INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

O.191

(02/00)

SERIES O: SPECIFICATIONS OF MEASURING EQUIPMENT

Equipment for the measurement of digital and analogue/digital parameters

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Equipment to measure the cell transfer performance of ATM connections

ITU-T Recommendation O.191

(Previously CCITT Recommendation)

ITU-T O-SERIES RECOMMENDATIONS

SPECIFICATIONS OF MEASURING EQUIPMENT

For further details, please refer to ITU-T List of Recommendations.

ITU-T RECOMMENDATION O.191

EQUIPMENT TO MEASURE THE CELL TRANSFER PERFORMANCE OF ATM CONNECTIONS

Summary

This Recommendation describes algorithms and processes for the out-of-service estimation of the ATM layer cell transfer performance by means of the network performance parameters defined in Recommendations I.356 and I.357. Further guidance is provided for in-service measurements and UPC/NPC function performance measurements.

Source

ITU-T Recommendation O.191 was revised by ITU-T Study Group 4 (1997-2000) and was approved under the WTSC Resolution No. 1 procedure on 4 February 2000.

Keywords

ATM Measuring Equipment (AME), Cell Delay Variation (CDV), Cell Error Ratio (CER), Cell Loss Ratio (CLR), Cell Transfer Delay (CTD), Network Performance Parameters (NPP), Out-of-Service (OOS), Reference Load Model (RLM), Test Cell Payload Format, Traffic Profiles, UPC/NPC performance.

FOREWORD

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NOTE

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Introduction and background

The requirements for the characteristics of the ATM measuring equipment (AME) described in this Recommendation must be adhered to in order to ensure that the following objectives are met:

- **Compatibility between test equipment produced by different manufacturers**: any generation of ATM cells by the AME should be equivalent given the same control settings on different test equipment. Any analysis of ATM cell performance by the AME should provide the same results as different test equipment when provided with the same cell stream(s).
- **Compatibility between test equipment and network equipment**: any in-service measurement by the AME of network performance parameters and defects defined in Recommendations I.356 and I.610 should provide the same results as network equipment monitoring when provided with the same cell stream(s).
- **Compatibility between out-of-service and in-service measurements**: any out-of-service analysis by the AME of performance parameters and defects defined in Recommendations I.356 and I.610 should provide higher quality results (in terms of accuracy and robustness) than in-service monitoring when applied to the equivalent network connection(s).

While requirements are given for the AME, the realization of the equipment configuration is not covered and should be given careful consideration by the designer and user. In particular, it is not required that all features listed below shall be provided in one piece of measuring equipment. Users may select those functions which correspond best to their applications.

This revised version is the combination of Recommendation O.191 as approved in April 1997, its Addendum 1, detailing the measurement of error-related and availability-related parameters, as approved in October 1997, and text covering the measurement of delay-related parameters and UPC/NPC performance developed and agreed since the approval of Addendum 1.

Recommendation O.191

EQUIPMENT TO MEASURE THE CELL TRANSFER PERFORMANCE OF ATM CONNECTIONS

(revised in 2000)

1 Scope

This Recommendation describes the functions which an equipment assessing the ATM layer cell transfer performance should fulfil. The measurement or estimation of the ATM adaptation layer performance is not addressed in this Recommendation.

Techniques developed in this Recommendation enable the measurement of the cell transfer outcomes and associated network performance parameters defined in Recommendation I.356 [13]. These parameters are the basis for the characterization of the ATM layer cell transfer performance. Availability decisions used are those specified in Recommendation I.357 [14] and associated availability parameters are measured.

Some guidance on the measurement of the performance of UPC/NPC functions is also given.

Semi-permanent VPCs or VCCs are considered. Currently developed techniques apply to non-tagging networks and ATM connections operated under DBR and SBR ATM Transfer Capabilities (ATCs) specified in Recommendation I.371 [16]. It might be expected that the set of functions provided will be augmented in future in order to take account of switched connections, tagging networks and other ATCs.

This Recommendation focuses on the measurement of error-, availability-, and delay-related parameters in the Out-Of-Service (OOS) mode. It details the complete performance estimation processes, indicates particular and exceptional cases, and specifies actions to be taken in these cases.

Network performance parameters can be monitored, in-service, by the OAM cell streams defined in Recommendation I.610 [21], using techniques developed in Recommendation I.356 [13] together with some guidance given in this Recommendation.

Functions defined in this Recommendation enable ATM Measuring Equipment (AME) conforming to this Recommendation to inter-operate and provide comparable results.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; all users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published.

[1] CCITT Recommendation G.702 (1988), *Digital hierarchy bit rates.*

[2] ITU-T Recommendation G.703 (1998), *Physical/electrical characteristics of hierarchical digital interfaces.*

[3] ITU-T Recommendation G.704 (1998), *Synchronous frame structures used at 1544, 6312, 2048, 8448 and 44 736 kbit/s hierarchical levels.*

[4] ITU-T Recommendation G.707 (1996), *Network node interface for the synchronous digital hierarchy (SDH).*

[5] ITU-T Recommendation G.772 (1993), *Protected monitoring points provided on digital transmission systems*.

[6] ITU-T Recommendation G.804 (1998), *ATM cell mapping into plesiochronous digital hierarchy (PDH).*

[7] ITU-T Recommendation G.823 (1993), *The control of jitter and wander within digital networks which are based on the 2048 kbit/s hierarchy.*

[8] ITU-T Recommendation G.824 (1993), *The control of jitter and wander within digital networks which are based on the 1544 kbit/s hierarchy.*

[9] ITU-T Recommendation G.825 (1993), *The control of jitter and wander within digital networks which are based on the synchronous digital hierarchy (SDH).*

[10] ITU-T Recommendation G.832 (1998), *Transport of SDH elements on PDH networks: Frame and multiplexing structures.*

[11] ITU-T Recommendation G.957 (1999), *Optical interfaces for equipments and systems relating to the synchronous digital hierarchy.*

[12] ITU-T Recommendation I.353 (1996), *Reference events for defining ISDN and B-ISDN performance parameters.*

[13] ITU-T Recommendation I.356 (1996), *B-ISDN ATM layer cell transfer performance.*

[14] ITU-T Recommendation I.357 (1996), *B-ISDN semi-permanent connection availability.*

[15] ITU-T Recommendation I.361 (1999), *B-ISDN ATM Layer specification.*

[16] ITU-T Recommendation I.371 (1996), *Traffic control and congestion control in B-ISDN.*

[17] ITU-T Recommendation I.432.2 (1999), *B-ISDN user-network interface – Physical layer specification: 155 520 kbit/s and 622 080 kbit/s operation.*

[18] ITU-T Recommendation I.432.3 (1999), *B-ISDN user-network interface – Physical layer specification: 1544 kbit/s and 2048 kbit/s operation.*

[19] ITU-T Recommendation I.432.4 (1999), *B-ISDN user-network interface – Physical layer specification: 51 840 kbit/s operation.*

[20] ITU-T Recommendation I.432.5 (1997), *B-ISDN user-network interface – Physical layer specification: 25 600 kbit/s operation.*

[21] ITU-T Recommendation I.610 (1999), *B-ISDN operation and maintenance principles and functions.*

[22] CCITT Recommendation O.3 (1992), *Climatic conditions and relevant tests for measuring equipment.*

[23] ITU-T Recommendation V.24 (2000), *List of definitions for interchange circuits between data terminal equipment (DTE) and data circuit-terminating equipment (DCE).*

[24] ITU-T Recommendation V.28 (1993), *Electrical characteristics for unbalanced double-current interchange circuits.*

[25] ITU-T Recommendation X.25 (1996), *Interface between data terminal equipment (DTE) and data circuit-terminating equipment (DCE) for terminals operating in the packet mode and connected to public data networks by dedicated circuit.*

[26] IEC Publication 60625 (1993), *Programmable measuring instruments – Interface system (byte serial, bit parallel).*

[27] IEEE Standard 488.1 (1987), *IEEE standard digital interface for programmable instrumentation.*

3 Terms and definitions

This Recommendation defines the following terms:

3.1 **CLP = 0**: Cells that have the cell loss priority bit in the payload type indicator set to 0.

3.2 **CLP = 1**: Cells that have the cell loss priority bit in the payload type indicator set to 1.

3.3 **CLP = 0 + 1**: Cells that have the cell loss priority bit in the payload type indicator set to either 0 or 1.

3.4 **CTD hit count**: The number of absolute CTD samples which exceed a programmable CTD threshold.

3.5 **Fx FM**: The OAM fault management flow at the Fx (x = 4 or 5) level as specified in Recommendation I.610 [21].

3.6 **Fx PM**: The OAM performance management flow at the Fx (x = 4 or 5) level as specified in Recommendation I.610 [21].

3.7 **In-service**: The in-service measurement mode makes use of the end user equipment or network elements OAM capabilities for estimating network performance parameters. The connection is available to the end user who is transmitting their own user data on the connection. In this case the user cells are those defined at the F4 (VPC) or F5 (VCC) level as user cells in Recommendation I.610 [21].

3.8 **Out-of-service**: The out-of-service measurement mode makes use of particular test cells transmitted, generally by a test equipment, on a connection for estimating accurately network performance parameters. The connection is not available for end user traffic.

3.9 **Peak-to-peak 2-point CDV**: The difference between the maximum and the minimum values of all absolute CTD samples.

3.10 **Policing**: Discarding or tagging cells when the traffic contract is exceeded.

3.11 **Timestamp clock**: A mechanism included in the AME which provides time information used to insert timestamps into the transmitted test cells or used to time stamp received test cells.

Δ: the mean cell transmission time on the physical link, for instance 2.831 μs for a 155 Mbit/s STM-1 interface that has an ATM bit rate of 149 760 kbit/s.

Other definitions can be found in Recommendations I.356 [13], I.357 [14] and I.610 [21].

4 Abbreviations

This Recommendation uses the following abbreviations:

AIS	Alarm Indication signal
AME	ATM Measuring Equipment
AR	Availability Ratio
ATC	ATM Transfer Capability
ATM	Asynchronous Transfer Mode
B-ISDN	Broadband Integrated Services Digital Network
BR	Backward Reporting
CBR	Constant Bit Rate
CC	Continuity Check
CDCC	Control of DCC

CDV	Cell Delay Variation
CDVT	Cell Delay Variation Tolerance
CER	Cell Error Ratio
CHC	CTD Hit Count
CHR	CTD Hit Ratio
CI	Control Information
CLP	Cell Loss Priority
CLR	Cell Loss ratio
CMR	Cell Misinsertion Rate
CRC	Cyclic Redundancy Check
CTD	Cell Transfer Delay
DBR	Deterministic Bit Rate
DCC	Data Communications Channel
EDC	Error Detection Code
FM	Forward Monitoring
GCRA	Generic Cell Rate Algorithm
GFC	Generic Flow Control
INI	Inter-Network Interface
LBRF	Loss of Backward Reporting Flow
LCD	Loss of Cell Delineation
LFMF	Loss of Forward Monitoring Flow
LOC	Loss Of Continuity
LPAC	Loss of Performance Assessment Capability
MBS	Maximum Burst Size
MCTD	Mean Cell Transfer Delay
MP	Measurement Point
MSB	Most Significant Bit
MTBO	Mean Time Between Outages
NPP	Network Performance Parameter
OAM	Operation, Administration and Maintenance
OOS	Out-Of-Service
PCR	Peak Cell Rate
PM	Performance Management
PPI	Proprietary Payload Indicator
PTI	Payload Type Identifier
QOS	Quality Of Service
RDI	Remote Defect Indication

REV	REVision
RLM	Reference Load Model
SBR	Statistical Bit Rate
SECB	Severely Errored Cell Block
SECBR	Severely Errored Cell Block Ratio
SES_{ATM}	Severely Errored Second at the ATM layer
SN	Sequence Number
STM	Synchronous Transport Module
TCPT	Test Cell Payload Type
TS	TimeStamp
TSC	Timestamp Synchronization Control
UN	UNused
UNI	User-Network Interface
UPC/NPC	Usage Parameter Control/Network Parameter Control
VC	Virtual Channel
VCC	Virtual Channel Connection
VCI	Virtual Channel Identifier
VP	Virtual Path
VPC	Virtual Path Connection
VPI	Virtual Path Identifier

5 Measurement of network parameters

5.1 Measurement point location and measurement process

The functional location of the ATM measurement points where the ATM layer cell transfer performance shall be assessed is defined in Recommendation I.353 [12]. The measurement point for a VPC is located at the interface between the VP multiplexing/demultiplexing function and other VP functions. Similarly, the measurement point for a VCC is located at the interface between the VC multiplexing/demultiplexing function and other VC functions.

Since these functional interfaces are generally not accessible to measuring equipment, practical ATM measurements can be performed with the AME connected at the physical interface, the AME being connected as near as possible to the functional measurement point. This implies that the time of occurrences of reference events can only be approximated by the AME and that it shall emulate the physical layer functions.

Network performance parameters are derived from the observation of different events occurring at one or more measurement points throughout the network. Events are processed in two steps: the sequence of monitored events is analysed to determine outcomes and defects, then outcomes and defects are further processed to compute the set of network performance parameters.

This general measurement process is illustrated in Figure 5-1.

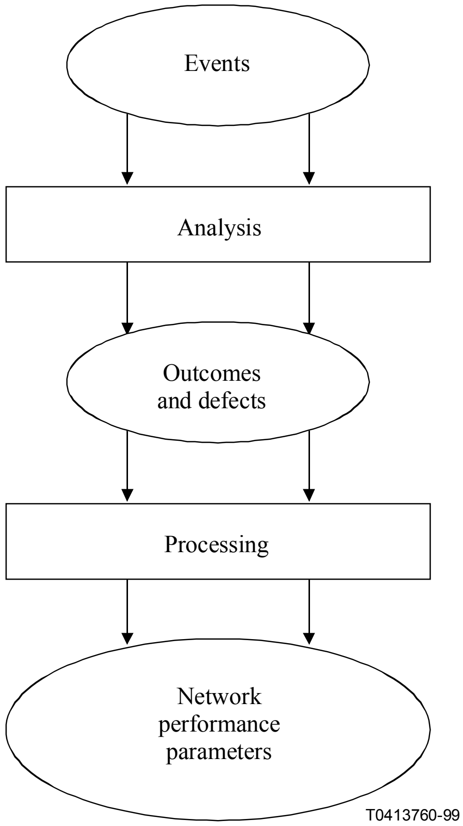


Figure 5-1/O.191 – General measurement process

5.2 ATM reference events and outcomes (anomalies and defects)

The two basic ATM reference events specified in Recommendation I.356 [13] are:

- Cell exit event;
- Cell entry event.

The following cell transfer outcomes are defined in Recommendations I.356 [13] and I.357 [14]:

- Successfully transferred cell;
- Errored cell;
- Lost cell;
- Misinserted cell;
- Tagged cell;
- Severely Errored Cell Block;
- Severely Errored Second.

Defects detected at the ATM layer are to be monitored for the purpose of network performance parameters determination. Among those, the following are defined in Recommendation I.610 [21]:

- VP-AIS;
- VP-LOC;
- VP-RDI;
- VC-AIS;
- VC-LOC;
- VC-RDI.

5.3 Physical layer reference events and outcomes (anomalies and defects)

No particular measurement of the physical layer performance is necessary for the measurement of the ATM layer network performance parameters. However, the AME shall act as a standard network equipment. It shall detect and propagate the physical layer anomalies and defects, e.g. LCD, as specified in the Recommendations related to the physical interface involved within the AME for the measurement. This applies particularly to the propagation of AIS and RDI from the physical media-dependent and transmission convergence sub-layers to the ATM layer.

5.4 ATM network performance parameters

The AME shall compute the following performance parameters defined in Recommendations I.356 [13] and I.357 [14]:

Error-related network performance parameters:

- Cell Error Ratio;
- Cell Loss Ratio;
- Severely Errored Cell Block Ratio;
- Cell Misinsertion Rate.

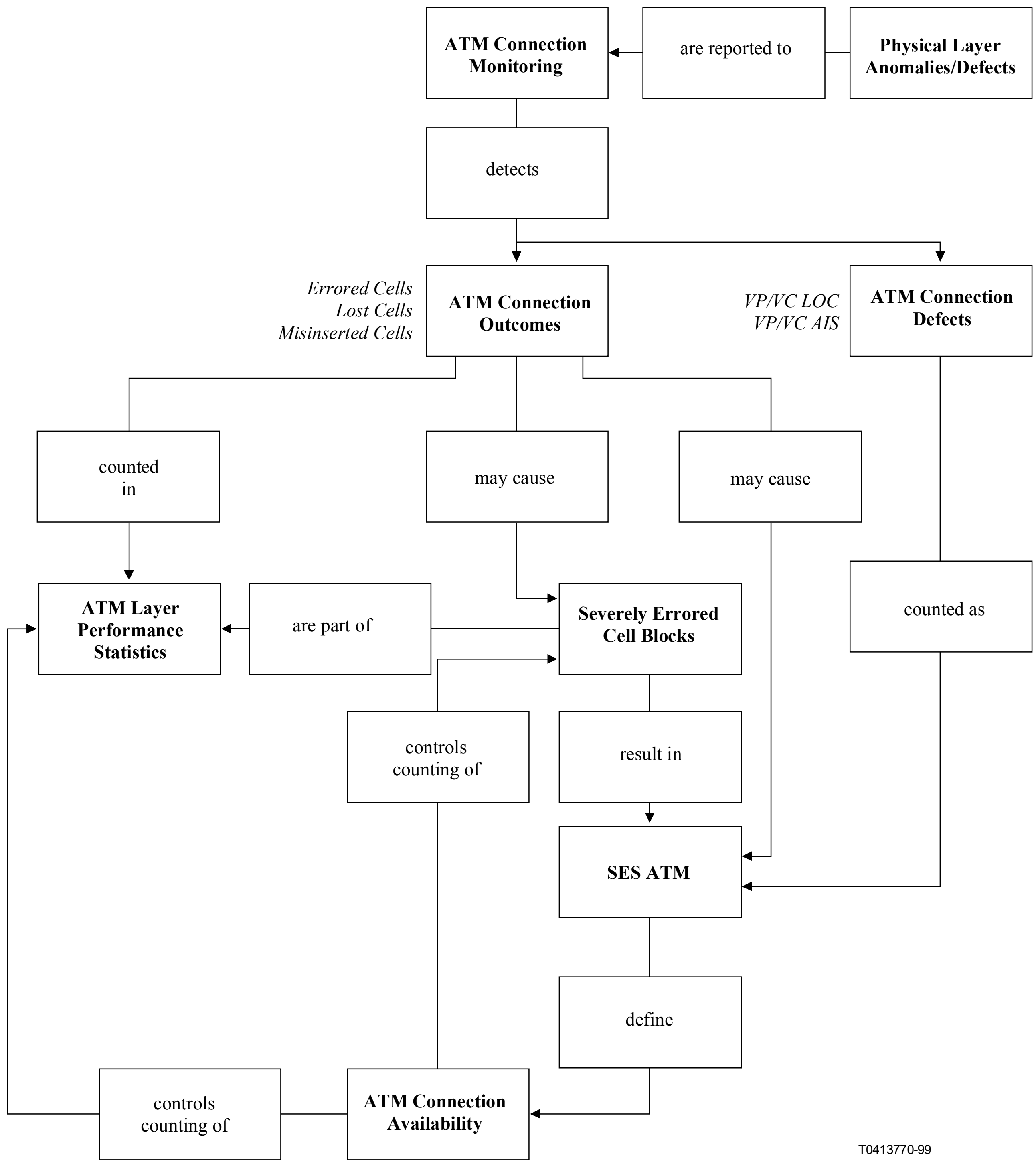
Availability-related network performance parameters:

- Availability Ratio;
- Mean Time Between Outages.

Delay-related network performance parameters:

- Mean Cell Transfer Delay;
- Cell Delay Variation (1-point and 2-point).

While a connection or a connection portion is under measurement, ATM events related to that connection shall be monitored and ATM outcomes shall be determined permanently independently of the availability status of the connection. The error-related and delay-related network performance parameters listed above shall only be computed when the ATM connection under test is in the available state as defined in Recommendation I.356 [13]. Figure 5-2 shows the basic relationships between ATM layer outcomes, ATM layer defects, and Severely Errored Cell Blocks (SECBs). It further highlights how the measurement of these parameters is controlled by the availability status of the ATM connection.



NOTE – This figure applies only to one direction of an ATM connection.

Figure 5-2/O.191 – Relationships between availability and ATM outcomes and defects

In addition, the AME may compute the number of non-conforming cells as defined in Recommendations I.356 [13] and I.371 [16]. The decision to declare a cell conforming or non conforming is based upon the arrival time of the cell as defined in Recommendation I.371 [16].

5.5 Measurement modes

Two measurement modes have been identified:

Out-of-service measurement mode: In this mode, after having set up a connection dedicated to the measurement of cell transfer performance, appropriate test cell sequences are transmitted on this connection and are analysed at the receive side.

In-service measurement mode: In this mode, generally the contents of OAM cells, which are provided by either the end user equipment or a network element, are analysed. The data derived from these contents are compared with corresponding data computed directly on the user cell stream.

Measurement modes 1 and 2 can be used simultaneously. It is possible to use the in-service measurement mode on a test connection which has been set up in order to perform out-of-service measurements.

