Using two ABT-20s, we can test the performance of the ATM link prior to setting up the connection. In this case, the CBR service category is used, but a bidirectional PVC must be switched through the network beforehand. Using extra UBR channels, additional data traffic can be simulated in order to test whether such traffic influences the higher-priority CBR traffic in any way.

A suitable time interval must be scheduled for measuring error-related QoS parameters. We'll look at this problem based on the CLR example: The orders of magnitude of the cell loss rates critical to services are between 10^{-10} and 10^{-5} . At a cell loss rate of, say, 10^{-10} , one cell out of 10,000,000,000 correctly received cells is lost. If no cell loss occurs, then we have CLR = 0 no matter whether 10 or 10,000,000,000 cells were analyzed. The following table shows the minimum number of cells that must be analyzed to justify the assessment "CLR = x". The test interval is thus a function of the cell rate or the bit rate of the test channel, i. e. the higher the bandwidth, the more test cells pass through the device under test per time interval.

CLR of ... means	1 cell loss within	On following interface (gross bit rate) full load		Test time for CLR assessment
10^{-5}	100 000 cells	DS1	(1.5 Mbit/s)	approx. 28 sec
10^{-5}	100 000 cells	E1	(2 Mbit/s)	approx. 22 sec
10^{-5}	100 000 cells	E3	(34 Mbit/s)	approx. 1.25 sec
10^{-5}	100 000 cells	DS3	(45 Mbit/s)	approx. 1 sec
10^{-5}	100 000 cells	STM-1	(155 Mbit/s)	approx. 0.3 sec
10^{-10}	10 000 000 000 cells	DS1	(1.5 Mbit/s)	approx. 33 days
10^{-10}	10 000 000 000 cells	E1	(2 Mbit/s)	approx. 25 days
10^{-10}	10 000 000 000 cells	E3	(34 Mbit/s)	approx. 35 hours
10^{-10}	10 000 000 000 cells	DS3	(45 Mbit/s)	approx. 26 hours
10^{-10}	10 000 000 000 cells	STM-1	(155 Mbit/s)	approx. 8 hours

Operation

- PVCs – Permanent
- Virtual Circuits (p. 10)
- ATM service categories (p. 11)
 - CBR
- QoS parameters (p. 12)
 - CLR

Interworking

PVCs and SVCs (p. 10)
 SVCs – Switched
 Virtual Circuits (p. 10)
 → Signaling
 → Addressing in ATM
 networks
 → ITU-T E.164 address
 Quality of Service (QoS)
 (p. 12)

In the *Quality of Service results* window, we see in addition to the QoS parameters the number of analyzed cells. If no errors occur (e. g. CLR = 0), we can tell quickly how many more cells must be analyzed to obtain a reliable assessment for the error-related QoS parameters.

ERROR RELATED RESULTS	Total		Intermediate	ACTIVITY	
	Count	Rate		Analyzed Cells	LPAC
Cell Loss	0	0.000000	0	8574085	
Cell Error	0	0.000000	0		38
Cell Misans.	0	0.000000	0		5
SECB	0	0.000000	0		

Fig. 8: Error-related QoS results

Example:

Building an out-of-service (OOS) performance management system

We can build a non-network-dependent (OOS) performance management system by permanently connecting several ABT-20s to central network nodes for long-term measurements. For test purposes, it is best to select representative connections. The Fig. below shows a backbone with five nodes:

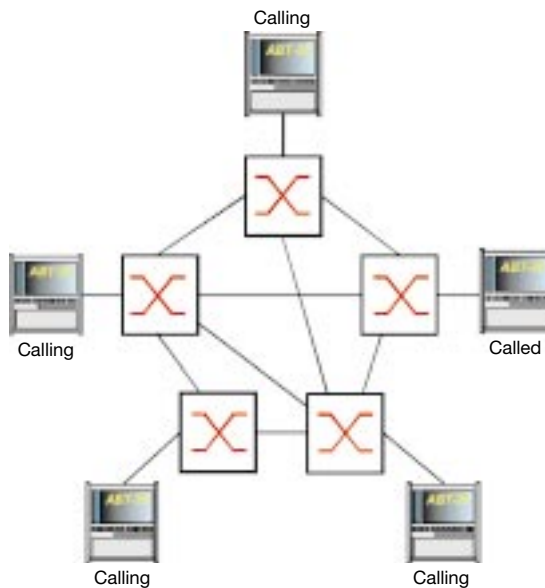


Fig. 9: Testing network performance with multiple ABT-20s

One of the five ABT-20s acts as a test server that is called by the other instruments for performance measurements. Based on the instrument log, we obtain a statistical overview which is useful for analyzing network performance.