The use of these measurement modes in various measurement configurations is illustrated in Appendix I.

6 Out-of-service measurement mode

In the out-of-service measurement mode, measurements are performed on a dedicated test connection. This measurement mode is used, for example, when bringing into service a new network element or testing the performance delivered by an entire ATM connection or a network portion.

Out-of-service estimation of the performance of an ATM connection is performed in an end-to-end configuration such as that illustrated in Figure 6-1. A flow of specific test cells is transmitted by the generator part of an AME located at one end of the connection. This flow is analysed by the receiver part of an AME located at the other end of the connection. To estimate performance of the backward direction of a test connection, the transmit and receive functions can be reversed in both AMEs. As an option, it may be possible to establish a looped connection using one AME which provides transmit and receive functions. However, care should be taken that, due to impairments introduced in the forward direction or due to asymmetric contracted rates between the forward and backward directions, looped cells may violate the traffic contract in the backward direction with the result that cells may be lost or misinserted.

The specific payload format of the test cells, which shall be transmitted on the connection under test for these out-of-service measurements, is described in 6.2. Characteristics of test traffic profile generators, capable of transmitting traffic that comply with a DBR or SBR traffic contract set-up for the connection under test, are described in 6.3. Subclause 6.7 defines the setting and filtering requirements regarding the CLP bit for the generator and receiver part of the AME as a function of the flow which shall be analysed. Subclause 6.8 details the processes involved in the determination of error-related and availability-related outcomes, as well as intermediate results, while subclause 6.9 describes the network performance parameters calculation based on these outcomes and intermediate results.

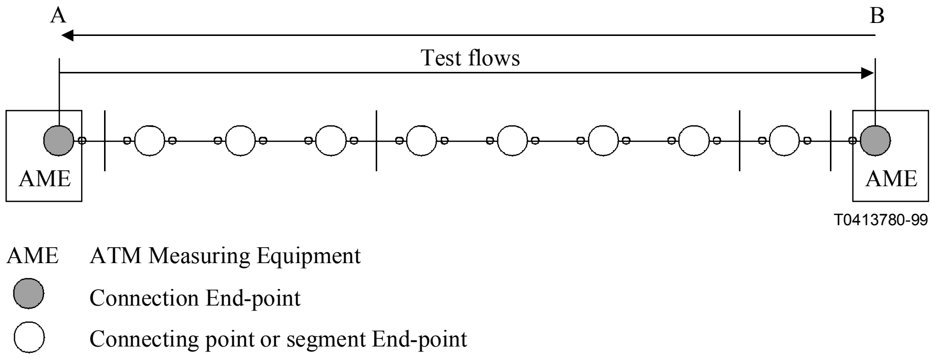


Figure 6-1/O.191 – Out-of-service end-to-end performance estimation configuration

6.1 Generation of traffic at the ATM layer

In the out-of-service measurement mode, the AME should be capable of generating both test and background traffic. Background traffic comprises cell streams that are generated by the AME but on which no monitoring is performed. Test and background traffic should be programmable in order to simulate realistic traffic. The patterns of test and background traffic are to be generated in a reproducible manner.

6.2 Test cell payload format

A test cell is a cell belonging to the cell stream of the connection which is dedicated to out-of-service measurement. Its information fields are coded in order to be able to identify ATM cell transfer outcomes and to measure network performance parameters.

6.2.1 Revision 0 test cell payload format

The payload format of the test cell is illustrated in Figure 6-2. It comprises the following consecutive fields:

- 4 bytes for a sequence number (SN);
- 4 bytes for a timestamp (TS);
- 37 unused bytes (UN);
- 1 byte defining the test cell payload type (TCPT);
- 2 bytes for an error detecting code (CRC-16).

The test cell payload, except the error detecting code, is scrambled to guarantee that sufficient transitions occur and to check transparency of crossed network elements.

Except for the SN, the following conventions, also described in Recommendation I.361 [15], are used:

- bits within a byte are sent in decreasing order, starting with bit 8;
- bytes are sent in increasing order, starting with byte 1;
- the first bit sent of each field is the most significant bit (MSB) of that field.

	Scrambled part of the test cell payload				
Header 5 bytes	SN 4 bytes	TS 4 bytes	UN 37 bytes	TCPT 1 byte	CRC-16 2 bytes
	bytes in reversed order	bytes in normal order			

Figure 6-2/O.191 – Revision 0 test cell payload format

Unless otherwise stated, the used field structure is the following:

- when a field is contained within a single byte, the lowest bit number of the field represents the lowest order value;
- when a field spans more than one byte, the order of bit values within each byte decreases progressively as the byte number increases. The lowest bit number associated with the field represents the lowest order value.

The transmit sequence number is a running 32-bit binary counter which is incremented by one at each test cell transmission, i.e. at each test cell exit event. The order of transmission of the 4 SN bytes is reversed and does not follow the previous conventions: the least significant byte shall be transmitted first and the most significant byte shall be transmitted last. The order of bit transmission within a byte is not reversed and follows the previous convention. Figure 6-3 details the SN field.

Payload Byte	8	7	6	5	4	3	2	1	bit / byte
1	SN 2^7	2^6	–	–	–	–	2^1	2^0	4
2	SN 2^{15}	2^{14}	–	–	–	–	2^9	2^8	3
3	SN 2^{23}	2^{22}	–	–	–	–	2^{17}	2^{16}	2
4	SN 2^{31}	2^{30}	–	–	–	–	2^{25}	2^{24}	1

Figure 6-3/O.191 – Detail of the SN field

The transmit timestamp is a 32-bit binary accumulator. The resolution of the timestamp and hence the value of the least significant bit of the accumulator is 10 ns. This resolution does not imply the use of a 100 MHz clock. For example, the timestamp may be incremented by 10 every 100 ns with the use of a 10 MHz clock. The timestamp value is placed in the timestamp field at the time of transmission of the test cell. Figure 6-4 details the TS field.

Payload Byte	8	7	6	5	4	3	2	1	bit / byte
5	TS 2^{31}	2^{30}	–	–	–	–	2^{25}	2^{24}	1
6	TS 2^{23}	2^{22}	–	–	–	–	2^{17}	2^{16}	2
7	TS 2^{15}	2^{14}	–	–	–	–	2^{9}	2^{8}	3
8	TS 2^{7}	2^{6}	–	–	–	–	2^{1}	2^{0}	4

Figure 6-4/O.191 – Detail of the TS field

Unused bytes are set to all zeros. The TCPT byte is used to indicate the test cell payload type. It comprises two fields: the PPI and the REV fields. The MSB of TCPT is defined as a Proprietary Payload Indicator (PPI) bit. When the PPI is set to zero, the content of the UN field is defined according to this Recommendation. When the PPI is set to one, the content of the UN field is undefined. The remaining 7 bits of the TCPT byte form the REV field which is used as a version control. Future revisions of this Recommendation may define additional test functions using the UN field. The REV field is used to maintain backwards compatibility with previous test cell definitions. The REV field (bits 1-7) is set to zero. Figure 6-5 details the TCPT field.

NOTE – If new fields are to be defined in future releases, it is envisaged to shorten the UN field and to place the new fields starting just after the TS field. For compatibility with future releases of this Recommendation, proprietary payload should use the UN bytes located just before the TCPT byte.

Payload Byte	8	7	6	5	4	3	2	1	bit / byte
46	PPI 2^{0}	REV 2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}	1

Figure 6-5/O.191 – Detail of the TCPT field

Part of the transmitted test cell payload starting with the first bit of the SN field up to the last bit of the REV field is scrambled applying the polynomial $x^9 + x^5 + 1$. At the start of each cell, the scrambler is reset to the all zeros state. At the receiving side, the test cell payload is descrambled accordingly so as to recover the initial data. An illustration of the scrambling/descrambling mechanisms is given in Annex C.

Error detection is performed by means of a CRC-16 EDC with a generator polynomial of $x^{16} + x^{12} + x^5 + 1$. It is calculated at the transmit side over 46 bytes of the cell payload after they have been scrambled (see Figure 6-2). The result of the CRC calculation is placed with the least significant bit right justified in the CRC field. To ensure that an all zeros payload does not pass the CRC check, the CRC field shall contain the ones complement of the sum (modulo 2) of:

1) the remainder of x^k $(x^{15} + x^{14} + x^{13} .... + x + 1)$ divided (modulo 2) by the generator polynomial, where k is the number of bits of the information over which the CRC is calculated; and

2) the remainder of the division (modulo 2) by the generator polynomial of the product of x^{16} by the information over which the CRC is calculated.

This procedure is identical to that described in Recommendation X.25 [25]. Figure 6-6 details the CRC-16 field.

Payload Byte	8	7	6	5	4	3	2	1	bit / byte
47	CRC-16 2^{15}	2^{14}	–	–	–	–	2^{9}	2^{8}	1
48	CRC-16 2^{7}	2^{6}	–	–	–	–	2^{1}	2^{0}	2

Figure 6-6/O.191 – Detail of the CRC-16 field

6.2.2 Revision 1 test cell payload format

The revision 1 test cell payload format is an extension of the revision 0 test cell payload format. Bit and byte order conventions used for revision 0 apply to revision 1. Backwards compatibility rules for the use of the PPI and UN fields also apply.

A four-byte Control Information field, CI, located just after the timestamp field replaces 4 previously unused bytes in the revision 0 test cell format as shown in Figure 6-7.

Header	SN	TS	CI	DCC	UN	TCPT	CRC-16
5 bytes	4 bytes	4 bytes	4 bytes	4 bytes	29 bytes	1 byte	2 bytes

Figure 6-7/O.191 – Extended test cell payload format

When transmitting this test cell format the revision number in the TCPT field (payload byte 47, bits 1-7) must be set to 0000001. This revision 1 format is backwards compatible with the basic revision 0 test cell format unless payload bytes 9 to 16 have been used for proprietary purposes.

NOTE – Implementation of this revision 1 test cell format does not imply that any optional capability is implemented in the AME.

The control information contains a Timestamp Synchronization Control field (TSC) in the first byte of the CI field at bit position 2^{24}-2^{26} as shown in Figure 6-8. The CI field may be used in the future for further enhancements to transport static or dynamic information between AMEs.

Payload Byte	8	7	6	5	4	3	2	1	bit / byte
9	2^{31}	2^{30}	–	CDCC 2^{28}	2^{27}	TSC 2^{26}	2^{25}	2^{24}	1
10	2^{23}	2^{22}	–	–	–	–	2^{17}	2^{16}	2
11	2^{15}	2^{14}	–	–	–	–	2^{9}	2^{8}	3
12	2^{7}	2^{6}	–	–	–	–	2^{1}	2^{0}	4

Figure 6-8/O.191 – Location of the timestamp synchronization control field within the control information

The coding of the TSC field is detailed in Table 6-1.

Table 6-1/O.191 –Coding of the timestamp synchronization

Coding	Meaning	Requirement
000	Full rollover of the timestamp, approximately 42 seconds	Mandatory
001	10 seconds timestamp resynchronization period	Mandatory if the optional timestamp clock synchronization is implemented in the AME
010	1 second timestamp resynchronization period	Optional
011	30 seconds timestamp resynchronization period	Optional
1xx	FFS	

When the TSC coding 001, 010 or 011 is used the timestamp value of all bits set to 1 has a special meaning. This value informs the receiving AME that no external synchronizing clock is available at the transmitting AME.

Another four byte DCC field, located just after the CI field, replaces four previously unused bytes in the Revision 0 test cell format as shown in Figure 6-7. This field provides a Data Communications Channel (DCC) between AMEs. The DCC may be implemented in a proprietary manner, but details for a standard implementation are for further study (FFS). Bits 2^{27} and 2^{28} within the CI field form the Control of DCC (CDCC) sub-field. They indicate whether or not the DCC is implemented and its version, and must be coded according to the Table 6-2.

Table 6-2/O.191 – Coding of the DCC control

Coding	Meaning
00	DCC not present
01	Standard DCC present
10	Proprietary DCC present
11	FFS

6.3 Test traffic profiles

Two types of test traffic generators are defined. The standard traffic generator is defined for use in cell transfer performance measurements and general purpose applications. The enhanced traffic generator is defined for UPC/NPC tests, and can be used also for performance measurements. In both cases the test traffic profile parameters can be related to the traffic parameters used in the traffic contract as defined in Recommendation I.371 [16], e.g. PCR, SCR, CDVT. Test traffic profiles are sometimes referred to as Reference Load Models (RLMs).

The profile of the test traffic is characterized by a set of traffic parameters such as Peak Cell Rate (PCR), Cell Delay Variation Tolerance (CDVT), distribution of instantaneous cell rate. PCR and CDVT should always be defined as specified in Recommendation I.371 [16].

Whenever the AME is used for out-of-service performance measurements, it shall be ensured that the transmitted VPC/VCC cell flow contains sufficient information to check whether the connection under test is in the available state or not. Continuity checking, which forms part of the availability state determination, shall be checked either by transmitting a minimum number of one test cell every second or by transmitting end-to-end continuity check cells as defined in Recommendation I.610 [21].

NOTE – The SES_{ATM} estimation process is improved if the transmitted test traffic profile of the CLP flow to be measured comprises more than 1 test cell per second.

Recommendation I.371 [16] defines different types of traffic contracts. The AME shall generate traffic for both DBR and SBR ATM Transfer Capabilities (ATCs). Specific traffic profiles for other ATCs are for further study.

6.3.1 Standard traffic generator

Traffic is controlled using the three profile parameters:

1) maximum cell rate (see Note 1);
2) mean cell rate;
3) burst size (i.e. the number of cells per burst) (see Note 2).

NOTE 1 – The maximum cell rate can be set by the user of the AME and can differ from the peak cell rate negotiated in the traffic contract. It can be higher or lower than the peak cell rate negotiated in the traffic contract.

NOTE 2 – The burst size parameter has no meaning when maximum cell rate is equal to mean cell rate. In that case, the generated traffic is an ideal constant bit rate traffic.

Cells shall be generated in regular bursts of constant burst size as illustrated in Figure 6-9.

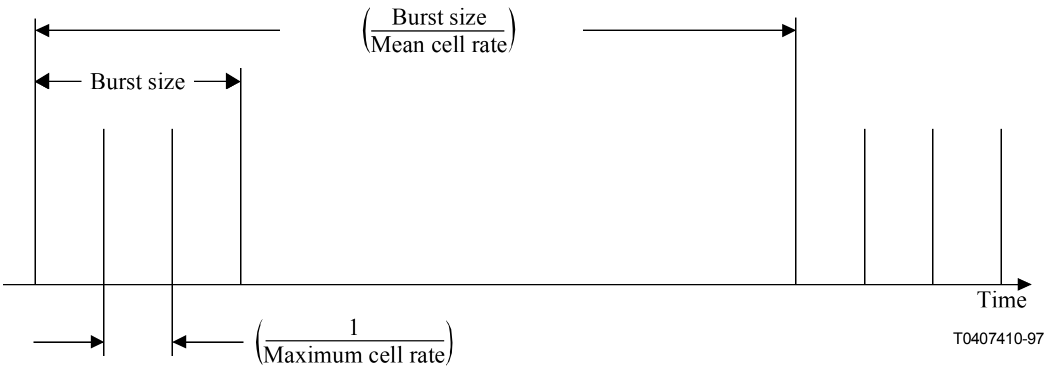


Figure 6-9/O.191 – Traffic profile parameters

The cell delay variation of transmitted traffic can be derived from the traffic profile parameters as follows:

$$\text{Cell Delay Variation} = (\text{Burst Size} - 1) * \left(\frac{1}{MeanCellRate} - \frac{1}{MaximumCellRate} \right)$$

These traffic profile parameters may have different meaning depending on whether they are used to define the traffic profile for a DBR contract or an SBR contract. For example, in the case of a DBR contract, maximum cell rate can be set to the maximum ATM cell rate on the physical path, mean cell rate can be set to PCR, burst size can be set so as to have CDV less than or equal to τ_{PCR}. In the case of an SBR contract, maximum cell rate can be set to PCR, mean cell rate can be set to SCR, burst size can be set to MBS or equivalently and burst size can be set so as to have CDV less than or equal to τ_{IBT}.

When test traffic is mapped onto the link, additional CDV may be generated. This additional CDV characterizes the difference between the nominal traffic profile parameters set by the user of the

AME and the actual traffic profile available at the physical output connector of the AME generator part. The maximum value of the additional CDV is for further study.

NOTE 3 – The additional CDV should be taken into account when setting up the AME if it is required to keep the generated test traffic within the conformance limits of the traffic contract.

The resolution available for setting the traffic profile parameters (i.e. maximum cell rate, mean cell rate, burst size) shall be sufficient to comply with the set of values of the coding scheme defined in Recommendation I.371 [16] for cell rate coding. Setting accuracy is for further study.

In the case where CLP = 0 + 1 cells are generated by an AME, it shall be possible to set the traffic profile for each flow (i.e. the CLP = 0 and the CLP = 1 subflows resulting in the aggregate CLP = 0 + 1 flow) so as to generate test traffic as required by the conformance definition for ATM transfer capability given in Recommendation I.371 [16].

6.3.2 Enhanced traffic generator

The enhanced traffic generator offers reference test traffic profiles that can precisely check a UPC/NPC function at a given operating point regarding the cell rates and cell delay variation. In particular, it can check the UPC/NPC function at a point where discarding/tagging actions should just begin or cease. Although other traffic profiles could exercise the UPC/NPC actions, the use of the specified traffic profiles ensures that different AMEs exercise a UPC/NPC function in the same way and, consequently, that the same policing ratio is measured for a given UPC/NPC implementation being excited by AMEs using the same set-up.

The enhanced traffic generator can generate traffic profiles that are over-stressing or under-stressing the UPC/NPC. In particular it can generate traffic profiles suitable for out-of-service cell transfer performance measurements.

Implementation of the enhanced test traffic generator and the associated UPC/NPC performance measurement is optional.

6.3.2.1 Test traffic algorithms

The test traffic profiles are defined by the suite of the cell emission times at which test cells must be transmitted. Test traffic may be combined with any form of background traffic profile provided that the test traffic has priority when multiplexed with other traffic.

Two algorithms, based on the conformance definitions given in Recommendation I.371 [16], are defined for the computation of the cell emission times (CET). The first algorithm is designed for the testing of UPC/NPC controlling a DBR traffic contract option 1 or 2, i.e. with aggregate or separate conformance definition. This algorithm is denoted DBR algorithm in the following and is shown in Figure 6-10. The second algorithm is designed for the testing of UPC/NPC controlling a SBR1 traffic contract where the traffic contract applies globally to the CLP = 0 + 1 cell flow. This algorithm is denoted SBR1 algorithm in the following and is shown in Figure 6-11. Traffic profiles for other ATCs being considered in Recommendation I.371 [16] are for further study.

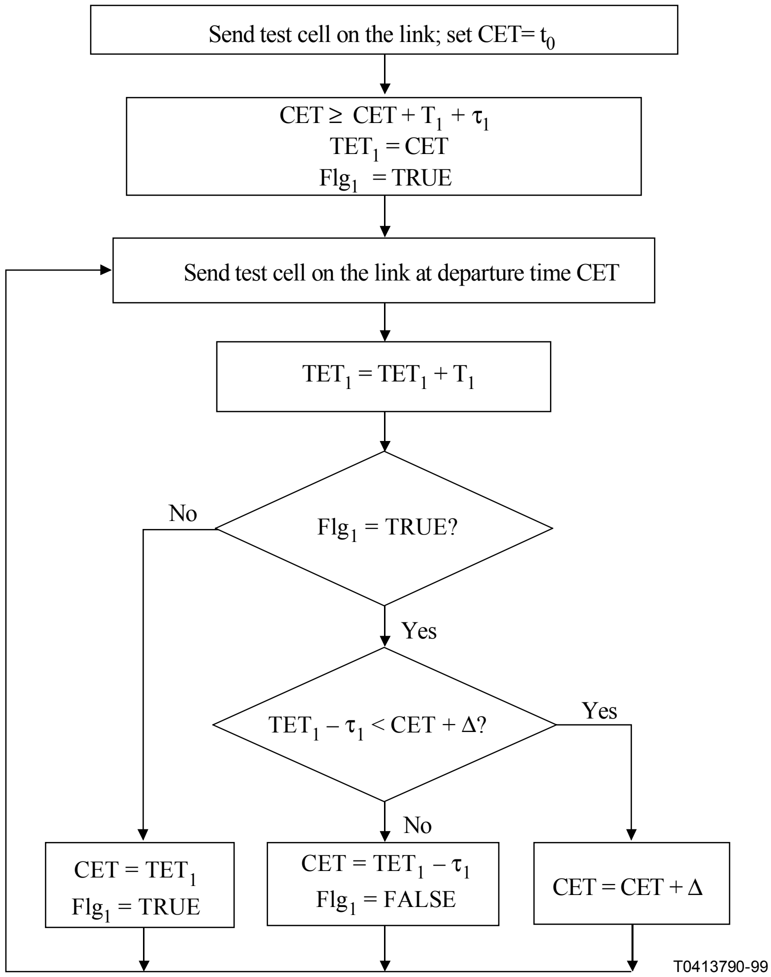
The DBR algorithm has two input parameters, T_1 and τ_1, and two intermediate parameters, TET_1 and Flg_1. A first cell is transmitted at an arbitrary time t_0. A quiet time interval without cell transmission at least equal to $T_1 + \tau_1$ is observed for the UPC/NPC to reset to an idle state. After that initialization period, cell emission times are computed following the main loop of the algorithm. When τ_1 is set to 0, the traffic profile is a fully constant cell rate with an interval equal to T_1 between every two consecutive cells. When τ_1 is different from 0, the traffic consists of a repetition of a burst of consecutive cells at the link rate followed by a quiet period of time. The burst length depends upon the value of τ_1 but the long term mean interval between cells is precisely equal to T_1. Although not completely precise the following explanations regarding this traffic profile can be given. Cells following the first cell of a burst may be considered as being transmitted with the maximum possible negative cell delay variation until the total CDV related to τ_1 is reached. The quiet period after the burst can be considered as the required time to ensure a mean interval of T_1 between cells.

The SBR1 algorithm has four input parameters, T_1, T_2, τ_1 and τ_2, and four intermediate parameters, TET_1, TET_2, Flg_1 and Flg_2. A first cell is transmitted at an arbitrary time t_0. A quiet time interval without cell transmission at least equal to $T_2 + \tau_2$ is observed for the UPC/NPC to reset to an idle state. After that initialization period, cell emission times are computed following the main loop of the algorithm. When τ_1 is set to 0, the traffic consists of repetitive bursts of cells. The interval between cells during a burst is equal to T_1. The burst length depends on the value of τ_2, but the long-term mean interval between cells is precisely equal to T_2.

6.3.2.2 Test traffic generator accuracy

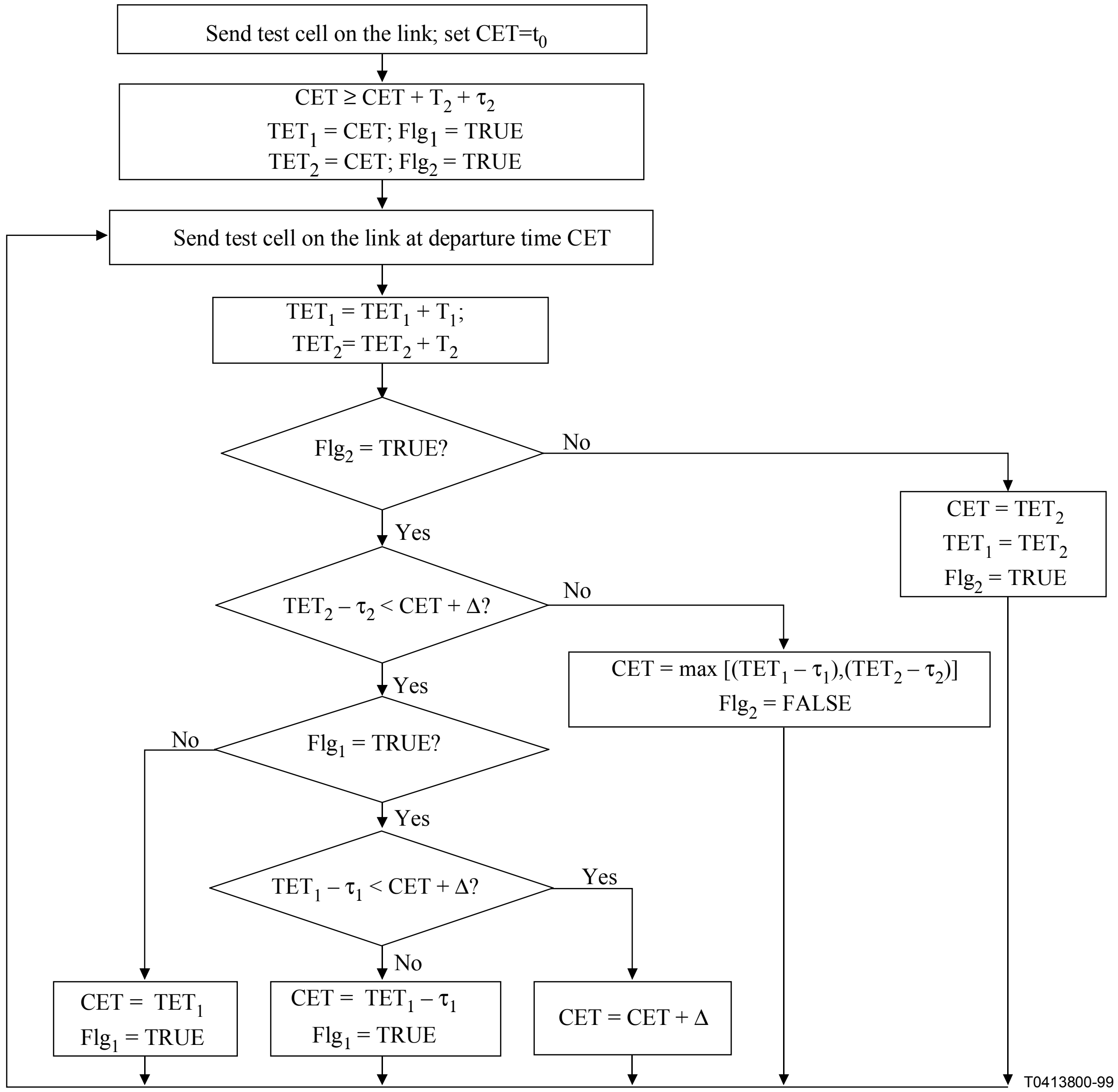
The overall accuracy of the actual cell emission times should be better than 0.1%. This includes any error resulting from a cell rate to a time conversion or vice versa, truncation, rounding, or similar computation errors as well as time inaccuracy, if appropriate. Resolution of the input parameters should be better than 0.1% over the full selection range to offer a better granularity than the granularity defined in Recommendation I.371 [16].

Most physical layers introduce an unavoidable cell delay variation when the traffic is mapped onto the physical link. This CDV depends on the particular physical interface used and is generally equal to one or two cell transmission times, Δ, at the ATM rate of the physical link. Table 6-11 lists the unavoidable CDV values $H(\Delta)$ for current B-ISDN UNIs. This unavoidable CDV is not included in the overall accuracy value given above.



Input parameters:	T_1:	Long term mean cell emission interval
	τ_1:	Maximum generated CDV
Output parameters:	CET:	Cell Emission Time
Intermediate variables:	TET_1:	Theoretical Emission Time
	Flg_1:	Indicates that next emission time should give maximum CDV
Other:	t_0:	First cell transmission time
	Δ:	Cell transmission time at the maximum ATM rate of the physical link

Figure 6-10/O.191 – DBR algorithm



Imput parameters:	T_1:	Mean cell emission interval during bursts when $\tau_1 = 0$
	T_2:	($T_2 > T_1$) Long term mean cell emission interval
	τ_1:	Maximum generated CDV related to T_1
	τ_2:	Maximum generated CDV related to T_2
Output parameters:	CET:	Cell Emission Time
Intermediate variables:	TET_1:	Theoretical Emission Time related to T_1
	TET_2:	Theoretical Emission Time related to T_2
Other:	Flg_1:	Indicates that next emission time should give maximum CDV related to T_1
	Flg_2:	Indicates that next emission time should give maximum CDV related to T_2
	T_0:	First cell transmission time
	Δ:	Cell transmission stime at the maximum ATM rate of the physical link max [x,v] = the greatest of the two values x and v

Figure 6-11/O.191 – SBR1 algorithm

6.3.2.3 Generator set-up for UPC/NPC performance measurements

A DBR traffic contract considers only one cell rate: a peak cell rate equal to $1/T_{PCR}$. In addition, a cell delay variation tolerance τ_{PCR} is considered to allow for some delay variation within the multiplexing and switching stages of ATM network elements. The set of traffic parameters (T_{PCR}, τ_{PCR}) is sufficient to unambiguously characterize the cell conformance by applying the Generic Cell Rate Algorithm, GCRA(T_{PCR}, τ_{PCR}), to the cell flow.

Since the enhanced generator DBR algorithm is closely derived from the conformance definition, there is a straight relationship between the two sets of parameters (T_1, τ_1) and (T_{PCR}, τ_{PCR}). The generated traffic has a peak cell rate equal to $1/T_1$ and a maximum CDV equal to τ_1. If it is desired to determine the behaviour of the UPC/NPC as a function of the cell rate only, τ_1 should be set to 0 or to a fixed value likely to be less than τ_{PCR}, and T_1 should be varied. Lost/tagged cells can then be measured in the measurement scheme indicated in Figure 6-16. If it is desired to determine the maximum CDV acceptable by the UPC/NPC at a given cell rate, T_1 should simply be set to the required cell rate and τ_1 increased starting from 0 until lost/tagged cells are detected at the receiver located after the UPC/NPC. Another simple "GO/NO-GO" test for UPC/NPC could be to set $T_1 = T_{PCR}$ plus the accuracy of the AME and $\tau_1 = \tau_{PCR}$ minus the accuracy of the AME minus the unavoidable CDV : no cells should normally be discarded/tagged by the UPC/NPC. It should be Noted that the actual value set up for τ_1 should take into account the unavoidable CDV, H(Δ), due to the physical interface as indicated in 6.3.2.2.

A SBR traffic contract considers the peak cell rate as for the DBR contract plus a second cell rate, a sustainable cell rate equal to $1/T_{SCR}$, for which a cell delay variation tolerance τ_{SCR} is considered to allow for a certain transmission time at the full peak cell rate. Actually, τ_{SCR} is the sum of τ_{IBT} and τ'_{SCR}. The sets of traffic parameters (T_{PCR}, τ_{PCR}) and (T_{SCR}, $\tau_{IBT} + \tau'_{SCR}$) characterize the cell conformance by applying two generic cell rate algorithms, GCRA(T_{PCR}, τ_{PCR}) and GCRA(T_{SCR}, $\tau_{IBT} + \tau'_{SCR}$), in a coordinated mode.

Since the enhanced generator SBR1 algorithm is closely derived from the conformance definition, there is a straight relationship between the sets of parameters (T_1, τ_1) and (T_{PCR}, τ_{PCR}) on one hand, and (T_2, τ_2) and (T_{SCR}, $\tau_{IBT} + \tau'_{SCR}$) on the other hand. Similar considerations as for DBR apply.

If the AME has the capability to set traffic parameters equal to the traffic contract, it should also provide automatic compensation for any internal accuracies in order to ensure that the actual traffic generated is conforming to the traffic contract.

6.3.2.4 Generator set-up for performance measurements

Network performance parameters can generally be measured with τ_1 set to 0.

For a DBR connection, the DBR algorithm should be used. Input parameters to the algorithm should then be:

- τ_1 equal to 0;
- T_1 greater than the reciprocal of the peak cell rate,

where peak cell rate is the PCR traffic parameter negotiated as part of the DBR traffic contract for the connection under test.

For a SBR connection, the SBR1 algorithm should be used. Input parameters to the algorithm should then be:

- τ_1 equal to 0;
- T_1 greater than the reciprocal of the peak cell rate;

- T_2 greater than T_1 and greater than one over the sustainable cell rate;
- τ_2 less than the intrinsic burst tolerance,

where peak cell rate, sustainable cell rate and intrinsic burst tolerance are respectively the PCR, SCR and τ_{IBT} traffic parameters negotiated as part of the SBR1 traffic contract for the connection under test. If the user has the knowledge of the maximum burst size rather than of τ_{IBT}, the following rule applies:

$$\tau_{IBT} = (MBS - 1)\left[(1/SCR) - (1/PCR)\right] \text{seconds}$$

The unavoidable CDV and accuracy of the AME shall be taken into account when setting these parameters.

The enhanced traffic generator is capable of transmitting all traffic profiles provided by the standard traffic generator. Table 6-3 gives some examples of settings for generating similar traffic profiles.

Table 6-3/O.191 – Set-up relationships for similar traffic generation

Standard traffic generator	Enhanced traffic generator
• maximum cell rate = mean cell rate	DBR algorithm • $\tau_1 = 0$ • T_1 = 1/maximum cell rate
• maximum cell rate = maximum ATM cell rate of the physical link • mean cell rate • burst size	DBR algorithm • τ_1 = (burst size – 1)*[(1/mean cell rate) – (1/maximum cell rate)] • T_1 = 1/maximum cell rate
• maximum cell rate • mean cell rate • burst size	SBR1 algorithm • $\tau_1 = 0$ • τ_2 = (burst size – 1)*[(1/mean cell rate) – (1/maximum cell rate)] • T_1 = 1/maximum cell rate • T_2 = 1/mean cell rate

6.4 Background traffic

The background traffic shall be generated in a defined manner to ensure that the content of the cell information fields and the traffic profile for each background traffic connection is reproducible.

An AME shall be able to generate traffic for at least two VPCs or VCCs. For example, it shall generate traffic on the connection under test and background traffic on at least one other VPC or VCC. It shall be possible to control separately the transmitted traffic profile for these connections (test and background traffic). When multiplexing test and background traffic, the test traffic shall have priority with the result that the actual background traffic profile could be affected.

Details require further study.

6.5 OAM traffic

The AME should be capable of generating OAM cells associated with fault and performance management applications. One example of this is the application of CC cells in order to monitor the available state, especially in the case of low cell rate test traffic conditions.

Details are for further study.

6.6 Simulation of anomalies and defects

The specification of test cell sequences corresponding to given cell transfer outcomes needs further study. For validation purposes these sequences could include: single cells with errored header, sequences of cells with missing numbers of cells, sequences of cells with out-of-sequence cells.

Generation of other outcomes at the ATM layer might be useful for validation purposes: creation of "silent" periods on the test cell flow so as to simulate the occurrence of the loss of continuity defect defined in Recommendation I.610 [21] is one example.

6.7 CLP flow measurements

Three possible CLP flows on the VCC or the VPC under test are to be distinguished: the CLP = 0 flow, the CLP = 1 flow and the aggregate flow (CLP = 0 + 1). Depending on the CLP flow for which the NPPs are to be measured, cells transmitted on the connection under test and cells extracted from the connection under test for further analysis shall comply with the requirements given in Table 6-4.

With regard to QOS objectives defined in Recommendation I.356 [13], it is not required to estimate the performance of CLP = 1 only flow. However, it is useful to measure the performance of this flow from a network performance point of view.

Both generator and receiver part of the AME need to be aware of the flow to be measured.

It should be noted that, for the time being, the test cell format and the performance estimation process (including the measurement algorithm) do not allow a simultaneous measurement of more than one CLP flow. This issue is for further study.

Table 6-4/O.191 – Requirements related to the measured CLP flow

CLP flow for which NPP is to be measured	Transmitted flow	Requirements for the cells transmitted on the test connection	Requirements for the cells extracted from the test connection
CLP = 0	CLP = 0 only	The cell stream shall consist only of test cells having a CLP set to 0. The SN field shall be incremented at each cell transmission.	Only cells with a CLP equal to 0 shall be analysed by the measurement algorithm. (Note 1)
CLP = 0 + 1	CLP = 0 + 1	The cell stream shall consist of test cells having a CLP set either to 0 or to 1. The SN field shall be incremented at each cell transmission regardless of the CLP value. (Note 4)	All cells shall be analysed by the measurement algorithm regardless of the CLP value.
CLP = 0	CLP = 0 + 1	The cell stream shall consist of a mix of test cells having a CLP set to 0 and of other cells having a CLP set to 1. The SN shall be incremented at each transmission of a test cell with a CLP set to 0. (Note 2)	Only cells with a CLP equal to 0 shall be analysed by the measurement algorithm.
CLP = 1	CLP = 0 + 1	The cell stream shall consist of a mix of test cells having a CLP set to 1 and of other cells having a CLP set to 0. The SN shall be incremented at each transmission of a test cell with a CLP set to 1. (Notes 2, 3)	Only cells with a CLP equal to 1 shall be analysed by the measurement algorithm.
CLP = 1	CLP = 1 only	The cell stream shall consist only of test cells having a CLP set to 1. The SN field shall be incremented at each cell transmission.	Only cells with a CLP equal to 1 shall be analysed by the measurement algorithm.

NOTE 1 – The term "measurement algorithm" refers to the "Basic out-of-service cell transfer outcome measurement algorithm" as described in Annex B.

NOTE 2 – "Other cells" can have a format different from standard test cells because they are not part of the measured flow.

NOTE 3 – This method is not applicable to traffic contracts using the tagging option. Measurement of tagged cells is for further study.

NOTE 4 – It shall be possible to transmit CLP = 0 (or CLP = 1) cells only but still analyse an aggregate CLP = 0 + 1 flow. This allows, for example, the detection of misinserted cells regardless of whether the CLP bit is set to 0 or 1.

6.8 Measurement process

The measurement process estimates the performance parameters and the connection availability defined in Recommendations I.356 [13] and I.357 [14] respectively. This process is performed by the receiver part of the AME which analyses the cells belonging to the cell flow to be measured. The complete out-of-service measurement process is summarized in Figure 6-12. It comprises four processes and two complementary functions. The three main processes, namely the cell monitoring process, the outcome monitoring process and the availability monitoring process, are each working at a different level: the cell level, the cell block level and a one-second interval level, respectively. Figure 6-12 illustrates the interactions between processes and functions. These processes and functions are quite similar to those described in Recommendations I.356 [13] and I.357 [14] for the in-service mode.

A basic cell transfer outcome measurement algorithm is used to provide an estimation of errored, misinserted and lost cell counts. This estimation is included in the cell monitoring process as shown in Figure 6-12. This process also monitors the Fault Management flow associated with the measured flow in order to detect AIS and Continuity Check cells.

Counts of outcomes provided by the measurement algorithm are accumulated in per block counters within the outcome monitoring process. Based on the per block counts of lost, errored and misinserted cells, the Severely Errored Cell Block is determined according to the definition given in Recommendation I.356 [13].

Per block outcome counts are accumulated in per second counters, within the per second outcome and event monitoring function in the availability monitoring process, to assess the performance observed during a one-second time interval. The per second outcome counts are used to determine SES_{ATM} and the unavailable state within this availability monitoring process according to the definitions given in Recommendation I.357 [14].

The storage control process allows or inhibits the storage in performance registers of outcomes observed during periods of time considered as available or unavailable. These stored performance results are then used to calculate the Network Performance Parameters as defined in Recommendation I.356 [13].

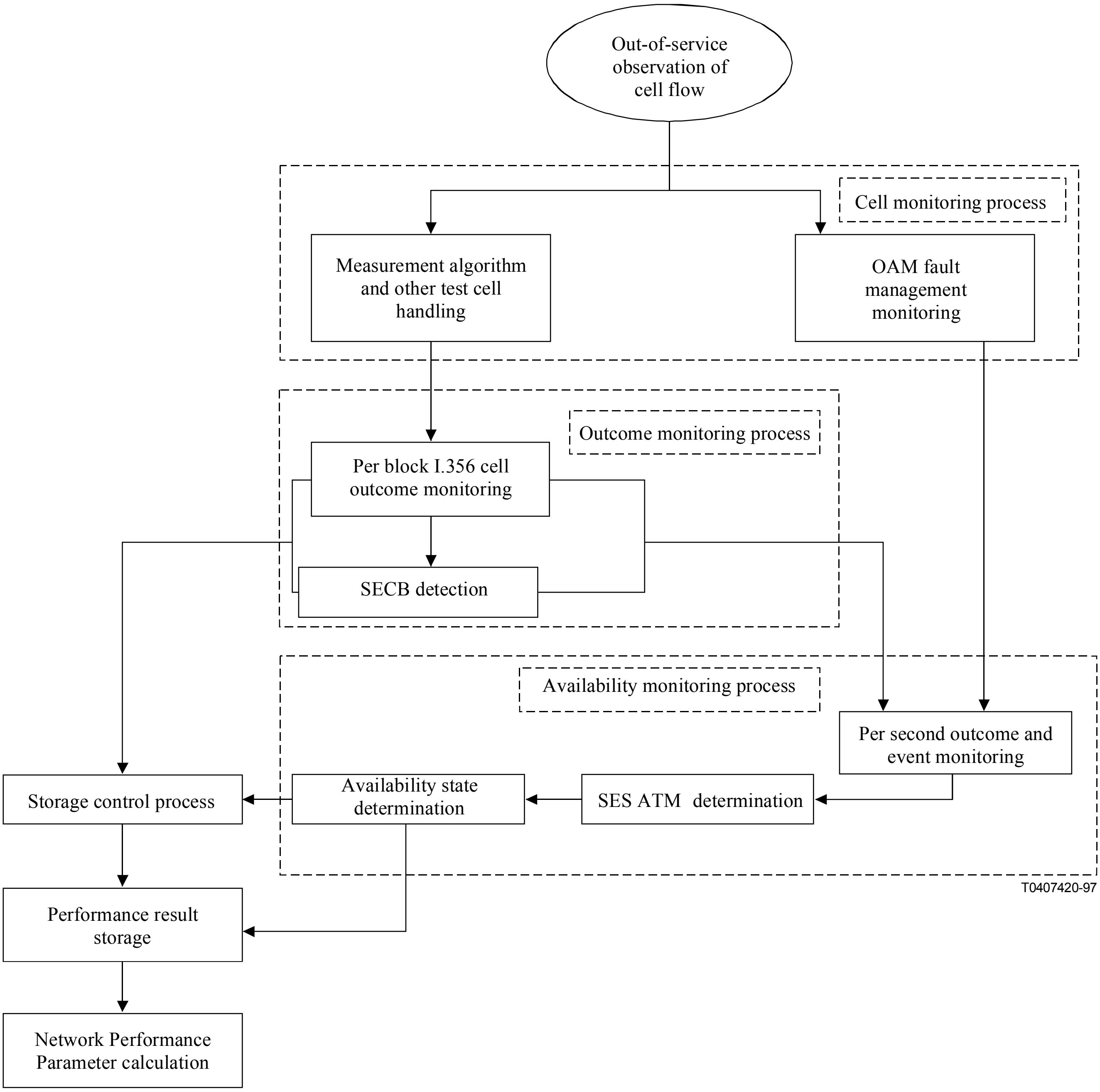


Figure 6-12/O.191 – Out-of-service performance estimation process

6.8.1 Cell monitoring process

The AME is capable of measuring error-related and availability-related Network Performance Parameters (NPPs) on either a VCC or a VPC. Tables 6-5 to 6-8 give details about the monitored cells. A VCC under test is identified by a given VPI value and a given VCI value and all cells transmitted on this VCC have the same VPI and VCI. A VPC under test is identified only by a given VPI value and all cells transmitted on this VPC have the same VPI. All VCI values are allowed for the VCCs embedded in the VP although ATM standards require that user VCCs have VCI values greater than 31.