Interworking: Accessibility of subscribers across a network interconnection

Interconnecting ATM networks via different carriers is a major challenge due to the complexity of the operations between the interfaces. Acceptance testing is very complicated as a result.

In the following sample case, two carriers are interconnected, and PVC services have already been implemented across the network limits. We now wish to expand the range of services to include SVCs. The quality of service was already checked using a few long-term measurements on several representative permanent links (see also the section “Operation: Verifying end-to-end connection quality”). To provide ATM switched virtual circuits (SVCs) across network limits, the signaling must work properly and channel transparency must be ensured. It is also of interest to compare the QoS values for the SVC connections with those for the PVC connections.

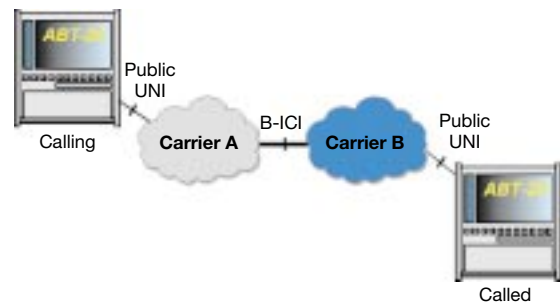


Fig. 10: Checking accessibility across a network interconnection

Using two ABT-20s, we can make sure that two subscribers are mutually accessible by simulating a call setup between two terminals.

- First use *Self Call* tests for both ABT-20s to verify whether the device addresses are known to the network (see also the section “Turn-up: A fast test of UNI signaling”).
- Now configure one instrument in *Calling* mode and the other in *Called* mode (*Test Setup* window, see also Fig. 2).

The ABT-20 acts like a terminal – it handles the common signaling protocols and addressing types. The input dialog field makes it easy to enter the address (see Fig. 11).

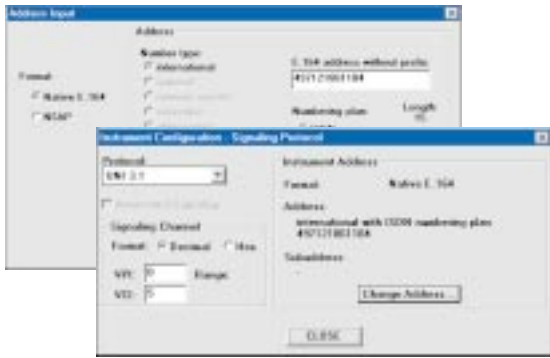


Fig. 11: Entering the address

In this case, an E.164 address is needed since the signals pass via a public UNI interface and this address format is the only one currently specified. Are the E.164 addresses properly forwarded between the networks?

- Start the measurement. Can the *called* ABT-20 be reached? Look in the *Test results: Signaling* window of the *calling* ABT-20 to make sure.

Suggestion: Use an instrument in *Remote Operation* mode.

Benchmarking: What's the cell transfer delay (CTD) of an ATM switch?

In ATM networks, delay parameters are relevant to the quality of many timing-critical services. The cell transfer delay (CTD) is a function of the physical signal delay and the delays in the switches. The CTD in the switches itself is a function of many other conditions (utilization, buffering capacity, etc.) The cell delay variation (CDV) parameter can be used to represent the fluctuation of these conditions.

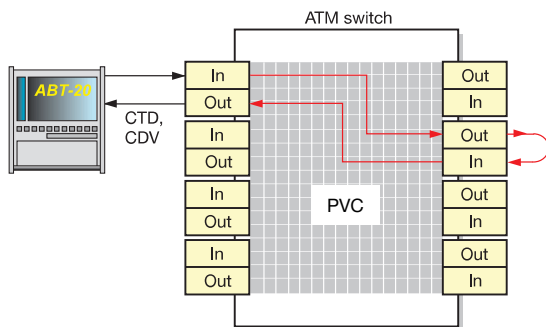


Fig. 12: CTD/CDV measurements on an ATM switch

An ATM connection can pass via multiple switches. Poor CTD figures in the switches along the path can accumulate to produce unacceptable values for the overall connection. Accordingly, a benchmarking test is useful since it compares the CDV and CTD figures for individual ATM switches.

- Connect the ABT-20 to a port of the switch, as shown in the Fig.
- Short-circuit another port and create a *physical layer loop* by setting the same VCI/VPI value for Rx and Tx on the short-circuited port.
- Set up a bidirectional connection (PVC) through the switch.