Table 6-5/O.191 – Monitored cells to determine cell transfer outcomes for a VPC

Monitored cells	End-to-end VPC
Monitored Fx OAM flow	End-to-end F4
Header of monitored Fx OAM cells	GFC (Note 1): BBBB (Note 2) VPI: VPI value of the monitored VPC VCI: 4 PTI (Notes 2, 3): 0B0 CLP (Notes 2, 4): B
Header of monitored test cells	GFC (Note 1): BBBB (Note 2) VPI: VPI value of the monitored VPC VCI: > 31 PTI: BBB (Notes 2, 5) CLP: D (Note 6)

NOTE 1 – Applicable only to measurements at a UNI.

NOTE 2 – B indicates the bit is a "don't care bit".

NOTE 3 – Recommendation I.361 [15] specifies that the second bit of the PTI can be 0 or 1 and is available for use by the appropriate ATM layer function.

NOTE 4 – Recommendation I.361 [15] specifies that the CLP bit can be 0 or 1. As Recommendation I.610 [21] does not give more information about CLP, the AME shall monitor OAM cells regardless of the value of the CLP bit.

NOTE 5 – As Recommendation I.610 [21] does not specify any restriction on the value of the PTI for a VPC, the AME shall monitor cells regardless of the PTI value.

NOTE 6 – D shall be in accordance with the measured CLP flow (see 6.7).

Table 6-6/O.191 – Monitored fault management cells for a VPC

Monitored fault management cells	End-to-end VPC
Monitored ATM cells for the forward direction	VP-AIS cells VP-CC cells
Monitored ATM cells for the backward direction	VP-RDI cells (For further study)

Table 6-7/O.191 – Monitored cells for a VCC

Monitored cells	End-to-end VCC
Monitored Fx OAM flow	End-to-end F5
Header of monitored Fx OAM cells	GFC (Note 1): BBBB (Note 2) VPI: VPI value of the monitored VCC VCI: VCI value of the monitored VCC PTI: 101 CLP (Notes 2, 3): B
Header of monitored test cells	GFC (Note 1): BBBB (Note 2) VPI: VPI value of the monitored VCC VCI: VCI value of the monitored VCC PTI: 0BB (as defined in Recommendation I.610 [21]) CLP: D (Note 4)
NOTE 1 – Applicable only to measurements at a UNI. NOTE 2 – B indicates the bit is a "don't care bit". NOTE 3 – Recommendation I.361 [15] specifies that the CLP bit can be 0 or 1. NOTE 4 – D shall be in accordance with the measured CLP flow (see 6.7).	

Table 6-8/O.191 – Monitored fault management cells for a VCC

Monitored fault management cells	End-to-end VCC
Monitored ATM cells for the forward direction	VC-AIS cells VC-CC cells
Monitored ATM cells for the backward direction	VC-RDI cells (For further study)

6.8.1.1 Cell transfer outcome determination

Estimation of basic cell transfer outcomes comprising lost cells, misinserted cells and errored cells is the foundation for the calculation of error related network performance parameters. These outcomes shall be determined according to the algorithm described hereafter and shown in Annex B. This algorithm is defined in order that different AMEs provide the same outcome counts while disturbed conditions are experienced. It shall be applied to the monitored cells for a VPC or VCC of the appropriate CLP flow previously described. The given description is not intended to constrain the design of the AME to any particular implementation.

The algorithm makes use of the characteristics of the test cell format. The sequence number field (SN) and the error detection field (CRC-16) are used to estimate cell losses, cell misinsertions and cell errors. Every time the measurement algorithm makes a decision it notifies the outcome monitoring process along with the numbers of lost, errored and misinserted cells estimated at the time of decision. The process shall also pass to the outcome monitoring process sufficient information (test cell sequence number value) to enable a correct detection of the cell block boundaries and correct estimation of the number of test cells transmitted since the beginning of the block (see 6.9.2 for details). The performance measurement algorithm shall also indicate to the availability monitoring process whether it was possible to make a decision during the current one-second time interval.

The first check made by the basic measurement algorithm on a received cell is to determine if errors have occurred on the test cell payload. The CRC-16 value carried in the cell is compared with the CRC-16 calculated over the test cell payload at the receive side. If these are equal, the CRC-16 is said to have a syndrome value equal to zero. In this case, the cell is considered valid, otherwise it is considered non-valid.

When a non-valid test cell is received, a temporary counter E1 is incremented and records the number of non-valid cells received. A non-valid cell occurs as the result of either an errored cell or a misinserted cell. Characterizing these non-valid cells as lost cells or misinserted cells is postponed until the algorithm is able to make the decision with sufficient confidence. After the decision is made, the temporary counter E1 is reset to zero.

When a valid test cell is received and contains a SN value which is not considered to be in sequence with the previously received test cell, a temporary counter Nbreak is incremented and records the sequence break(s) in the sequence. A sequence break may occur on a cell loss or on an errored SN not detected by the CRC-16. Characterizing the corresponding outcomes is postponed until the algorithm is able to make the decision. After the decision is made, the temporary counter Nbreak is reset to zero.

For a high level of confidence, the algorithm postpones any decision, if required, until:

- either two consecutive valid cells (both CRC-16 syndrome values equal to 0) containing SN values in sequence are received (SN values are considered to be in sequence when $SN_{(n+1)} = SN_{(n)} + 1$, where the SN_x is the SN value of the xth received cell);
- or one valid test cell is received and the content of its SN field is equal to SNRef (the expected SN value).

Whenever the above decision criteria are reached, the algorithm gives the characterization of cell transfer outcomes and their respective number of occurrences when appropriate. Determining the number of lost and misinserted cells is based on the sequence number value. Basically, the difference between the test cell SN value and the reference SN value (SNRef), incremented by the algorithm at each test cell arrival, gives the number of either the lost cells (if it is positive) or the misinserted cells (if it is negative).

In some critical conditions, the AME could enter a state where it is not capable of making any decision for a long time and where performance assessment would not be possible. Therefore, at least one decision shall be made over a period of time of 10 seconds. For this purpose, the algorithm includes the detection of a Loss of Performance Assessment Capability (LPAC) anomaly. See Annex A for further details. The 10-second period before entering the LPAC state and periods in the LPAC state are considered to be part of the unavailable time. Actually, the LPAC state is not directly forwarded to the unavailability determination, but is considered in the SES_{ATM} determination and therefore is implicitly integrated in the unavailable time determination.

In addition to the basic measurement algorithm, the cell monitoring process shall include the observation of the end-to-end OAM fault management flow corresponding to the measured test cell flow (see Tables 6-5 and 6-7). Depending on the connection under test, the VP-AIS or VC-AIS defect defined in Annex A shall be detected and the existence of a defect within any one-second time interval shall be reported to the availability monitoring process. The arrival of end-to-end VP or VC continuity check cells shall be monitored and the arrival of a continuity check cell within the current one-second time interval shall be reported to the availability monitoring process (see 6.9.2 for more details).

6.8.2 Outcome monitoring process

The AME shall perform the SECB determination on cell blocks of size N. Default values of N shall be selected, in conformance with Recommendation I.356 [13], as a function of the peak cell rate (PCR) of the connection under test according to Table 6-9. Other values of N may be user selectable among the values defined in this table.

Table 6-9/O.191 – Cell block sizes and SECB thresholds

PCR (cells/second)	(User information rate in Mbit/s)	N (block size)	M (threshold)
$0 < x \leq 3200$	$(0 < y \leq 1.23)$	128	4
$3200 < x \leq 6400$	$(1.23 < y \leq 2.46)$	256	8
$6400 < x \leq 12\,800$	$(2.46 < y \leq 4.92)$	512	16
$12\,800 < x \leq 25\,600$	$(4.92 < y \leq 9.83)$	1 024	32
$25\,600 < x \leq 51\,200$	$(9.83 < y \leq 19.66)$	2 048	64
$51\,200 < x \leq 102\,400$	$(19.66 < y \leq 39.32)$	4 096	128
$102\,400 < x \leq 204\,800$	$(39.32 < y \leq 78.64)$	8 192	256
$204\,800 < x \leq 409\,600$	$(78.64 < y \leq 157.29)$	16 384	512
$409\,600 < x \leq 819\,200$	$(157.29 < y \leq 314.57)$	32 768	1024
NOTE – This table applies to the peak cell rate of the aggregate cell flow, CLP = 0 + 1.			

A cell block of size N shall be declared a Severely Errored Cell Block (SECB) if the sum of errored, lost or misinserted cell outcomes within the cell block, as detected by the outcome monitoring process, is greater than M = N/32.

Cell blocks have a size $N = 2^p$ cells, p being equal to 7 for a block size of 128, 8 for a block size of 256 and so on. For a given cell block of size $N = 2^p$, a cell block shall be considered to begin with the cell having the p least significant bits of the SN all equal to zero, and shall be considered to end with the cell having these p bits all equal to one, the (32-p) most significant bits keeping the same value.

However, errors and losses can affect cells which delineate cell blocks and it is not always possible to detect the actual block end. Therefore, a check is made for the beginning of a cell block every time the measurement algorithm described in Annex B makes a decision. The (32-p) most significant bits of the SN of the test cells are used to denote the block number Bx. Checking for the beginning of a new cell block is achieved by comparing the value B2 of the current test cell for which the algorithm has taken the last decision and the value B1 of the test cell for which the algorithm made the previous decision. Three cases can be distinguished:

1) B2 = B1: the currently received test cell belongs to the same cell block as the previous test cell.
2) B2 = B1+1: one cell block boundary is detected.
3) B2 > B1+1: several cell block boundaries are detected.

The difference between B2 and B1 gives the number of block ends (NbBE) which are detected.

To determine the SECB outcome, it is required to have per block counts of outcomes observed within the cell block. Outcomes estimated by the measurement algorithm before a new block is detected are accumulated in the corresponding per block counters as follows:

- NbETC is the number of errored test cells observed within the block by the measurement algorithm.
- NbLTC is the number of lost test cells observed within the block by the measurement algorithm.
- NbMTC is the number of misinserted cells observed within the block by the measurement algorithm.

To determine the SES_{ATM}:

- NbTC, the total number of test cells transmitted since the beginning of the block is required. This can be estimated, for example, by evaluating the Sequence Number of the received cells.

The Severely Errored Cell Block (SECB) is defined in Recommendation I.356 [13]. A block of size N shall be declared as an SECB if the sum of errored, lost and misinserted cells observed within the block is greater than N/32. This condition can be tested using per block counters defined above by:

$$NbETC + NbLTC + NbMTC > \frac{N}{32}$$

When the end of a cell block is not impaired, the above condition shall be used to determine whether the previous cell block is an SECB or not. All per block counters are reset after being processed in order to accumulate outcomes of the next cell block.

When the end of a cell block is impaired by errors or is lost, it is only possible to make a decision concerning the status of this cell block at the next time the measurement algorithm is able to make a decision. This situation can occur when a degradation period spans one or more cell block boundaries. In this case, it is not possible to get the exact count of the outcomes observed within each block. The following rules are used to apportion outcomes between impaired cell blocks. It is then determined whether the block(s) is (are) SECB(s) or not. Two cases are considered depending on the number of cell block boundaries impaired.

- If only one cell block boundary is impaired by degradation (NbBE = 1), 50% of each outcome estimated by the measurement algorithm are assigned to each impaired cell block. 50% of each outcome are accumulated within the current value of the corresponding per block counters and it is then decided, using these per block counters, whether the previous cell block is an SECB or not. All per block counters are then reset before the remaining 50% of each outcome are assigned to the corresponding per block counter for the next cell block.

  If the division process described above results in non-integers, assignments are rounded up for the previous block and rounded down for the next block.

- If more than one cell block boundary falls within a degradation period (NbBE > 1), all NbBE blocks are considered to be SECBs. Outcomes estimated by the measurement algorithm are not processed and per block counters are reset.

When the cell block is not considered to be an SECB, the contents of per block counters shall be added to the contents of corresponding temporary counters called Set1s and Set10s. These sets of temporary counters are defined in 6.8.3 and 6.9.2 respectively.

Set1s is a set of temporary counters accumulating outcomes observed during the current one-second period.

Set10s is a set of temporary counters accumulating each outcome observed during at most ten consecutive one-second intervals. Ten seconds correspond to the maximum period before triggering a possible unavailable state.

When the cell block is considered to be an SECB, a temporary counter called Set1s_SECB (defined in 6.9.2) is increased by "NbBE". Set1s_SECB is the count of SECBs observed during the current one-second interval.

6.8.3 Availability monitoring and storage control process

According to Recommendation I.357 [14], the unavailable state shall be declared after ten consecutive SES_{ATM}. During the unavailable state, performance outcomes estimated by the measurement algorithm shall not be considered for cell transfer performance parameter calculation. The storage control process inhibits/allows the storage of per block outcomes in performance registers (so called Globalcount), depending on the available state. I.356 outcomes observed are only stored in this performance register when the connection is in the available state. For this purpose, a set of temporary counters called Set10 is required.

Set10s registers are incremented with corresponding per block counters, when a cell block end is detected. These registers accumulate the I.356 outcomes observed during either the first 10 SES_{ATM} triggering the unavailable state, or the last 10 seconds non-SES_{ATM} triggering the available state. These counts exclude, from performance parameter estimation, outcomes observed during the first 10 SES_{ATM} belonging to the unavailable state. The counts also include outcomes observed during the last 10 seconds non-SES_{ATM} belonging to the available state. "Set10s" should include the following counters:

- Set10s_LC is the total count of lost test cells observed during the considered time interval excluding those counted in blocks declared as SECBs. It is updated by the per block counter NbLTC when a block end is detected and if the block is not declared as SECB.
- Set10s_EC is the total count of errored test cells observed during the considered time interval excluding those counted in blocks declared as SECBs. It is updated by the per block counter NbETC when a block end is detected and if the block is not declared as SECB.
- Set10s_MC is the total count of misinserted test cells observed during the considered time interval excluding those counted in blocks declared as SECBs. It is updated by the per block counter NbMTC when a block end is detected and if the block is not declared as SECB.
- Set10s_SECB is the total count of SECBs observed during the considered time interval. It is incremented each time a block is determined as SECB.
- Set10s_Block is the total count of complete blocks observed during the considered time interval. It is incremented each time a block end is detected.

When a decision is made concerning the availability status, either the Set10s counters are reset, if the corresponding seconds are considered to be part of unavailable time, or the Set10s counters are first added to corresponding performance result registers (Globalcount), if the corresponding seconds are considered to be part of available time, prior to being reset.

Therefore, Set10s counters can be reset before 10 consecutive seconds. For example, if a connection is in the available state, and a performance degradation produces 8 consecutive SES_{ATM} and the next second is not considered as SES_{ATM}, the contents of these Set10s counters are added to the corresponding performance result registers, Globalcount, before being reset.

Figures 6-13 and 6-14 provide an algorithm which describes the storage control process and the associated unavailability determination process. This algorithm is based on monitoring, for each cell, relevant events (arrivals of cells on the connection) and some time-outs, based on a one-second clock. The first part of the algorithm (Figure 6-13) processes different sets of outcome counters for available periods of time, and checks every second for the unavailable state according to Recommendation I.357 [14]. The second part of the algorithm (Figure 6-14) inhibits the accumulation of I.356 outcomes during the unavailable time and checks, every second, for the available state.

NOTE – This algorithm describes one part of the performance estimation process and does not imply any specific implementation.

In Figures 6-13 and 6-14, the box "cell monitoring process" is described in 6.8.1. The process of the "per block counts of outcomes" box is described in 6.8.2. The diamond box < Cell arrival? > checks, at the cell link rate, whether a cell to be processed has arrived or not. The diamond box < SES_{ATM}? > checks whether the one-second time interval is considered as SES_{ATM} or not. This test and relevant processes are described in this subclause.

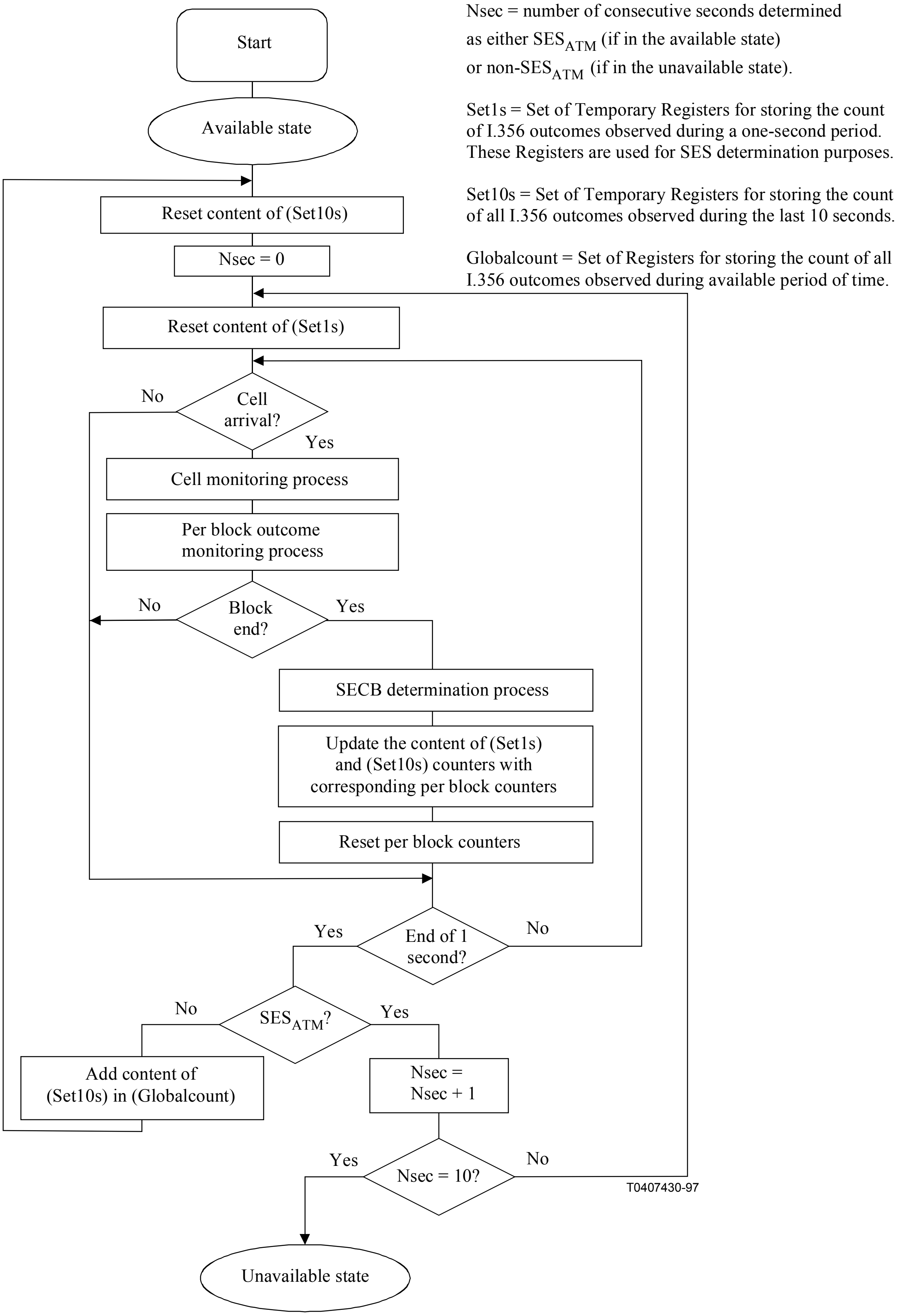


Figure 6-13/O.191 – Example of the part of an algorithm applicable in available time

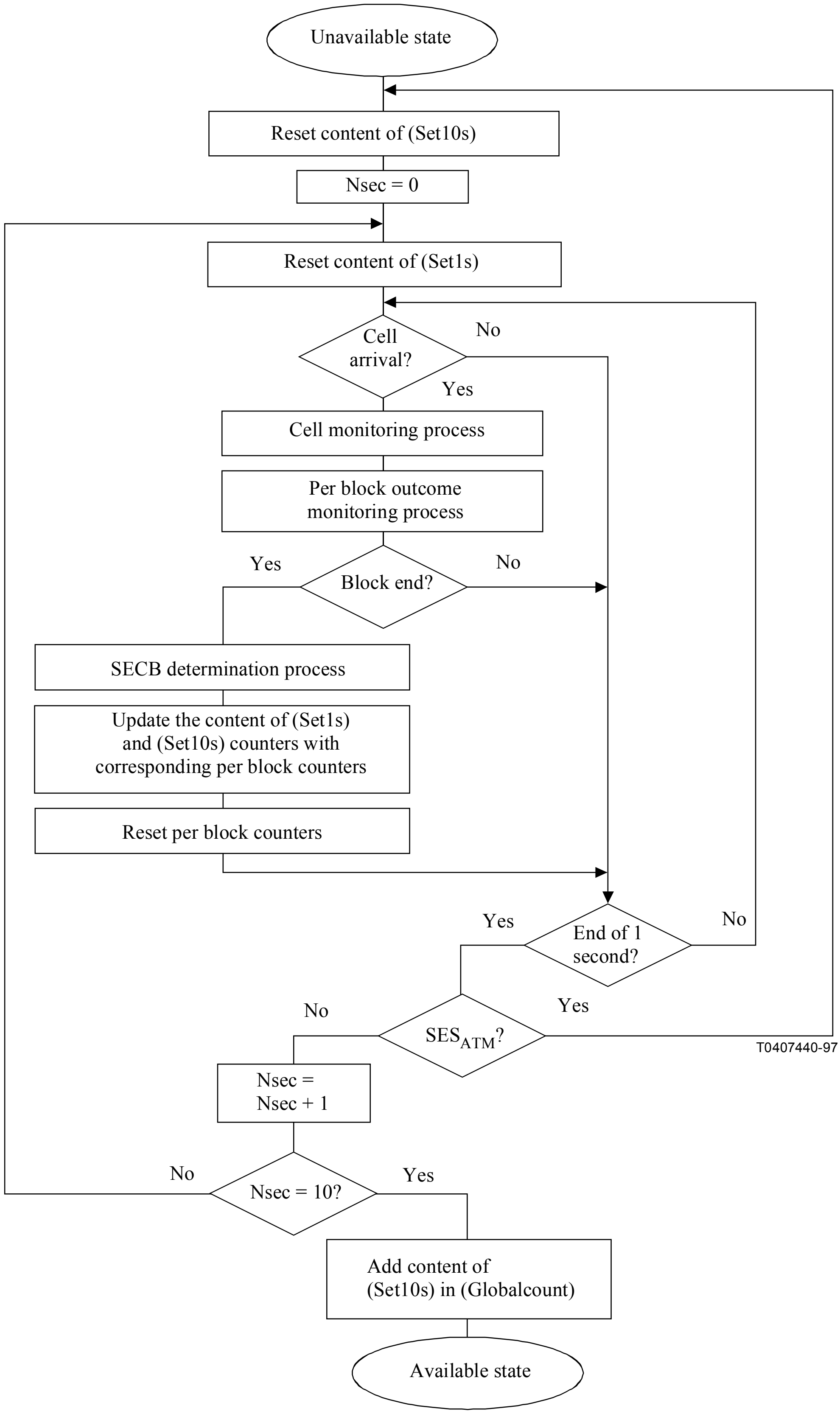


Figure 6-14/O.191 – Example of the part of an algorithm applicable in unavailable time

6.9 Network performance parameters calculation

The set of performance registers (Globalcount) is used to compute cell transfer performance parameters according to Recommendation I.356 [13]. This set includes the following registers:

- Globalcount_LC is the total count of lost test cells observed during available periods of time. It is updated by counter Set10s_LC as shown in both Figures 6-13 and 6-14.
- Globalcount_EC is the total count of errored test cells observed during available periods of time. It is updated by counter Set10s_EC as shown in both Figures 6-13 and 6-14.
- Globalcount_MC is the total count of misinserted test cells observed during available periods of time. It is updated by counter Set10s_MC as shown in both Figures 6-13 and 6-14.
- Globalcount_SECB is the total count of SECBs observed during available periods of time. It is updated by counter Set10s_SECB as shown in both Figures 6-13 and 6-14.
- Globalcount_Block is the total count of complete blocks detected during available periods of time. It is updated by counter Set10s_Block as shown in both Figures 6-13 and 6-14.

In order to compute unavailability performance parameters, each occurrence of an unavailable period of time shall be recorded in a specific unavailability "history" register. Each record should identify the time stamped information related to the unavailability beginning and ending times.

NOTE – As an option, other counters for parameters not defined in Recommendations I.356 [13] and I.357 [14] may be provided for maintenance purposes. For example, the number of observed SES_{ATM} outcomes could be evaluated.

The Cell Loss Ratio (CLR), Cell Error Ratio (CER), Cell Misinsertion Rate (CMR) and Severely Errored Cell Block Ratio (SECBR) are cell transfer performance parameters defined in Recommendation I.356 [13]. They are calculated over the measurement period.

6.9.1 Error-related network performance parameters

Error performance parameters should only be calculated during available time. Availability and unavailability conditions from a network performance point of view are defined in Recommendation I.357 [14]. Therefore, successfully transferred cells, errored cells, misinserted cells, lost cells and SECBs shall not be accumulated during unavailable time for the purpose of performance assessment.

The SECBR shall be estimated for a set of S consecutive or non-consecutive cell blocks by dividing the total number of severely errored cell blocks by S.

All calculations are based on the theoretical definition given in Recommendation I.356 [13].

The Cell Loss Ratio for the measured flow is defined as:

$$CLR = \frac{Globalcount\_LC}{N * (Globalcount\_Block - Globalcount\_SECB) - Globalcount\_LC}$$

where N is the number of cells within a cell block (see 6.8.2).

The Cell Error Ratio for the measured flow is defined as:

$$CER = \frac{Globalcount\_EC}{N * (Globalcount\_Block - Globalcount\_SECB)}$$

The Cell Misinsertion Rate for the measured flow is defined as:

$$CMR = \frac{Globalcount\_MC}{Duration\_of\_available\_state}$$

where Duration_of_available_state is the sum of the available periods of time during the observation period.

The Severely Errored Cell Block Ratio for the measured flow is defined as:

$$SECBR = \frac{Globalcount\_SECB}{Globalcount\_Block}$$

6.9.2 Availability-related network performance parameters

Entering or exiting the unavailable state is declared after the observation of ten consecutive SES_{ATM} or ten consecutive non-SES_{ATM} respectively.

In order to determine SES_{ATM} as defined in Recommendation I.357 [14], the total count of lost cells and SECBs observed during the current one-second time interval must be known. This is the purpose of the set of the following temporary counters called Set1s.

- Set1s_LC is the total count of lost test cells observed within the current one-second time interval excluding those counted in blocks declared as SECBs. It is updated by per block counter NbLTC when a block end is detected and if the block is not determined as SECB.
- Set1s_SECB is the total count of SECBs observed within the current one-second time interval. It is incremented each time a block is declared as SECB within the current one-second time interval.
- Set1s_Block is the total count of complete blocks observed within the current one-second time interval. It is incremented each time a block end is detected within the current one-second time interval.
- Set1s_AIS has a Boolean value and indicates whether an AIS defect (see Annex A) has existed within the current one-second time interval.
- Set1s_Decision has a Boolean value and indicates whether the measurement algorithm was able to make a decision within the current one-second time interval. This flag is set by the cell monitoring process (see 6.8.1) and is reset at the end of each one-second time interval.
- Set1s_CC has a Boolean value and indicates whether an end-to-end continuity check cell has been received within the current one-second time interval. This flag is set by the cell monitoring process and is reset at the end of each one-second time interval.

The per block counts of outcomes accumulated within the per second counters shall correspond only to cell blocks whose end has been observed within the current one-second time interval. In other words, outcomes accumulated in the per block counters for the current cell block shall not be added to the per second counters before the end of this current cell block is detected within the outcome monitoring process and the SECB determination is made. When one cell block spans over two one-second time intervals, the per block counts for this cell block are taken into account in the second time interval.

Per second counters shall then be reset for the next one-second time interval. An example of per second counter management is given in Figures 6-13 and 6-14.

For each one-second time interval, the AME shall determine whether the elapsed second was an SES_{ATM} or not. One-second time intervals shall be consecutive and are not synchronized to any ATM event. One-second time intervals can be derived by the AME from a free running clock, a clock synchronized through the physical layer to a network reference clock or a clock synchronized to a UTC reference distribution system.

From a network perspective of availability, a given one-second time interval is considered to be an SES_{ATM} if CLR > 1/1024 or the SECB ratio is greater than 1/32, where CLR and SECBR are computed over the considered time interval. A given one-second interval is also considered to be an SES_{ATM} if the connection is unable to provide acceptable cell transfer performance because an interruption has occurred within the connection, even if test cells are not transmitted during this period of time. In order to detect an interruption, an AME shall send at least one test cell or continuity check cell per second (see 6.3).

A given one-second interval is also considered to be an SES_{ATM} if an AIS defect has existed within the current one-second time interval.

If the block size N is selected in accordance with Recommendation I.356 [13], the maximum number of cell blocks per second is normally limited to 25. Therefore, if only one SECB is observed within a one-second time interval, this interval shall be declared an SES_{ATM}. This is not intended to mean that the AME shall check conformance with the traffic contract before making the measurement or that more than 25 blocks per second is impossible.

The per block counts of outcomes relevant to determine the SES_{ATM} shall correspond to cell blocks whose end has been detected within the one-second time interval. However, a decision about SES_{ATM} determination shall be made every second, even if no block end has been detected within a one-second time interval (this may occur in case of high degradation or when a block spans several one-second time intervals). In this particular case, the SES_{ATM} determination for the considered one-second time interval is based upon the current value of the per block counters and/or per second flag.

From a network perspective of availability, two cases are distinguished depending on whether a cell block end is detected within the one-second time interval or not.

When at least one cell block end is observed, during the one-second time interval (Set1s_Block > 0), counts of lost cells (Set1s_LC) and number of SECBs (Set1s_SECB), related to cell blocks ending within this one-second time interval (Set1s_Block), shall be taken into account for the SES_{ATM} determination. Conditions to declare a one-second time interval an SES_{ATM} are:

a.1 $\text{Set1s\_LC} > \dfrac{\text{Set1s\_Block} - \text{Set1s\_SECB}}{1024} * N$; or

a.2 Set1s_SECB > 0; or

a.3 Set1s_AIS = TRUE.

If there is no block end detected within a one-second time interval (Set1s_Block = 0), the per block counters shall not be reset but shall be used to determine the SES_{ATM} as follows:

b.1 On condition that the measurement algorithm is able to make a decision during the one-second time interval (Set1s_Decision = TRUE), an SES_{ATM} is declared if:

b.1.1 $NbLTC > \dfrac{NbTC}{1024}$; or

b.1.2 $NbLTC + NbETC + NbMTC > \dfrac{NbTC}{32}$; or

b.1.3 Set1s_AIS = TRUE.

b.2 On condition that the measurement algorithm is not able to make a decision during the one-second time interval (Set1s_Decision = FALSE), an SES_{ATM} is declared if:

b.2.1 If Set1s_CC = FALSE; or

b.2.2 If Set1s_AIS = TRUE.

NOTE 1 – If the transmitted test traffic profile comprises more than 1 test cell per second, the SES_{ATM} estimation process is improved.

NOTE 2 – If the duration of the block is longer than one second, the SES_{ATM} estimation may be inaccurate.

At the end of SES_{ATM} determination, the per second temporary counters and flags are all reset.

This approach ensures that a decision about SES_{ATM} is always made, even in the specific case when a block spans several one-second time intervals. In this particular case, the SES_{ATM} outcome is determined based on known information at the end of each one-second time interval.

LPAC is not directly considered in the availability determination process. This state, which is determined by the measurement algorithm, is implicitly considered in the SES_{ATM} determination by using the Set1s_Decision flag.

The network Availability Ratio (AR) is defined in Recommendation I.357 [14], as the proportion of time that the connection is in the available state over an observation period. The network AR is calculated by dividing the total network available time during the observation period by the duration of the observation period. Network AR can be estimated taking into account the time stamped information indicating beginning and ending times of unavailability.

The measurement of service AR is for further study.

The network Mean Time Between Outages (MTBO) is defined in Recommendation I.357 [14], as the average duration of a continuous time interval during which the connection is available from the network perspective. Network MTBO can be estimated taking into account the time stamped information indicating beginning and ending times of unavailability.

The measurement of service MTBO is for further study.

6.9.3 Delay-related network performance parameters

Mean Cell Transfer Delay (CTD) and 2-point Cell Delay Variation (CDV) are delay-related network performance parameters defined in Recommendation I.356 [13]. CTD is measured out-of-service by transmitting timestamped test cells through the network on an established connection. A transmitted test cell contains in its timestamp field the time t_s at which the cell is transmitted. A CTD sample is obtained at the receive side by subtracting the time t_r at which the test cell is received from the time t_s extracted from the received cell. The CTD samples are used to calculate the mean CTD. The same samples are used to characterize the 2-point CDV. These out-of-service measurements are applicable to a VCC or a VPC carrying test cell traffic.

The measurement accuracy depends on a variety of factors including whether the measuring AME is transmitting the test cell flow it is analysing or not, as well as the cell rate of the test cell flow and the desired number of samples. Under certain circumstances and when high accuracy is required, the timestamp clocks of the transmitting and receiving AMEs are required to be frequency and/or phase synchronized. The timestamp clock is the mechanism included in the AME which provides time information used to insert timestamps into the transmitted test cells or used to time stamp received test cells.

Figure 6-15 illustrates the terms and results used in this subclause.

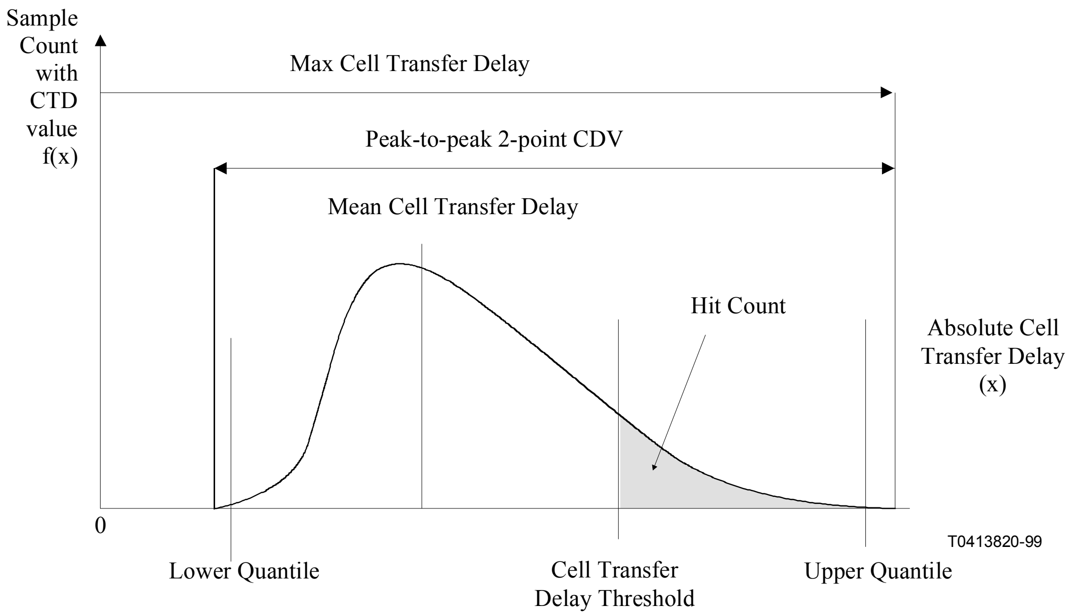


Figure 6-15/O.191 – CTD and CDV terms

While 2-point CDV and CTD are inherently end-to-end measurements, they may be achieved on a looped basis. It should be noted that due to possible impairments introduced in the forward direction, the traffic contract in the backward direction may be violated with the result that some samples may be lost.

The transmitted test traffic profile used for CTD/CDV measurement is the same as that used for error performance.

For network performance estimation of delay-related parameters, care should be taken by the user of the AME as for error-related parameters. The traffic profile parameters must be set up within the limits of the traffic contract of the connection under test in order to have meaningful calculated results. However, the mean cell rate should be sufficiently high to be representative of the traffic on the connection, and to allow for the transmission of a statistically significant number of cells over the period of measurement. 1000 cells or more per measurement period should be considered.

6.9.3.1 Measurement duration

For long-term measurement of network performance parameters, the AME should indicate the following results:

- the mean CTD (MCTD);
- optionally the maximum CTD;
- the peak-to-peak 2-point CDV;
- optionally a CTD Hit Count (CHC) and CTD Hit Ratio (CHR),

over all valid cells for the whole measurement period.

A CTD threshold is associated with the CTD hit count. This threshold is entered by the user of the AME based on the knowledge of the maximum CTD that a cell may experience on the tested connection.

In addition to the long-term measurement, a repetitive short-term measurement for current operational purposes may be useful. For instance, short-term measurements can help in the detection of changing network load conditions. The results consist of the same set as for long term, but are calculated over a period of time and updated at the end of the period. For example, periods of 5 or

15 minutes could be selectable. For ease of comparison of results between two or more related AMEs, the beginning of measurement periods in each AME should be synchronized.

It may be valuable to store the consecutive sets of results in the AME for further processing by the AME or an external device.

Quantile-based measurements of peak-to-peak 2-point CDV are for further study.

6.9.3.2 Result calculation

A sample CTD value shall be calculated for every valid cell received during the available time. Refer to 6.8.1 for the definition of a valid cell and to 6.8.3 for the definition of available time.

As an option, it may be useful to measure a sample CTD value calculated for every valid cell received during both available and unavailable time. This option provides a complete second set of results. These results should not be mixed with the standard results that exclude periods of unavailability.

The sample CTD value is calculated as $t_r - t_s$, where t_s is the value of the timestamp read from the received test cell, and indicates the time relative to the transmit synchronized time reference when the cell was transmitted, and t_r is the value of the synchronized time reference in the receiver at the time when the test cell is received.

The mean CTD is the sum of the sample CTD values divided by the total number of calculated samples.

The peak-to-peak 2-point CDV is the difference between the maximum and the minimum values of all CTD samples calculated over the whole measurement period.

The maximum CTD is the maximum sampled CTD value over the whole measurement period.

CTD samples exceeding the CTD hit threshold are included in the three previous calculations.

The CTD hit ratio is the number of CTD samples having a value exceeding the set CTD hit threshold divided by the total number of calculated samples over the whole measurement period.

6.9.3.3 Timestamp clock synchronization

As mentioned in 6.9.3, accurate long-term end-to-end CDV measurements require that the clock used for the timestamp generation in the transmitting AME and the clock used to timestamp the received cells in the receiving AME are frequency synchronized.

In the same configuration, accurate CTD measurements additionally require that the rollover of the timestamp counters of the two distant AMEs occur at the same time or equivalently that the transmit timestamp counter and the relevant receive timestamp counter are reset at the same time. A repetitive reset may simplify the synchronization problem. Systems providing this phase synchronization capability over a significant geographical area have synchronization periods of 1 second or multiples of 1 second and therefore require the transmit timestamp counter to be reset before its natural rollover (occurring approximately every 42 s).

Resetting the timestamp counter on the basis of 1s or multiples of 1s is considered as an option.

However, a receiving AME must know if the transmit timestamp counter rolls over on the basis of its natural period or on a forced period. Therefore, the revision 1 test cell payload format shall be used when the resetting of the transmit timestamp counter is implemented.

6.9.3.4 Measurement accuracy

Accuracy of CTD and peak-to-peak 2-point CDV measurements depends on several causes of error that must be taken into account. Table 6-10 summarizes these causes and their respective influence on the measurements.