Configure the instrument:

- To measure the delay parameters, the port configuration must be *Looped*.
- Select a representative test channel. It is best to use one with a timing-critical nature (CBR, 2 Mbit/s bandwidth). Of course, the ABT-20's VCI/VPI values for Rx and Tx must match those of the connected port of the switch.

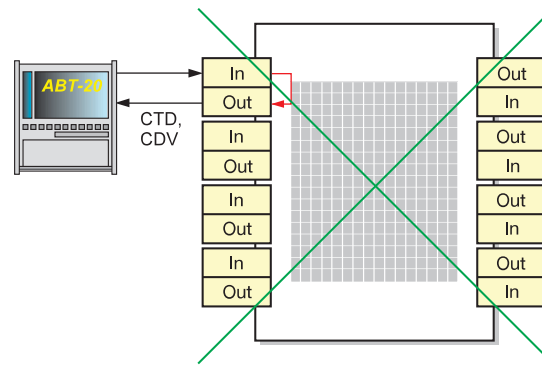


Fig. 13: Improper test setup

Note: If the test loop is internal (*ATM layer loop*), the test cell path through the switch is unknown. The test cells might be directly switched back at the port and not pass through all parts of the switch architecture. This yields corrupt results.

Start the measurement. In the *Quality of Service results* window, you will see the delay-related parameters in addition to the error-related ones. Note: The DUT (the switch) is traversed twice so that the measured CTD value is for the double path. In other words, divide the result by two. The CDV value is also a function of the transmission rate of the interface used. This is important if you wish to compare the results with other measurements. Typical values for CTD are between 10 and 100 ms for the 155 Mbit/s interface, and the results fluctuate greatly depending on the background load (real-life situation).

Benchmarking

QoS parameters (p. 12)
→ CTD
→ CDV

Further measurements:

- Make another test with an additional background channel. A good choice is an nrt-VBR channel with high burstiness. Does this influence the CBR channel?
- Connect the test channel via multiple ports (see Fig. 14). This tests passage via multiple ATM switches.

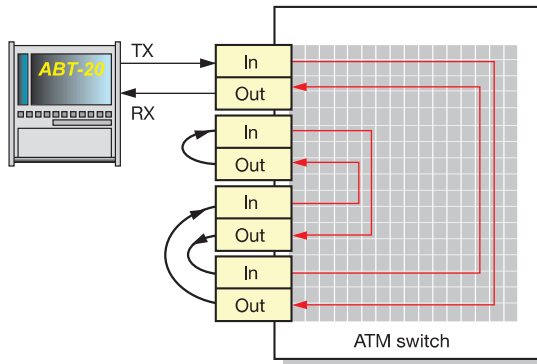


Fig. 14: Test channel connected via multiple ports

Installation: What to do if ATM tests aren't possible?

In ATM testing, there are some problems that can prevent us from starting the actual measurements. For example, poor lines, incorrect levels or faulty connectors can produce physical layer defects. We have to correct these faults before analyzing the signaling or measuring the quality of service. The ABT-20's *Receiver Status* window provides a fast overview that is useful for spotting errors:

- *Physical layer defects*
If an error in the physical layer is displayed in the *Receiver Status* window, the ABT-20 offers several options: The first option, a look at the built-in optical power level meter in the *Signal Structure* window, is helpful for checking whether the optical connections are functional.



Fig. 15: Displaying the optical power level in the *Signal Structure* window

In the ABT-20's *Anomaly and Defect Analyzer* window, you can also examine the PL defect in detail (resolution: 100 μ s).

Besides the histogram shown in Fig. 16, other windows show the anomalies and defects in tabular format with precise timing information and in numerical format as error rates.

- *LCD (loss of cell delineation)*
If LCD errors are detected, then cell synchronization is lost (no synchronization to cell headers is possible). The received signal is faulty. → Further analysis with the *Anomaly & Defect Analyzer*.
- *Header errors*
If header errors occur regularly, check the "Switch – ABT-20" connection. Here too, you can view the optical power level meter in the *Signal Structure* window. Maybe the received level is close to the limit and is causing header errors.
- *Overall bandwidth*
If no ATM cells are received, e. g. due to *physical layer defects*, then an asterisk (*) appears. If a value is shown, then the ATM layer is present and active, and the value represents the sum of the bandwidths for the four test channels. This is a fast way of telling whether the utilization is on the right order of magnitude. If the value is 0 Mbit/s, ATM cells are being received (e. g. idle cells), but not any test cells.