Table 6-10/O.191 – Error causes for CTD and 2-point CDV measurements

<table>
<tr><th rowspan="2">Error type</th><th rowspan="2"></th><th colspan="2">Influence on the accuracy of:</th></tr>
<tr><th>Mean and maximum CTD</th><th>Peak-to-peak 2-point CDV</th></tr>
<tr><td colspan="4">Errors due to the transmitting AME</td></tr>
<tr><td>A</td><td>Delay between the insertion of the timestamp in a test cell and the actual departure time of the cell plus transmit timestamp resolution plus jitter introduced by the physical layer plus other internal causes</td><td>Yes</td><td>(Note 1)</td></tr>
<tr><td colspan="4">Errors due to timestamp clocks in the transmitting and receiving AMEs</td></tr>
<tr><td>B</td><td>Error due to the lack of frequency synchronization to a common reference when phase synchronization is not achieved</td><td>Yes (Note 2)</td><td>Yes (Note 2)</td></tr>
<tr><td>C</td><td>Error due to the lack of phase synchronization to a common reference when frequency synchronization is not achieved</td><td>Yes (Note 2)</td><td>No</td></tr>
<tr><td>D</td><td>Error due to the lack of frequency synchronization to a common reference when only phase synchronization is achieved</td><td>Yes</td><td>Yes</td></tr>
<tr><td>E</td><td>Error due to the lack of phase synchronization to a common reference when only frequency synchronization is achieved</td><td>Yes (Note 2)</td><td>No</td></tr>
<tr><td>F</td><td>Inaccuracy of the phase synchronization reset mechanism</td><td>Yes</td><td>Yes</td></tr>
<tr><td>G</td><td>Inaccuracy of the frequency synchronization mechanism</td><td>Yes</td><td>Yes</td></tr>
<tr><td colspan="4">Errors due to the receiving AME</td></tr>
<tr><td>H</td><td>Delay between the time stamping of a received test cell and its actual arrival time plus receive timestamp resolution plus other internal causes</td><td>Yes</td><td>(Note 1)</td></tr>
<tr><td>I</td><td>Computation errors</td><td>Yes</td><td>Yes</td></tr>
<tr><td colspan="4">NOTE 1 – When the delay consists of a fixed part plus a variable part only the variable part degrades the accuracy of peak-to-peak 2-point CDV measurements.
NOTE 2 – In this case, a measurement is not recommended but may be performed if the effect of lack of phase or frequency synchronization can be quantified. The maximum error due to the lack of frequency synchronization can be expressed as:
Error (μs) = ±Delta F (ppm) × Number of samples × Number of bits per cell (including the header)/Mean ATM bit rate of the test cell stream (bit/s) where Delta F is the sum of the frequency accuracy of both the transmitter and the receiver timestamp clocks. If the timestamp clocks of the transmitting and receiving AMEs can be manually synchronized and the users of the two AMEs have a means to communicate and synchronize their manual setting, the error due to lack of phase synchronization can be reduced. It is felt that 1 second is the order of magnitude of what can be achieved.</td></tr>
</table>

Error type A depends mainly on the implementation of the AME and secondarily on the characteristics of the physical layer. It is likely that timestamps will be generated at the ATM layer within the AME. Therefore, an unavoidable delay variation due to the physical interface must be taken into account. For most physical interfaces it includes a delay variation equal to $\pm \Delta/2$, where Δ is the transmission time of a cell on the physical link, because an idle cell or a cell belonging to the background traffic is being transmitted. Another delay variation, Φ, results from the multiplexing at the physical level of the cell and of framing, rate adaptation, or signalling information. On a 155 Mbit/s SDH physical link, an ATM cell can be interrupted by a variable number of overhead bytes. On a 2 Mbit/s link, an ATM cell can be interrupted by 3 or 4 time slots. Table 6-11 lists these delay variations $H(\Delta)$ as a function of the physical interface. Note that this error fully applies to the peak-to-peak 2-point CDV, but can be reduced for the mean CTD.

Table 6-11/O.191 – Error H(Δ) as a function of physical B-ISDN UNIs

Bit rate (kbit/s)	Signal structure	Recommendation	$H(\Delta) = \pm (\Delta/2) \pm \Phi$		
			$\pm\Delta/2$	$\pm\Phi$	Explanation for Φ
1 544	Frame based	I.432.3 [18]	±138.02 µs	±0.32 µs	1 framing bit
2 048	Frame based	I.432.3 [18]	±110.42 µs	±1.95 µs	1 time slot (0 or 16)
25 600	Byte based	I.432.5 [20]	±0.07 µs	±0.15 µs	No idle cell; 1 sync character
51 840	Frame based	I.432.4 [19]	±4.38 µs	±0.39 µs	3 SOH bytes + 1 POH bytes or fixed stuff + 1 pointer adj bytes
51 840	Cell based	I.432.4 [19]	±4.38 µs	±4.38 µs	1 physical layer cell
155 520	Frame based	I.432.2 [17]	±1.42 µs	±0.33 µs	9 SOH bytes + 1 POH bytes + 3 pointer adj bytes
155 520	Cell based	I.432.2 [17]	±1.42 µs	±1.42 µs	1 physical layer cell
622 080	Frame based	I.432.2 [17]	±0.35 µs	±0.33 µs	36 SOH bytes + 4 POH/stuff bytes + 12 pointer adj bytes
622 080	Cell based	I.432.2 [17]	±0.35 µs	±0.35 µs	1 physical layer cell
NOTE – The column explanation indicates the bits or bytes that may be randomly and arbitrarily forced or not by the physical layer during the transmission of a cell.					

Error types B, C, D, E, F and G must be taken into account when an AME measures mean CTD or peak-to peak 2-point CDV on test cells that it has not generated, that is, when the measuring AME is physically different from the transmitting AME. This includes, in particular, all unidirectional end-to-end measurements between two distant sites. Degree of inaccuracy depends not only on the synchronization capabilities offered by the AMEs, but also on the synchronization scheme used for the measurement, and on the stability characteristics of external synchronizing sources. Four synchronization schemes are identified:

The time clocks of the two AMEs are phase and frequency synchronized to a single time reference. This time reference must cover the two sites where the AMEs are located. The Global Positioning System (GPS) with its worldwide coverage may be used as a time reference. Frequency synchronization may be achieved using a single-network clock or an external reference frequency, for example, as provided by GPS. In this scheme only error types F and G must be taken into account. The error type F, inaccuracy of the phase synchronization, includes any jitter that could occur even with sophisticated time reference systems on the time position of the repetitive pulse, generally used for synchronization and any further error introduced by the AME during the phase synchronization process. Similar considerations apply to error type G.

The time clocks of the two AMEs are phase synchronized, but the two AMEs are synchronized to plesiochronous clocks, i.e. each AME uses either an internal stable free running oscillator or is synchronized to the network frequency through its physical interface. Note that the network frequencies at each AME may not be entirely the same. In this scheme error types D and F must be taken into account. The maximum type D error introduced is equal to:

$$\text{Error } (\mu s) = \pm \text{Delta F (ppm)} \times \text{Resynchronization period (s)}$$

where Delta F is the sum of the frequency accuracy of both the transmitter and the receiver timestamp clocks.

The time clocks of the two AMEs are frequency synchronized. This may be achieved by synchronizing each of the time clocks to the network frequency or external reference frequency where the frequency at both ends is traceable to a common reference. In this scheme error, type E must be taken into account.

The time clocks of the two AMEs are neither phase nor frequency synchronized. In this scheme error, types B and C must be taken into account.

Error types H and I depend only on the implementation of the AME. Error type I, computation errors, includes all inaccuracies internal to the AME such as limited resolution, truncating, rounding, and algorithmic errors.

Recommendation I.356 [13] defines a limit of 400 ms for MCTD and a limit of 3 ms for peak-to-peak 2-point CDV for class 1 QOS. The 3 ms limit applies when there are no more than 9 ATM nodes in the connection with 34 or 45 Mbit/s output links and all other ATM nodes are operating at 155 Mbit/s or higher. 2-point CDV will generally increase as transport rates decrease.

Error types A and H may contain fixed and variable components. It is possible that the user or the AME itself may correct the fixed components. If the AME does not compensate for the fixed components, it shall indicate it by any appropriate means.

The following accuracies are suggested to allow for variable components of error types A, H and I for frame based interfaces:

- $\pm 1\ \mu s \pm 0.2\ \Delta$ for the mean CTD;
- $\pm 2\ \mu s \pm 2\ \Delta$ for the peak-to-peak 2-point CDV and the maximum CTD;

where Δ is the transmission time of a cell on the physical link.

CTD and CDV results should only be associated when the respective measurements are performed at the same time on the same test traffic flow.

The measurement range for both the maximum CTD and the peak-to-peak 2-point CDV is 10 seconds or the timestamp resynchronization period, whichever is smaller.

6.10 UPC/NPC performance parameters

Usage/network parameter control (UPC/NPC) is defined in Recommendation I.371 [16] as the set of actions taken by the network to monitor and control that the traffic contract on a given connection is respected in terms of traffic offered and validity of the ATM connection, at the user-network interface and the inter-network interface respectively. The primary purpose is to protect network resources from malicious as well as unintentional misbehaviour of ATM sources which can affect the QOS of other already established connections.

Therefore, UPC/NPC functions monitor the cell flow conformance on a connection at a UNI/INI according to the traffic contract parameters negotiated at connection set-up. They are allowed to discard/tag cells whenever the cell flow is non-conformant. UPC/NPC functions are not standardized nor mandatory. However, incorrect operation of UPC/NPC functions on a given connection can adversely affect the performance offered to this connection by taking excessive policing action and erroneously discarding/tagging some conforming cells on that connection. Incorrect UPC/NPC operation taking insufficient policing actions on other simultaneous connections may overload a network element with non-conforming cells and can indirectly decrease the performance offered to the previous connection.

Transparency, a main performance parameter characterizing a UPC/NPC function, is defined in Recommendation I.371 [16] as the accuracy with which a UPC/NPC initiates appropriate control actions on a cell stream in which some cells are non-conforming, and avoids inappropriate control actions on a stream of conforming cells. On a practical viewpoint it can be expressed, for a given set of traffic characteristics, as the difference between the ideal reference policing ratio γ_r and the actual policing ratio γ_a, the policing ratio being the number of discarded/tagged cells over the total number of transmitted cells. A positive difference means that the UPC/NPC is taking less action than a reference process should do. A negative difference means that policing actions are unduly taken by the UPC/NPC.

The most appropriate method to determine the policing ratio uses the out-of-service measurement scheme shown in Figure 6-16. The generator of an AME transmits test cells with a given traffic profile on a connection towards the UPC/NPC functions of a network element, an ATM switch or cross-connect for instance. The receiver of an AME counts the number of lost/tagged and the number of received cells at the egress of the network element using the characteristics of test cells. The policing ratio is equal to the number of lost/tagged cells over the sum of the lost/tagged cells plus the received cells.

It should be noted that heavy traffic loads applied to the network element may lead to cells lost inside the network element that are not discarded by the UPC/NPC functions, and therefore may affect the accuracy of the measured policing ratio.

As indicated in Figure 6-16, the ideal reference policing ratio γ_R should be determined on the basis of the actual traffic profile sent by the generator. It could be either measured using a reference conformance implementation or computed.

Exercising the UPC/NPC functions independently or simultaneously for peak cell rate, cell delay variation tolerance, sustainable cell rate and burst tolerance requires the generation of particular test traffic profiles. Subclause 6.3.2 defines such a generator.

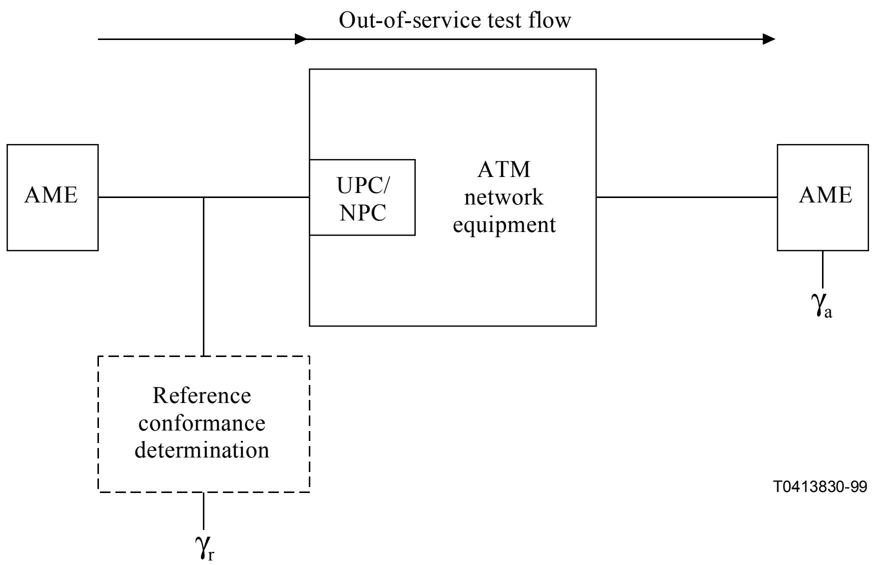


Figure 6-16/O.191 – UPC/NPC policing ratio measurement scheme

7 In-service measurement mode

In-service measurement is performed when testing the performance delivered by a network to a user connection. It can also be used for maintenance purposes and/or to check the OAM procedures.

In the in-service measurement mode, the live traffic of an ATM connection is monitored directly. The Fx fault management flow is analysed to detect severe impairments on the connection. This mode also makes use of the Fx performance monitoring flow provided by ATM network elements for the measurement of some performance parameters.

This measurement mode is totally non-intrusive if protected monitoring points are provided for the connection of the AME to the physical medium. In any case, the method is non-intrusive with respect to the resource allocation provided by the network because:

i) user traffic characteristics are specified for the network at connection set-up; and

ii) OAM traffic characteristics are specified for the network either at connection set-up or at the time of OAM activation/deactivation.

7.1 Network performance parameters estimation

7.1.1 Monitored cell flows

Table 7-1 defines the cell population which shall be monitored to detect cell transfer outcomes for measurement on a VPC. Table 7-2 lists further outcomes related to defects and indications at the ATM layer which shall also be detected. All these outcomes are observed on the forward direction at the measurement point located close to the near end as defined in Figure 7-1.

Table 7-1/O.191 – Monitored cells to determine cell transfer outcomes for a VPC

Monitored connection type	End-to-end VPC	Segment VPC
Monitored Fx PM OAM flow	End-to-end F4	Segment F4
Header of monitored Fx PM OAM cells (Note 7)	GFC (Note 1): BBBB VPI: VPI value of the monitored VPC VCI: 4 PTI (Notes 2, 3): 0B0 CLP (Notes 2, 4): B	VPI: VPI value of the monitored VPC VCI: 3 PTI (Notes 2, 3): 0B0 CLP (Notes 2, 4): B
Header of monitored "user cells"	GFC (Note 1): BBBB VPI: VPI value of the monitored VPC VCI: As per definition of "user cells" at F4 level given in Recommendation I.610 [21] PTI (Note 5): BBB CLP (Note 6): D	VPI: VPI value of the monitored VPC VCI: As per definition of "user cells" at F4 level given in Recommendation I.610 [21] PTI (Note 5): BBB CLP (Note 6): D

NOTE 1 – Applicable only to measurements at a UNI.

NOTE 2 – B indicates the bit is a "don't care bit".

NOTE 3 – Recommendation I.361 [15] specifies that the second bit of the PTI may be 0 or 1 and is available for use by the appropriate ATM layer function. As Recommendation I.610 [21] does not specify different ATM processing functions based on the received value of this bit, the AME shall monitor cells regardless of the value of this bit.

NOTE 4 – Recommendation I.361 [15] specifies that the CLP bit may be 0 or 1. As Recommendation I.610 [21] does not give more information about CLP, the AME shall monitor OAM cells regardless of the value of the CLP bit.

NOTE 5 – As Recommendation I.610 [21] does not specify any restriction on the value of the PTI for a VPC, the AME shall monitor user cells regardless of the PTI value.

NOTE 6 – D indicates that the bit may be 0 or a "don't care" bit depending on the traffic component of the ATM connection. CLP = 0 or CLP = 0 + 1 as defined in Recommendation I.371 [16] are to be measured.

NOTE 7 – The Fx PM OAM flow comprises the Fx FM flow for the assessment of the connection in the forward direction and the Fx BR flow for reporting the performance assessment related to the backward direction of the connection.

Table 7-2/O.191 – Monitored outcomes related to ATM defects and indications for a VPC

Monitored connection type	End-to-end VPC	Segment VPC
Monitored ATM outcomes on the Fx fault management OAM flow for the forward direction	VP-AIS, VP-LOC } (See Annex A)	VP-AIS, VP-LOC } (See Annex A)
Monitored ATM outcomes on the Fx FM OAM flow for the forward direction	VP-LFMF (Note 1)	VP-LFMF (Note 1)
Monitored ATM outcomes on the Fx fault management OAM flow for the backward direction	VP-RDI (See Annex A)	VP-RDI (See Annex A)
Monitored ATM outcomes on the Fx BR OAM flow for the backward direction	VP-LBRF (Note 2)	VP-LBRF (Note 2)

NOTE 1 – The VP-LFMF indication is defined only for measurement purposes. It indicates the loss of F4 forward monitoring flow. Criteria to declare or release the VP-LFMF indication are given in Annex A. Processing of the VP-LFMF requires further study.

NOTE 2 – The VP-LBRF indication is defined only for measurement purposes. It indicates the loss of F4 backward reporting flow. Criteria to declare or release the VP-LBRF indication as well as its processing require further study.

Table 7-3 defines the cell population which shall be monitored to detect cell transfer outcomes for measurement on a VCC. Table 7-4 lists further outcomes related to defects and indications at the ATM layer which shall also be detected. All these outcomes are observed on the forward direction at the measurement point located close to the near end as defined in Figure 7-1.

Table 7-3/O.191 – Monitored cells to determine cell transfer outcomes for a VCC

Monitored connection type	End-to-end VCC	Segment VCC
Monitored Fx PM OAM flow	End-to-end F5	Segment F5
Header of monitored Fx PM OAM cells (Note 5)	GFC (Note 1): BBBB VPI: VPI value of the monitored VCC VCI: VCI value of the monitored VCC PTI: 101 CLP (Notes 2, 3): B	VPI: VPI value of the monitored VCC VCI: VCI value of the monitored VCC PTI: 100 CLP (Notes 2, 3): B
Header of monitored "user cells"	GFC (Note 1): BBBB VPI: VPI value of the monitored VCC VCI: VCI value of the monitored VCC PTI: As per definition of "user cells" at F5 level given in Recommendation I.610 [21] CLP (Note 4): D	VPI: VPI value of the monitored VCC VCI: VCI value of the monitored VCC PTI: As per definition of "user cells" at F5 level given in Recommendation I.610 [21] CLP (Note 4): D

NOTE 1 – Applicable only to measurements at a UNI.

NOTE 2 – B indicates the bit is a "don't care bit".

NOTE 3 – Recommendation I.361 [15] specifies that the CLP bit may be 0 or 1. As Recommendation I.610 [21] does not give more information about CLP, the AME shall monitor OAM cells regardless of the value of the CLP bit.

NOTE 4 – D indicates that the bit may be 0 or a "don't care" bit depending on the traffic component of the ATM connection. CLP = 0 or CLP = 0 + 1 as defined in Recommendation I.371 [16] are to be measured.

NOTE 5 – The Fx PM OAM flow comprises the Fx FM flow for the assessment of the connection in the forward direction and the Fx BR flow for reporting the performance assessment related to the backward direction of the connection.

Table 7-4/O.191 – Monitored outcomes related to ATM defects and indications for a VCC

Monitored connection type	End-to-end VCC	Segment VCC
Monitored ATM outcomes on the Fx fault management flow for the forward direction	VC-AIS, VC-LOC (See Annex A)	VC-AIS, VC-LOC (See Annex A)
Monitored ATM outcomes on the Fx FM OAM flow for the forward direction	VC-LFMF (Note 1)	VC-LFMF (Note 1)
Monitored ATM outcomes on Fx fault management flow for the backward direction	VC-RDI (See Annex A)	VC-RDI (See Annex A)
Monitored ATM outcomes on the Fx BR OAM flow for the backward direction	VC-LBRF (Note 2)	VC-LBRF (Note 2)

NOTE 1 – The VC-LFMF indication is defined only for measurement purposes. It indicates the loss of F5 forward monitoring flow. Criteria to declare or release the VC-LFMF indication are given in Annex A. Processing of VC-LFMF requires further study.

NOTE 2 – The VC-LBRF indication is defined only for measurement purposes. It indicates the loss of F5 backward reporting flow. Criteria to declare or release the VC-LBRF indication as well as its processing require further study.

7.1.2 Error-related network performance parameters

Network performance parameters related to cell errors or bit errors, such as CLR, CMR and SECBR, are evaluated by monitoring simultaneously the live user cell flow and the corresponding Performance Management (PM) OAM flow. This PM OAM flow is part of the F4 (F5) flow associated to a VP (VC) connection and is defined in Recommendation I.610 [21]. The content of the performance management OAM cells is analysed and the data derived from this content are compared with the data computed directly on the live user cell stream.

From the network perspective, error performance evaluation requires the use of the continuity check mechanism on the measured connection or the certainty that the live traffic source transmits at least one user cell per second during the whole measurement time.

By monitoring the adequate Fx PM OAM flow, in-service measurements support network performance evaluation of:

- an end-to-end VPC using the F4 end-to-end PM OAM flow;
- an end-to-end VCC using the F5 end-to-end PM OAM flow;
- a segment VPC using the F4 segment PM OAM flow;
- a segment VCC using the F5 segment PM OAM flow.

An adequate Fx PM flow shall be activated for the monitored connection prior to the measurement if it has not been activated at connection set-up. The AME is not required to provide a means to activate/deactivate the OAM flows. Users of the AME should make use of facilities provided by network elements or by network management for this purpose. Procedures for activation/deactivation of performance monitoring and continuity check, either by OAM activation/deactivation cells or entirely by the TMN, are described in Recommendation I.610 [21].

Depending on the capabilities of the network elements or of the customer equipment and depending on the required measurement, network performance of an ATM connection or an ATM connection segment can be evaluated at the near end for:

- the forward (or receive) direction when the forward monitoring (FM) Fx PM flow is activated;

- the backward (or send) direction when the backward reporting (BR) Fx PM flow is activated;
- both the forward and backward (or send and receive) directions when the forward monitoring and backward reporting Fx PM flows are activated.

In addition to the observation of the Fx PM flows, ATM defects on the measured connection are detected by monitoring the corresponding Fx fault management OAM flow. Figure 7-1 illustrates the conventions used. This reference measurement configuration assumes that NPP estimation is performed on a bidirectional ATM connection at one end (the near end) on a signal sent in the forward direction by the other end (the far end). Basic flows monitored for the assessment of the forward direction are:

- the user cell flow in the forward direction;
- the forward monitoring PM flow related to the forward direction and co-directional with it;
- the fault management flow in the forward direction for the detection of defects related to this direction (Vx-AIS, Vx-LOC).

Complementary flows simultaneously monitored at the same measurement point for the assessment of the backward direction are:

- the backward reporting PM flow related to the backward direction and contra-directional with this direction (this BR stream flowing from the far end to the near end can only be activated when the FM flow is activated in the backward direction);
- the fault management flow in the forward direction for the detection of defects related to the backward direction (Vx-RDI).

NPP estimation for one direction of an ATM connection is obtained by monitoring only the basic flows examined for the assessment of the forward direction of the ATM connection.

An interruption or severe degradation of the Fx PM flow(s) may affect the capability of the AME to measure or continue to measure performance parameters. Therefore, the recurrent presence of OAM PM cells is monitored. For this purpose two indications are provisionally defined: The Loss of Forward Monitoring Flow (LFMF) and the Loss of Backward Reporting Flow (LBRF). See Annex A for definitions.

Appendix I shows examples of Fx PM flow directions for some end-to-end and segment connection measurement cases.

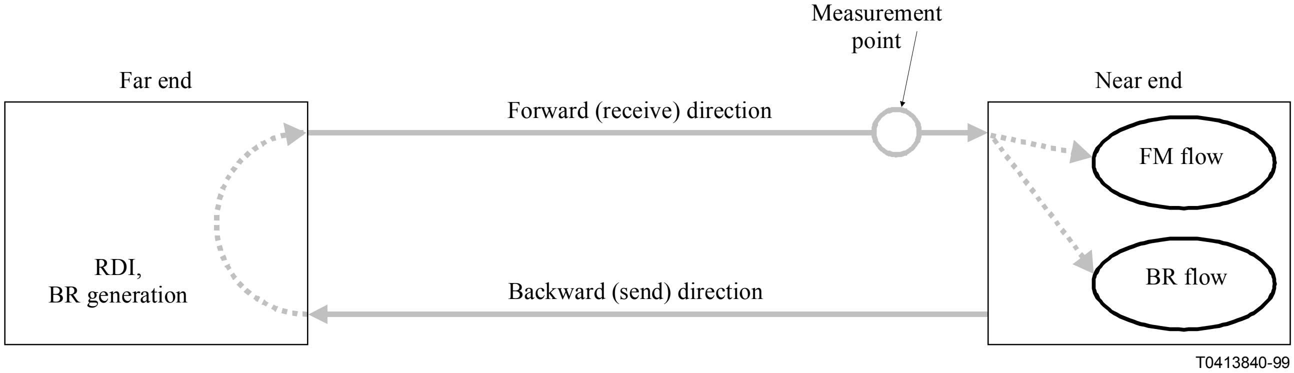


Figure 7-1/O.191 – Evaluation of the forward and backward directions

It should be noted that in-service measurements of CER may not provide accurate results when high bit error ratios or bursty errors are experienced.

7.1.3 Availability-related network performance parameters

ATM outcomes defined in 5.2 detected during an error-related NPP measurement are necessary and sufficient to determine availability NPPs as described in Recommendation I.357 [14]. The level of confidence on the AR and the MTBO depends upon the duration of the measurement period. Long observation periods on various ATM connections are necessary to provide meaningful statistics from a network perspective.

7.1.4 Delay-related network performance parameters

An estimation of CTD can be achieved by analyzing the forward monitoring Fx PM flow when the optional timestamp field of the Fx PM cell defined in Recommendation I.610 [21] is adequately filled with a timestamp. The accuracy of the measurement requires further study with respect to the sampling effect of PM OAM cells and the use of two clocks located at different geographical sites.

For the same reasons, 2-point CDV measurement based on PM OAM cells also needs further study.

One-way CDV measurement is important. For connections supporting CBR service, it is possible to estimate the peak-to-peak 2-point CDV on the basis of the observations of the 1-point CDV values instead of using timestamp values contained within the received test cells. This allows peak-to-peak 2-point CDV to be estimated in-service on a live connection and does not require test traffic to be generated.

1-point CDV is defined in Recommendation I.356 [13] as follows:

the 1-point CDV (y_k) for cell k at an MP is the difference between the cell's reference arrival time (c_k) and actual arrival time (a_k) at the MP: $y_k = c_k - a_k$. The reference arrival time pattern (c_k) is defined as follows:

$$c_0 = a_0 = 0$$

$$c_{k+1} = c_k + T \text{ when } c_k \geq a_k;$$

$$= a_k + T \text{ otherwise}$$

One method of estimating the range of 2-point CDV values from observations of 1-point CDV can be found in Annex C/I.356 [13]. In this method, the value of emission interval T must be controlled precisely to equal the average arrival interval of the received cells. Otherwise, the measurement will be unstable. For this reason, this method could be difficult to implement.

An alternative method of estimating the 2-point CDV from 1-point CDV observations is shown in Figure 7-2. A measurement of maximum 1-point CDV is made by monitoring the value y'_k within the algorithm. The estimated 2-point CDV then equals the maximum 1-point CDV result. This algorithm operates in the same manner as the GCRA used for UPC/NPC conformance of DBR transfer capability.

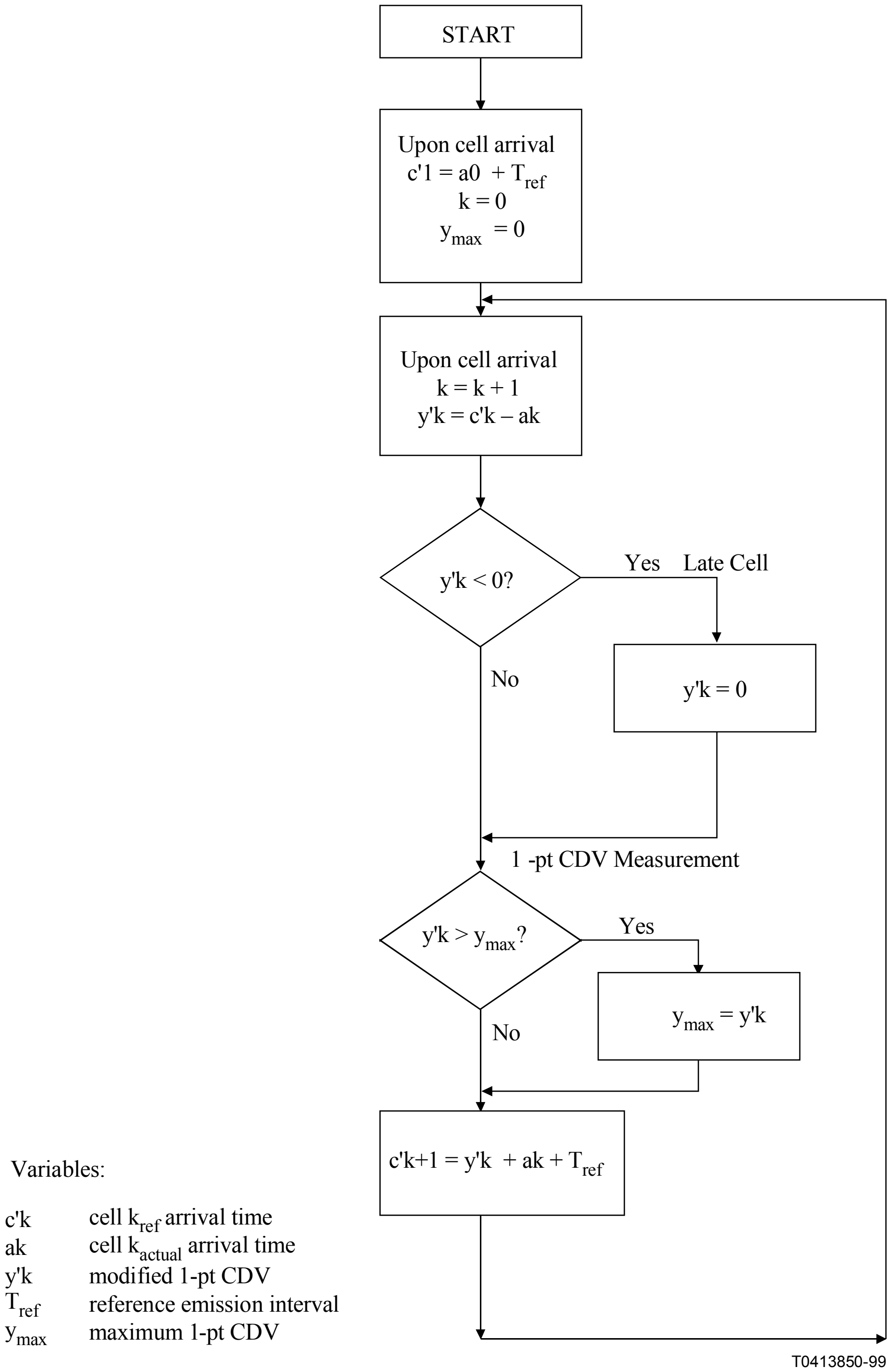


Figure 7-2/O.191 – Measurement of maximum 1-point CDV

This estimation method can be used in-service or out-of-service on a VCC or VPC. It requires that the source of the observed ATM flow sends cells at a constant cell rate. A live circuit emulation service for in-service measurement, or an AME generating CBR traffic for out-of service measurement, can be used as sources. The receiver of an AME can be located at any point along the connection and estimate the 2-point CDV up to this location.

It should be noted that the result includes not only the CDV introduced by the ATM network elements between the source and the measurement point, but also the CDV generated by the source itself. If a network element is used as a CBR source the CDV due to the multiplexing of several VPC or VCC may be a significant factor of added CDV.

Two potential sources of error exist. First, errors in calculating the maximum 1-point CDV value are:

- error in the AME due to variable delays (if any);
- error in the AME due to the clock that processes the received cells;
- arithmetic calculation errors in the AME.

Also, estimation errors occur that cause the maximum 1-point CDV to not equal the peak-to-peak 2-point CDV. These are:

- Error in the chosen value of T_{ref} where the error is proportional to $T_{av} – T_{ref}$ where T_{av} is the average arrival interval of the received cells. To ensure stability of the measurement, T_{ref} must be chosen to be $\leq T_{av}$.
- Errors dependent on the CDV characteristic. These are likely to reduce as the measurement period increases. For a deterministic CDV characteristic, the estimation error is minimized after one period of the CDV. For example, if the reference transmission algorithm for DBR defined in 6.3.2.1 is used as the data source, and T_{ref} is chosen to equal T_1, the maximum 1-point CDV result will equal the transmitted τ_1 within a period equal to burst size x T_1 where the burst size = $1 + \lfloor \tau_1/(T_1 – \Delta) \rfloor$ where $\lfloor x \rfloor$ stands for rounding down x to the nearest integer value.
- Errors due to lost or misinserted cells. The occurrence of lost cells causes the estimate to be reduced. The occurrence of misinserted cells causes the estimate to be increased. Therefore, care should be taken, especially when using the in-service method, to ensure that the initial cell flow does not include non-conforming cells that might be discarded by UPC/NPC functions within the network and that the probability of a network overload during the measurement is very low.

An accuracy of ±10 µs is suggested under the conditions where the applied CDV characteristic is deterministic and that no lost or misinserted cells have occurred.

A measurement range of 0 to 100 ms is suggested.

The effect of step changes in the CTD versus time characteristic and the resulting accuracy of in-service and out-of-service CDV measurements are for further study.

8 Physical interfaces of the AME

The ATM layer can be accessed at various physical interfaces and bit rates.

8.1 General interface characteristics and bit rates

The generator part and/or the receiver part of the AME shall enable access to one or more interfaces and bit rates listed in Tables 8-1 to 8-3. Tables 8-1 and 8-2 define interfaces which may be found within a network as a physical measurement access point. These interfaces can be practically considered as NNI. Table 8-3 lists currently recommended B-ISDN user network interfaces. Although some recommended bit rates are nominally the same for UNIs or NNIs, recommended physical characteristics such as levels, clock frequency accuracy or clock recovery range, may differ between UNI and NNI.

Table 8-1/O.191 – Physical interfaces based on the PDH bit rates

Recommendation applicable to ...	Bit rate (kbit/s) and signal structure				
	1544 Frame based	2048 Frame based	34 368 Frame based	44 736 Frame based	139 264 Frame based
ATM cell mapping into PDH	G.804 [6]	G.804	G.804	G.804	G.804
Synchronous frame structures at primary and secondary levels	G.704 [3]	G.704	–	–	–
Frame and multiplexing structures	–	–	G.832 [10]	G.832	G.832
Interface characteristics	G.703 [2]	G.703	G.703	G.703	G.703
Control of jitter and wander	G.824 [8]	G.823 [7]	G.823	G.824	G.823

Table 8-2/O.191 – Physical interfaces based on the SDH bit rates

Recommendation applicable to ...	Bit rate (kbit/s) and signal structure			
	155 520 Frame based	155 520 Cell based	622 080 Frame based	622 080 Cell based
Physical layer specification	I.432.2 [17]	I.432.2	I.432.2	I.432.2
Frame structure	G.707 [4]	None	G.707	None
Digital interface specification	G.703 [2] (Note 1) G.957 [11] (Note 2) I.432.x (Note 3)	G.703 (Note 1) G.957 (Note 2) I.432.x (Note 3)	G.957 (Note 2) I.432.x (Note 3)	G.957 (Note 2) I.432.x (Note 3)
Control of jitter and wander	G.825 [9]	G.825	G.825	G.825
NOTE 1 – For an electrical interface. NOTE 2 – For an optical interface. NOTE 3 – Applicable to the T_B reference point at the B-ISDN user network interface.				

Table 8-3/O.191 – B-ISDN user network interfaces

Bit rate (kbit/s)	Signal structure	Recommendation
1 544	Frame based	I.432.3 [18]
2 048	Frame based	I.432.3 [18]
25 600	Unframed, cell based	I.432.5 [20]
51 840	Frame or cell based	I.432.4 [19]
155 520	Frame or cell based	I.432.2 [17]
622 080	Frame or cell based	I.432.2 [17]

8.2 Specific generator interface characteristics

If the AME comprises a generator part, the characteristics of its digital output port shall comply with the Recommendations referred to in Table 8-4 (as applicable).

Table 8-4/O.191 – Interface characteristics of the generator output port

Characteristic	Relevant Recommendation(s)
Bit rate	G.702 [1], G.707 [4], I.432.2 [17], I.432.3 [18], I.432.4 [19], I.432.5 [20]
Signal structure	G.804 [6], G.707, I.432.2, I.432.3, I.432.4, I.432.5
Signal amplitude and waveform	G.703 [2], I.432.2, I.432.3, I.432.4, I.432.5
Impedance	G.703, I.432.2, I.432.3, I.432.4, I.432.5
Return loss	G.703, I.432.2, I.432.3, I.432.4, I.432.5
Maximum output jitter	G.823 [7], G.824 [8], G.825 [9], I.432.2, I.432.3, I.432.4, I.432.5

The AME shall provide means to synchronize its generator part to one of the synchronization sources listed below:

- internal clock (accuracy is for further study);
- external clock input (specifications for further study);
- clock recovered from the input signal to the AME receiver part – if provided.

8.3 Specific receiver interface characteristics

If the AME comprises a receiver part, the characteristics of its digital input port shall comply with the Recommendations referred to in Table 8-5 (as applicable).

Table 8-5/O.191 – Interface characteristics of the receiver input port

Characteristic	Relevant Recommendation(s)
Bit rate	G.702 [1], G.707 [4], I.432.2 [17], I.432.3 [18], I.432.4 [19], I.432.5 [20]
Signal structure	G.804 [6], G.707, I.432.2, I.432.3, I.432.4, I.432.5
Input sensitivity and waveform	G.703 [2], I.432.2, I.432.3, I.432.4, I.432.5
Protected (electrical) monitoring points	G.772 [5]
Impedance	G.703, I.432.2, I.432.3, I.432.4, I.432.5
Return loss	G.703, I.432.2, I.432.3, I.432.4, I.432.5
Maximum tolerable input jitter	G.823 [7], G.824 [8], G.825 [9], I.432.2, I.432.3, I.432.4, I.432.5

8.4 Information available at physical interfaces

Additional information concerning physical layer events (e.g. faults, alarms, error performance) can be obtained at the physical interface. This information includes anomalies and defects which may affect ATM layer measurements.

9 Miscellaneous functions

These functions do not directly influence the ATM network performance parameter measurements and may be considered as optional for the AME.

9.1 Event timestamping

Timestamping of events relevant to performance monitoring (e.g. lost cell, severely errored second, unavailable period) may be provided as an aid to troubleshooting.

9.2 Output to recording devices

The AME may provide the capability to connect an external recording device (e.g. a printer) using an interface in accordance with Recommendations V.24 [23] and V.28 [24].

9.3 Remote control

The AME may be remotely controllable using an interface in accordance with IEEE 488.1 or IEC 60625 Standards [26] [27] or Recommendations V.24 [23] and V.28 [24].

10 Operating conditions

10.1 Environmental conditions

The electrical and functional performance requirements shall be met when operating the AME under the conditions specified in Recommendation O.3 [22].

10.2 Behaviour in case of power failure

A power failure shall be recognized by the AME.

ANNEX A

Criteria for the detection of anomalies, defects and indications

VP-AIS

The VP-AIS defect shall be declared as soon as one of the following occurs:

- a VP-AIS cell is received;
- a transmission path AIS defect is detected;
- a VPC defect is detected (e.g. loss of VPC continuity).

The VP-AIS defect shall be released when a user cell or a continuity check cell is received.

VP-RDI

The VP-RDI defect shall be declared as soon as a VP-RDI cell is received. The VP-RDI defect shall be released when no VP-RDI cell is received during a period of 2.5 ± 0.5 seconds.

VP-LOC

The VP-LOC defect shall be declared when the receiver does not receive any user cell or continuity check cell within a time interval of 3.5 ± 0.5 seconds. The VP-LOC defect shall be released when a user cell or a continuity check cell is received.

VC-AIS

The VC-AIS defect shall be declared as soon as one of the following occurs:

- a VC-AIS cell is received;
- a transmission path AIS defect is detected;

- a VPC defect or a VCC defect is detected (e.g. loss of VPC continuity or loss of VCC continuity).

The VC-AIS defect shall be released when a valid user cell or a continuity check cell is received.

VC-RDI

The VC-RDI defect shall be declared as soon as a VC-RDI cell is received. The VC-RDI defect shall be released when no VC-RDI cell is received during a period of 2.5 ± 0.5 seconds.

VC-LOC

The VC-LOC defect shall be declared when the receiver does not receive any user cell or continuity check cell within a time interval of 3.5 ± 0.5 seconds. The VC-LOC defect shall be released when a user cell or a continuity check cell is received.

VP-LFMF

The following criteria are provisional and may be superseded in future releases by another definition resulting from the work on Recommendations related to network aspects.

The VP-LFMF indication shall be declared when the number of received user cells since the latest F4 Forward Monitoring cell is greater than 3.5 × N (i.e. after at least 2 PM OAM cells have been lost) where N is the nominal cell block size activated at the VP level.

The VP-LFMF indication shall be released as soon as a single F4 Forward Monitoring cell has been correctly received without error detected by CRC-10.

The monitored F4 flow shall be either the end-to-end flow or the segment flow depending on the actual measurement.

This indication is valid only when the forced insertion option for the F4 PM flow is used.

VC-LFMF

The following criteria are provisional and may be superseded in future releases by another definition resulting from the work on Recommendations related to network aspects.

The VC-LFMF indication shall be declared when the number of received user cells since the latest F5 Forward Monitoring cell is greater than 3.5 × N (i.e. after at least 2 PM OAM cells have been lost) where N is the nominal cell block size activated at the VC level.

The VC-LFMF indication shall be released as soon as a single F5 Forward Monitoring cell has been correctly received without error detected by CRC-10.

The monitored F5 flow shall be either the end-to-end flow or the segment flow depending on the actual measurement.

This indication is valid only when the forced insertion option for the F5 PM flow is used.

VP-LBRF

For further study.

VC-LBRF

For further study.

LPAC

The Loss of Performance Assessment Capability indicates that the AME is no longer capable of measuring network performance parameters with sufficient confidence. Entering and exiting this state shall be time stamped with a one-second resolution.

The LPAC state shall be declared if the basic OOS cell transfer outcome measurement algorithm was not able to make any decision during the last 10 seconds (refer to Annex B for the definition of a decision).

The LPAC state shall be cleared by the AME when two consecutive received test cells are error free and the contents of their SN fields are in sequence [i.e. SN(n + 1) = SN(n) + 1 where SN(n + 1) corresponds to cell # n + 1 and SN(n) to the previously received cell #n].