Fig. 16: Detecting the error in the *Receiver Status* window and further analysis with the *Anomaly/Defect Analyzer*

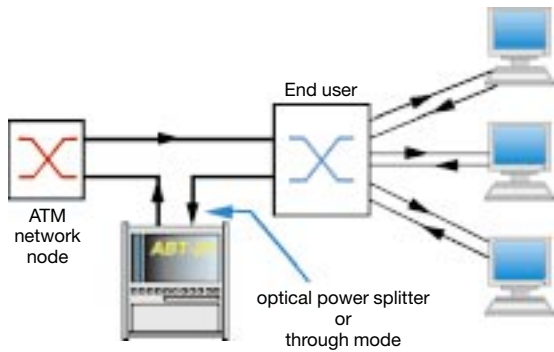


Fig. 17: Connecting the ABT-20 for monitoring

Monitoring: How are new end users behaving?

The ABT-20 includes facilities for monitoring ATM signals. One real-world application involves monitoring how a newly connected end user behaves. Do the traffic rates conform with the agreed rates? What virtual channels (VCI/VPI) are currently active? What bandwidth do the individual channels require? Are there ATM alarms (e. g. VC-AIS) in the signal?

To monitor the signal, we can use the built-in *Optical Power Splitter* to divert 10 % of the test signal. To check an electrical signal, the ABT-20 can be operated in *Through Mode*. In both cases, ABT-20 monitors the signal with practically no effect on the communications (“in-service monitoring”).

Once we’ve connected the instrument as shown in Fig. 17, we can use the *Channel Explorer* to obtain various information about the end user, e. g.:

- With the *Channel Scan* function, we can check the VCI/VPI range used by the customer. To do this, we let the scan run unattended for some time interval (e. g. 1 day). Besides the currently active channels, we can also see which VCI/VPI values were used during this time. Using the *Aging* button, we can sort out the no longer active channels, thereby limiting the display to the currently used channels.
- For the detected channels, the bandwidths are now determined, including the current bandwidth (CuBW) and the average bandwidth (AvBW). This information helps to make an initial conclusion about the channel service type (if $AvBW = CuBW \rightarrow$ CBR service) and in case of high CuBW figures (compared to the AvBW) to conclude that the burstiness is high. We can also sort the channels by bandwidth and determine what connections are most bandwidth-intensive.

- In the *Channel Explorer* window, there is more information on the CLP-1 bandwidth. If CLP-1 bandwidths are detected in some of the customer’s virtual channels, we can conclude that the traffic was non-conforming and cells were tagged but not necessarily all dropped.
- With the *AAL Scan* and *AAL Type Distribution*, we obtain more information about the services used.
- Besides the *Channel Scan*, the *Channel Explorer* window also includes a *Trouble Scan*: This is useful for determining what connections (ATM layer) contain alarms, e. g. VP-AIS or VC-RDI. This lets us know what channels the customer has problems with in order to take a closer look at these channels.

Overall, the *Channel Explorer* provides much useful information about ATM traffic of an end user. This information allows us to configure the network more efficiently and check whether the customer complies with agreed values.

No.	VPI	VCI	Cl BW (%)	CLP1-BW (%)	AvBW (Mbps)	CuBW (Mbps)	AAL
1	0	0	0.00	100.00	22.78	27.26	Unset
2	0	33	0.00	0.00	11.51	13.06	AAL 3/4
3	0	35	0.00	0.00	7.50	8.54	AAL 3/4
4	0	40	0.00	0.00	0.00	0.00	Unchecked
5	0	50	0.00	0.00	2.93	4.45	AAL 3/4
6	0	4040	0.00	0.00	14.82	15.75	AAL 3/4
7	1	990	0.00	0.00	52.00	53.34	AAL 1
8	2	992	0.00	0.00	7.00	8.01	Unset
9	3	993	0.00	0.00	1.53	1.75	Unchecked
10	120	21010	0.00	0.00	25.62	33.77	AAL 5
11	200	40	0.00	0.00	5.96	6.74	AAL 3/4

Fig. 18: The *Channel Explorer* window

Monitoring

ATM service categories
(p. 11)
→ CBR
→ UBR

PVCs and SVCs

Turn-up: ... (p. 3)

→ Signaling

→ Addressing

Operation: ... (p. 5)

→ PVC

Interworking: ... (p. 6)

→ PVC

→ SVC

→ Addressing

→ E.164 address

Background

PVCs and SVCs

There are two basic connection types in ATM networks:

- Permanent Virtual Circuits (PVCs)
- Switched Virtual Circuits (SVCs)

There are also permanent virtual paths (PVPs) for bundled (multiplexed) connections. PVPs can transport PVCs as well as SVCs.