ANNEX B

Measurement algorithms

Basic out-of-service cell transfer outcome measurement algorithm

Figure B.1 describes the basic cell transfer outcome measurement algorithm that shall be used for out-of-service NPP measurement.

The time-out value for the Timer_LPAC is 10 seconds.

The SNRef value shall be initialized with the SN value, incremented by 1, read in the first valid received test cell after the activation of the algorithm.

A cell arrival event occurs when defects are not present at the physical transmission level and when a test cell is identified on the connection under test.

The algorithm makes a decision when:

- either two consecutive received test cells are error free and the contents of their SN fields are in sequence [i.e. SN(n + 1) = SN(n) + 1 where SN(n + 1) corresponds to cell # n + 1 and SN(n) to the previously received cell #n]; or
- one error free test cell is received and the content of its SN field is equal to SNRef.

Decisions are highlighted in Figure B.1 by double lined boxes.

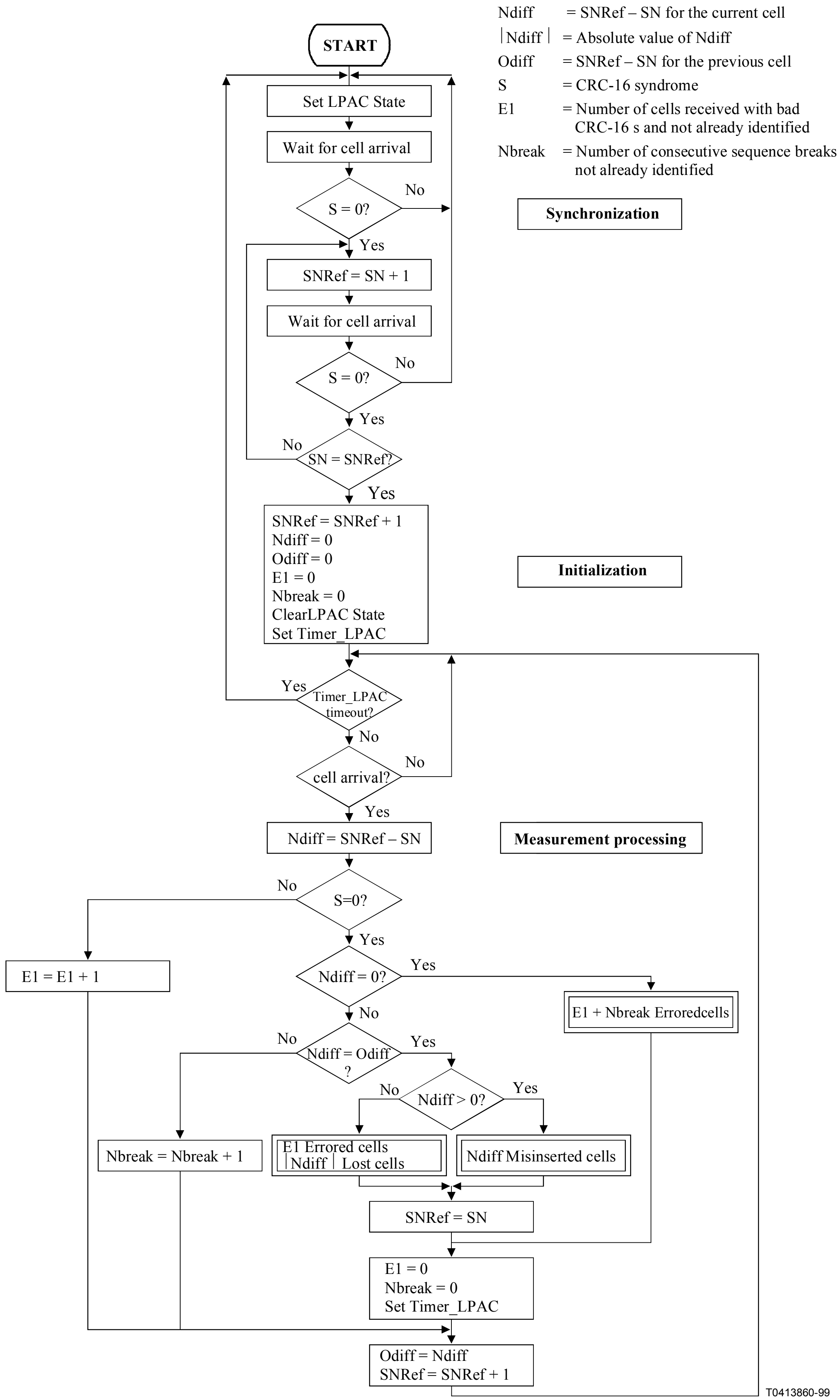


Figure B.1/O.191 – Out-of-service cell transfer outcome measurement algorithm

ANNEX C

Test cell payload scrambling/descrambling

C.1 Scrambling/descrambling

The following figures describe the functional test cell payload scrambling/descrambling mechanisms with the $x^9 + x^5 + 1$ polynomial. They are provided for explanation purposes and do not preclude any other implementation. Nevertheless, it is required that the operation of the scrambler/descrambler is functionally identical to that depicted in Figures C.1 and C.2 even though the actual hardware or software implementation may be different.

Figure C.1 shows the scrambler circuit in serial form using a shift register. At the start of the cell (cell start), the scrambler is reset to the all zeros state. Cell data, starting with the most significant bit of the least significant byte of the sequence number (transmission of the SN is byte reversed), is added modulo 2 with the modulo 2 sum of the x^9 and x^5 terms from the shift register. The scrambled data is output and also enters the shift register.

Figure C.2 shows the descrambler circuit in serial form. At the start of the cell (cell start), the descrambler is reset to the all zeros state. Scrambled cell data, starting with the most significant bit of the least significant byte of the sequence number (the SN is byte reversed), is added modulo 2 with the modulo 2 sum of the x^9 and x^5 terms from the shift register. The scrambled data also enters the shift register.

C.2 Scrambling and CRC

The following two examples illustrate the result of the scrambling plus the CRC calculation on the ATM test cell. The TS, PPI and REV fields are assumed to be equal to 0.

a) Sequence number = 0

00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 F7 40

b) Sequence number = 1

01 08 C2 72 AC 37 A6 E4 50 AD 3F 64 96 FC 9A 99 80 C6 51 A5
FD 16 3A CB 3C 7D D0 6B 6E C1 6B EA A0 52 BC BB 81 CE 93 D7
51 21 9C 2F 6C D0 BB 1C

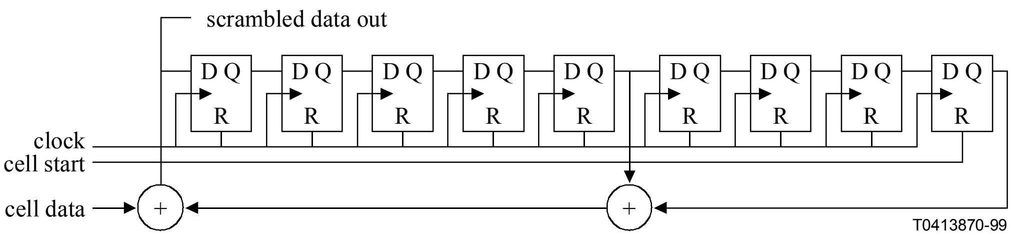


Figure C.1/O.191 – Scrambler circuit using polynomial $x^9 + x^5 + 1$

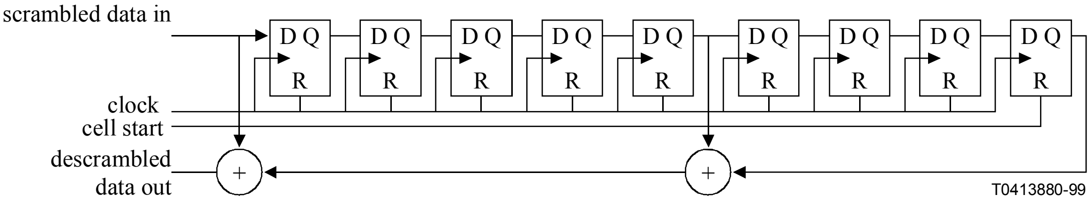


Figure C.2/O.191 – Descrambler circuit using polynomial $x^9 + x^5 + 1$

APPENDIX I

Examples of use of the different measuring modes

I.1 Use of the out-of-service measurement mode

Figure I.1 shows an example of a measurement configuration using the out-of-service measurement mode of the AME. In this configuration, two AMEs are used, one at each end of the ATM VP or VC connection set-up for the measurement. The AME at location A sends test cells on the monitored connection. Additional background traffic may be generated on other connections at location A in order to simulate a more realistic traffic between location A and the nearest connecting point. The AME at location B analyses the test cells received at this location. The two AMEs are acting as VP or VC terminating end-points.

In order to achieve simultaneous point-to-point measurements in the two directions of a bidirectional ATM connection, the AME at location B may simultaneously generate test cells towards location A, and the AME at location A analyses the received test cells.

Figure I.2 illustrates a variation of the preceding example with the use of a loopback at location B. Test cells received at location B on the monitored ATM connection are looped back towards location A by the AME. Loopback can be achieved by other means also: the AME at location B can be replaced by a network element providing the loopback capabilities described in Recommendation I.610 [21]. This configuration may be useful in some cases for the measurement of CTD assuming that the CTD is the same for the two opposite directions and that the delay introduced by the loopback is known or small compared to the expected CTD.

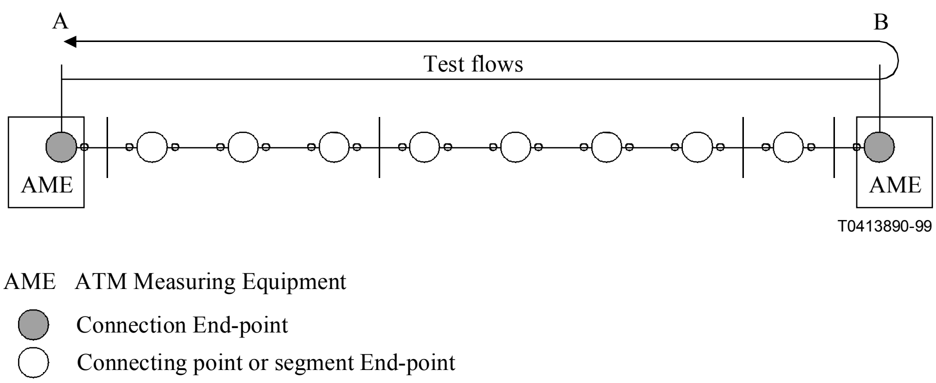


Figure I.1/O.191 – Out-of-service end-to-end test

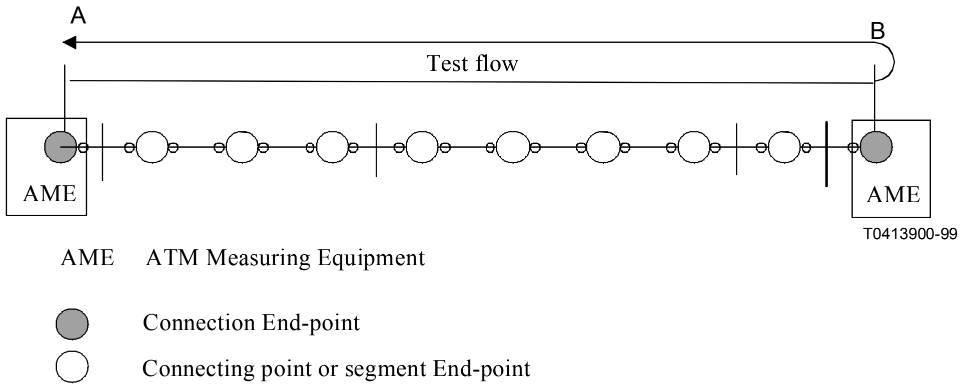


Figure I.2/O.191 – Out-of-service test with test flow loopback

I.2 Use of the in-service measurement mode

I.2.1 End-to-end test

Figure I.3 shows an example of a measurement configuration using the in-service measurement mode of the AME, with network elements at locations A and B providing ATM termination connection functions.

In this example, the Fx PM flow is activated only in the direction A towards B. Forward monitoring cells are generated by the VP or VC terminating equipment. Measurements of the VP or VC connection for this direction are carried out at location B by analyzing simultaneously the user cells and the Fx PM forward monitoring cells flowing in the same direction.

End-to-end performance evaluation is performed when measurements are carried out at MP number n.

Measurement at intermediate MPs allows the localization of a faulty segment. For this purpose, measurements can be carried out successively at MPs number n, n − 1, n − 2, ... until the detected trouble is found. Measurement at MP number 1 provides the performance evaluation of the user access line when the equipment at location A is a customer equipment.

For a bidirectional connection, network performance parameters for both directions can be evaluated at location B as shown in Figure I.4 by:

- activating the Fx PM forward monitoring and reporting flows for the direction B towards A;
- activating the Fx PM forward monitoring flow for the direction A towards B;
- analyzing the user cells, the forward monitoring and the reporting Fx PM flows in the A to B cell flow at one measurement point.

1-point CDV can be measured at any MP independently of any Fx PM flow activation/deactivation.

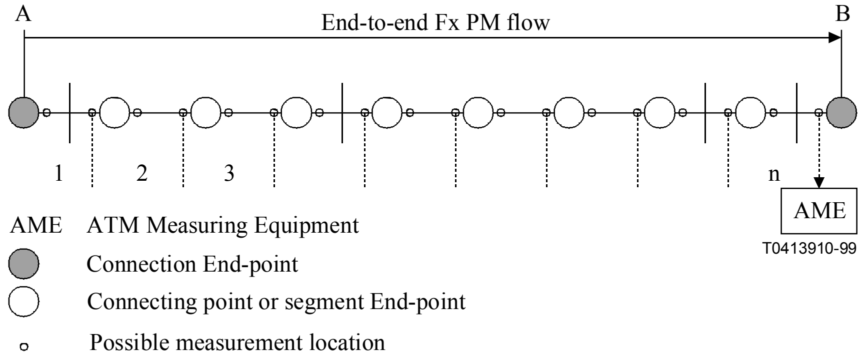


Figure I.3/O.191 – In-service end-to-end test

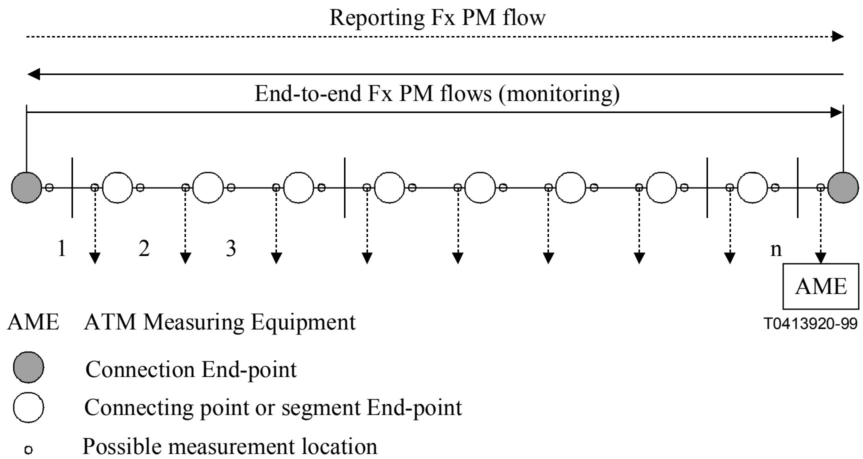


Figure I.4/O.191 – In-service test for fault localization

I.2.2 Segment test

Figure I.5 shows an example of a measurement configuration for testing segments.

Forward monitoring cells of the Fx PM flow are generated by the first network element of a segment. Segment test provides performance evaluation for the forward direction of the whole segment when the AME is located at MP number 3 or of part of it when it is located at MP number 1 or 2.

Measurement of the performance delivered by the VP or VC connection is carried out at location 3 by analyzing simultaneously the user cells and the Fx segment PM forward monitoring cells flowing in the same direction. A similar measurement performed at location 1 or 2 yields an estimation of the performance of a correspondingly restricted connection portion.

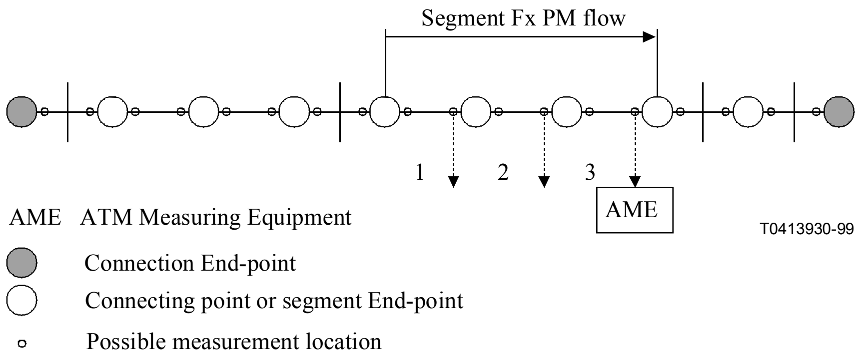


Figure I.5/O.191 – In-service segment test

I.2.3 UPC/NPC testing

Measurement of the performance of a UPC/NPC mechanism is carried out by comparing the number of cells that are passed by the UPC/NPC to the number of cells that are conforming to the standard cell conformance algorithm. This scenario implies that the AME accesses both sides of the equipment where the UPC/NPC is located. Figure I.6 shows an example of this measurement configuration.

The AME derives the number of conforming cells by a direct computation on the cell stream before it enters the UPC/NPC mechanism.

The number of cells that are passed by the UPC/NPC mechanism may be obtained by analyzing the Fx segment PM forward monitoring cell stream that either includes the UPC/NPC mechanism or is adjacent to it. In particular, if the Fx segment PM forward monitoring cells are inserted just behind the UPC/NPC mechanism, the number of cells that are passed by the UPC/NPC is carried by the TUC field of the Fx segment PM forward monitoring cell.

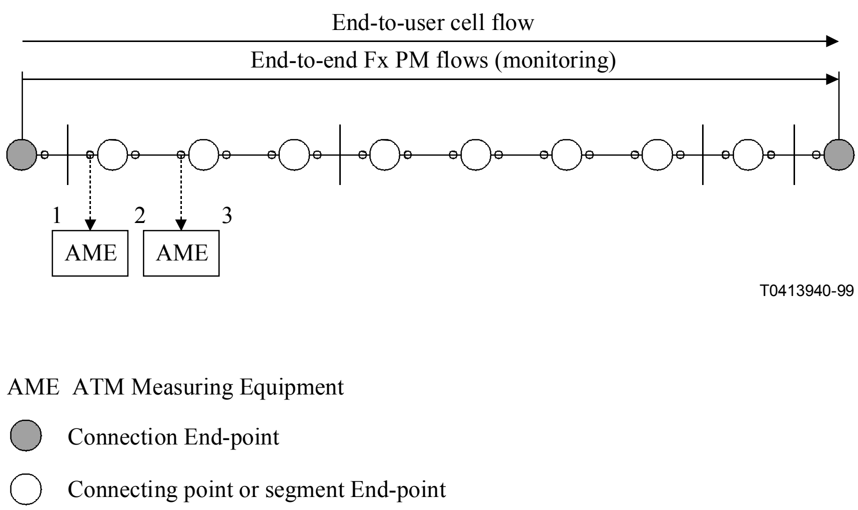


Figure I.6/O.191 – UPC/NPC testing configuration

I.3 Combined use of out-of-service and in-service measurement modes

Figure I.7 shows an example of measurement configuration using both out-of-service and in-service measurement modes of the AME.

An out-of-service measurement is performed on a VP or VC connection as described in I.1, with the test traffic being generated by the AME at location A. This AME is also generating the Fx PM traffic associated to the main test traffic.

All measurements described in the in-service measurement mode can be carried out on this traffic by the AME shown on the figure and connected at location n-2.

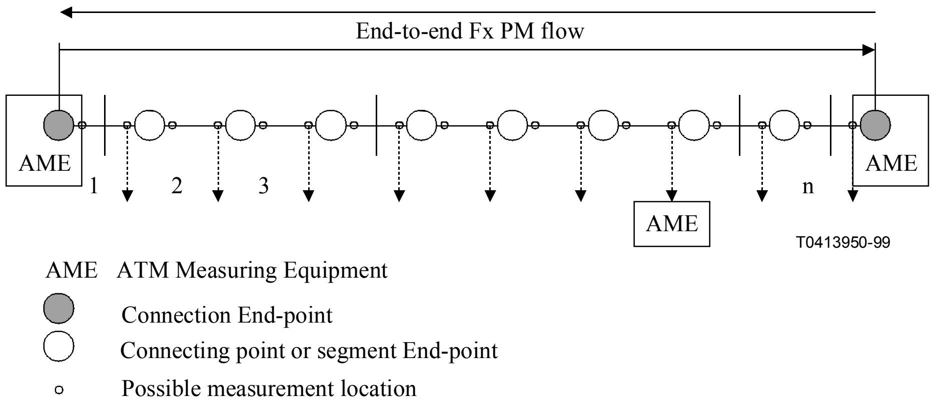


Figure I.7/O.191 – Combination of in-service and out-of-service modes

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