Call setup in ATM networks

ATM is a connection-oriented technology, meaning a virtual connection must be set up through the network between subscribers **prior to** communication. Call setup is necessary to clear up a few details:

- The called party
- The required bandwidth
- The service type (e. g. video = constant bit rate with a fixed time reference)

A traffic contract is negotiated between the subscribers and the network. For more information about traffic contracts, see page 13.

PVCs (Permanent Virtual Circuits)

PVCs are very similar to leased lines, except that a **virtual** ATM channel takes the place of the actual physical line. PVCs are most cost-effective when a connection is required over a longer time interval to meet a long-term demand for communications between two sites, for example. Repeatedly setting up a circuit (i. e. assignment of VCI/VPI values) over a short period of time would be wasteful since each call setup and clear-down operation costs time and money.

It is not uncommon to have to order PVCs several days in advance by fax or telephone. Without central management, the connections (VCI/VPI values) must be manually set on each switch terminal involved.

Network management can be centralized, e. g. using a computer connected to all network elements (see Fig. 19).

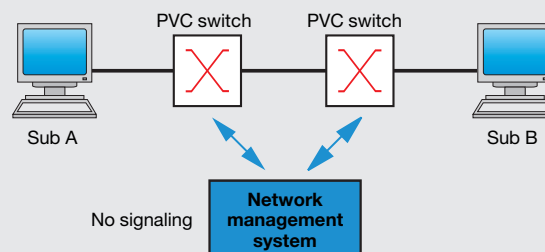


Fig. 19: Setting up a PVC connection

SVCs (Switched Virtual Circuits)

An ATM network without signaling (→ PVC) is like a telephone network without dialing capabilities. We need our little “operator” to connect our call. In ATM-SVC networks, terminals can dynamically set up and clear down connections. However, ATM network elements (NEs) and ATM terminals (TEs) must have a certain degree of local intelligence and speak the same language. In this case, the intelligence comes in the form of signaling implemented in the various elements using a signaling protocol (the common language). This is costly since not all network elements and terminals have signaling capabilities. Standards for signaling protocols are developed by the ITU-T (e. g. Q.2931) and the ATM Forum (e. g. UNI 3.1). It is important to note that there are some differences in these standards. ATM signaling works by exchanging messages, represented in Fig. 20 using arrows.

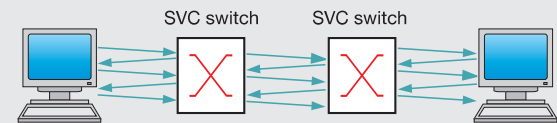


Fig. 20: Setting up an SVC connection

Messages are exchanged using special ATM cells in the virtual signaling channel (VPI = 0, VCI = 5) reserved for this purpose. For a proper (user) connection, the following points must be cleared up in the network:

- The accessibility of the called party
- The route through the network
- The available resources (bandwidth, etc.)

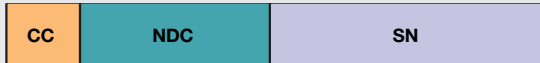
A virtual channel (traffic channel) is established between the ATM switches involved.

Addressing in ATM networks

Each subscriber in an ATM network using dial-up connections needs an ATM address (telephone number) to be reached.

ITU-T E.164 address

E.164 specifies addresses for (narrowband) ISDN, including normal telephone numbers. An address consists of a maximum of 15 characters, each of which is BCD-encoded. It is structured in three parts with regional codes (CC, NDC) and the actual telephone number (SN). The character lengths vary from country to country.



CC: Country Code
 NDC: National Destination Code
 SN: Subscriber Number

Fig. 21: ITU-T E.164 address

NSAP address formats:

These are 20 bytes long and consist of network-specific and device-specific parts. To distinguish the different formats, one byte is reserved for the format indicator (AFI – Authority and Format Identifier). The device-specific part of the address has 6 bytes (ESI – End System Indicator) and can contain, e.g. a 48-bit MAC address, commonly known as a “hardware” address.

the start and in the last byte, padding (“1111” or “F” hex) is inserted to have a full 8 bytes.

DCC-(Data Code Country) and ICD-(International Code Designator) format

It is indicated in the AFI whether the DCC format (country-oriented hierarchies) or ICD format (organizational hierarchies) is used.

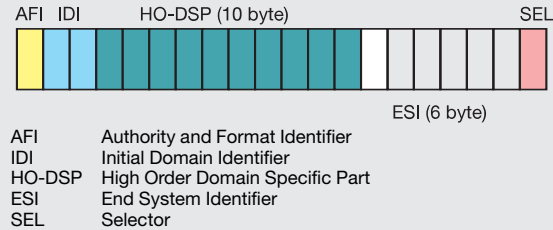


Fig. 23: NSAP address (DCC/ICD format)

Integrated ITU-T E.164 address:

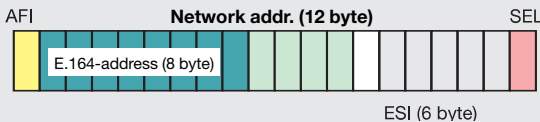


Fig. 22: Integrated ITU-T E.164 address

Since E.164 addresses have a maximum of 15 characters (7.5 bytes), zeroes are used as fillers at

ATM service categories

As was mentioned in the introduction, ATM networks are characterized by a variety of services which meet the requirements of diverse applications. Since the ITU-T and ATM Forum use different names for these services, Table 1 provides a summary of the standardized services.

ATM service categories

- Acceptance: ... (p. 4)
→ nrt-VBR
- Operation: ... (p. 5)
→ CBR
- Benchmarking: ... (p. 7)
→ CBR
- Monitoring: ... (p. 9)

ATM-Forum	ITU-T	Possible traffic profile	Description/ Applications
Constant Bit Rate CBR	Deterministic Bit Rate DBR		Constant bit rate with time reference (real-time) Speech, video
Real-time Variable Bit Rate rt-VBR	under study		Variable bit rate with time reference (real-time) Compressed video/audio
Non real-time Variable Bit Rate nrt-VBR	Statistical Bit Rate SBR		Variable bit rate without time reference File transfer
Available Bit Rate ABR	Available Bit Rate ABR		Resource-dependent bandwidth-allocation, network has interactive control
Unspecific Bit Rate UBR	-		No guarantee for traffic and QoS parameters

Table 1: Summary of ATM service categories

ATM service categories (p. 11)

- GCRA or “leaky bucket” algorithm (p. 14)
→ CLP-1, tagging
→ Dropping

Of course, these different service categories each represent concrete applications. It is not always possible to say what service category is suitable for what application. Table 2 provides a summary based on some more concrete applications.

	CBR	rt-VBR	nrt-VBR	ABR	UBR
Critical data	★	✓	↑	✓	✗
LAN interconnect	✓	✓	★	↑	★
WAN transport	✓	✓	★	↑	★
Circuit emulation	↑	★	✗	✗	✗
Telephony, Video-conferencing	↑	?	?	✗	✗
Compressed audio	✓	↑	★	★	✓
Video distribution	↑	↑	✓	✗	✗
Interactive multimedia	↑	↑	★	★	✓

↑ Optimum ★ Good ✓ Fair
 ✗ Not suitable ? Under review

Table 2: ATM service categories and applications
(Source: ATM Forum)

Mean cell transfer delay (MCTD) is the arithmetic mean of a certain number of CTD values.

Cell Delay Variation (CDV) is the fluctuation range of the cell transfer delay on a virtual connection. The quality of service definition enables differentiation of services offered (e. g. using different guarantees for cell loss ratios) and can be used by service providers as a means of varying prices. However, the service provider must then be capable of proving the actual QoS to the customer.

QoS measurement as per ITU-T O.191 (How do we measure?)

In Recommendation O.191, the ITU-T specifies test methods for use in verifying the QoS on the ATM layer. Rec. O.191 is the ideal replacement for manufacturer-specific and otherwise deficient test methods previously in use.

O.191 specifies a diagnostics model for performance analysis in which test cells are transported via a specific virtual circuit. This is an out-of-service measurement.

Note: The measurement described in O.191 measures the performance on a cell basis, i. e. on the ATM layer. The functionality and performance of the individual AALs must be considered separately.

Quality of Service Measurements

Operation: ... (p. 5)
→ CLR

Interworking: ... (p. 6)

Benchmarking: ... (p. 7)
→ CTD
→ CDV

Quality of Service (QoS)

QoS parameters (What do we measure?)

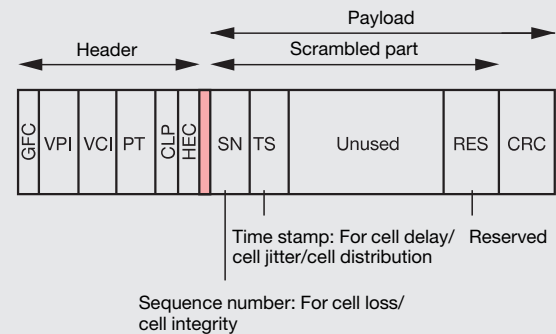
The following parameters are defined in Recommendation ITU-T I.356 and represent the results from a QoS test:

$$\text{Cell loss ratio (CLR)} = \frac{\text{Lost cells}}{\text{All transmitted cells}}$$

$$\text{Cell error ratio (CER)} = \frac{\text{Errored cells}}{\text{All transmitted cells (including errored)}}$$

$$\text{Cell misinsertion rate (CMR)} = \frac{\text{Misinserted cells}}{\text{Time interval}}$$

Cell transfer delay (CTD) is equal to $t_2 - t_1$ for a given test cell:
 t_1 : time of entry of cell into DUT
 t_2 : time of exit of cell from DUT



- GFC: Generic Flow Control
- VPI: Virtual Path Identifier
- VCI: Virtual Channel Identifier
- PT: Payload Type Identifier
- CLP: Cell Loss Priority
- HEC: Header Error Control
- SN: Sequence Number
- TS: Time Stamp
- RES: Reserved
- CRC: Cyclic Redundancy Check

Fig. 24: Basic structure of a test cell

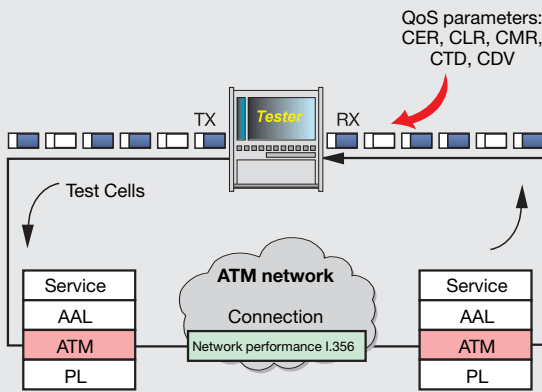


Fig. 25: Measuring performance/QoS parameters as per ITU-T O.191

- **Sustainable Cell Rate (SCR):** Upper limit of average cell rate that the source may transmit.
- **Cell Delay Variation Tolerance (CDVT) sustained:** Cell delay variation tolerance, referred to sustained cell rate.
- **Maximum Burst Size (MBS)/Burst Tolerance (BT):** Maximum time or cell burst that the source PCR may transmit.
- **Minimum Cell Rate (MCR):** Minimum cell rate guaranteed by network (for ABR)

Traffic Contract

ATM services are classified according to various criteria:

- The service type, characterized by the traffic parameters
- The service quality, characterized by the QoS parameters

The main properties must be negotiated prior to communication as part of a **traffic contract**.

Traffic parameters

The service type is characterized by the traffic parameters:

- **Peak Cell Rate (PCR):** Maximum bit rate that the source may transmit
- **Cell Delay Variation Tolerance (CDVT) peak:** Tolerance for cell delay variation referred to the peak cell rate. This is usually specified by the operator.

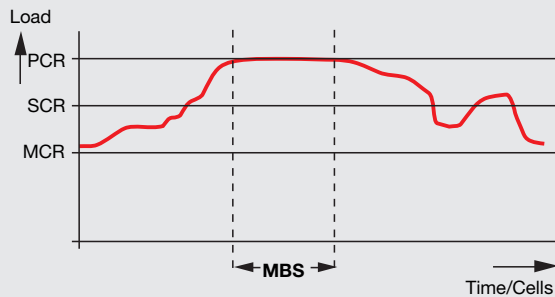


Fig. 26: ATM traffic parameters

Note: The traffic parameters stipulated in the traffic contract are only **indirectly** related to the source parameters of terminals. The source parameters reflect the transmit behavior of ATM terminals; they should not exceed the traffic parameters. Not all parameters are needed for every service category. For example, CBR only requires values for PCR and CDVT_{peak} (see also Table 3).

Summary

Attributes	CBR	rt-VBR	nrt-VBR	UBR	ABR	Parameter class
CLR	defined	defined	defined	not defined	defined	QoS
CTD and CDV	CDV and Mean CTD	CDV and Max CTD	only Mean CTD	not defined	not defined	QoS
PCR and CDTV	defined	defined	defined	defined	defined	Traffic
SCR and BT	not usable	defined	defined	not usable	not usable	Traffic
MCR	not usable	not usable	not usable	not usable	defined	Traffic

Table 3: Service categories and their parameters

Traffic contract
 Acceptance: ... (p. 4)
 → Traffic parameters
 → Source parameters

QoS classes

QoS classes are service-dependent. The following classes currently exist:

- Class 0: Unspecified
- Class 1: Circuit emulation, CBR video
- Class 2: VBR audio and video
- Class 3: Connection-oriented data traffic
- Class 4: Connectionless data traffic

The classes are distinguished by specifying different values for the following parameters:

- CTD
- CDV
- CLR (different for CLP = 1 and CLP = 0 cells)

Finer classifications are planned for the future. At the present time, not all systems support negotiation of QoS parameters.

Traffic management

In order to guarantee a specific quality of service for all ATM services, the network must never be loaded past its capacity ("overloaded"). Moreover, individual connections should not affect one another and cause quality degradations. For smooth, concurrent operation of the different virtual channels, various control mechanisms have been introduced under the guise of "traffic management".

Traffic management functions

- *Connection admission control (CAC)*
Checks according to the traffic contract (during the signaling process) whether a connection can have the requested QoS and the QoS will not impair the existing connections.
- *Usage parameter control (UPC) or policing*
Monitors the connection for conformance with the negotiated traffic contract; non-conforming cells are tagged (CLP = 1).
- *Cell loss priority control*
Ensures that tagged cells (CLP = 1) are discarded in case of overload.
- *Traffic shaping*
This is performed by terminals and also by some network elements to ensure that the outgoing cell stream always complies with the traffic contract.

GCRA (generic cell rate algorithm) or the "leaky bucket" algorithm

This algorithm is used in the UPC and in traffic shaping. It is the basis for checking the PCR, SCR and MBS parameters. Imagine a "bucket" holding ATM cells. The size of the leak in the leaky bucket is selected such that the bucket does not overflow for a conforming ATM cell flow.

Starting with a specific fill status, cells are tagged (CLP = 1).

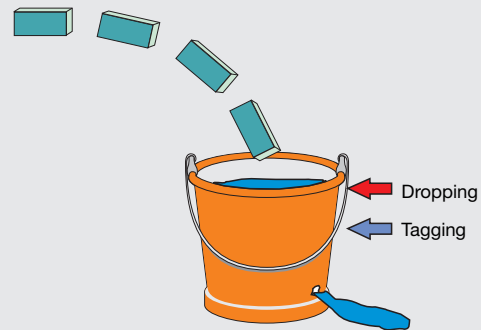


Fig. 27: Illustration of the "leaky bucket" algorithm

In the actual implementation of the algorithm, the bucket is a cell counter. The counter is incremented by one unit for each new incoming cell. In the algorithm the leak rate is the decrement rate that continuously decreases the cell counter by one unit.

It is obtained from the bit rate to be checked (e. g. $1/PCR$) and is determined by the minimum spacing between two successive cells. The bucket volume represents the range of the cell counter and is represented by the allowable tolerance in time of the incoming cells. This value is negotiated as part of the traffic contract or specified by the operator (cell delay variation tolerance, CDVT). If the cell counter now exceeds a specific value, then the cells are non-conforming. Possible responses are tagging (CLP = 1) or dropping of non-conforming cells. If multiple parameters are monitored simultaneously (e. g. PCR and SCR), we use the term "dual leaky bucket"; if a single parameter is monitored, we speak of a "single leaky bucket".

Traffic management

- Acceptance: ... (p. 4)
 - UPC, policing
 - Traffic shaping
 - Tagging, dropping
- Monitoring: ... (p. 9)
 - CLP-1 (tagging)
 - Dropping

Abbreviations

AAL	ATM Adaptation Layer
ABR	Available Bit Rate
AFI	Authority and Format Identifier
ATM	Asynchronous Transfer Mode
BCD	Binary Coded Decimal
B-ICI	Broadband-ISDN Inter-Carrier Interface
CBR	Constant Bit Rate
CC	Country Code
CDV	Cell Delay Variation
CDVT	Cell Delay Variation Tolerance
CLP	Cell Loss Priority
CRC	Cyclic Redundancy Check
CTD	Cell Transfer Delay
DBR	Deterministic Bit Rate
ESI	End System Identifier
GCRA	Generic Cell Rate Algorithm
GFC	Generic Flow Control
HEC	Header Error Control
HO-DSP	High Order-Domain Specific Part
IDI	Initial Domain Identifier
MAC	Media Access Control
MBS	Maximum Burst Size
MCR	Minimum Cell Rate
NDC	National Destination Code
nr-VBR	non-real-time Variable Bit Rate
NSAP	Network Service Access Point
PCR	Peak Cell Rate
PT	Payload Type
QoS	Quality of Service
RES	Reserved
rt-VBR	real-time Variable Bit Rate
SBR	Statistical Bit Rate
SCR	Sustainable Cell Rate
SDH	Synchronous Digital Hierarchy
SEL	Selector
SN	Subscriber Number
SN	Sequence Number
STM	Synchronous Transport Module
TS	Time Stamp
UBR	Unspecified Bit Rate
UNI	User Network Interface
UPC	Usage Parameter Control
VBR	Variable Bit Rate
VCI	Virtual Channel Identifier
VPI	Virtual Path Identifier