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SERIES I: INTEGRATED SERVICES DIGITAL
NETWORK

Maintenance principles

**B-ISDN operation and maintenance principles
and functions**

ITU-T Recommendation I.610

(Previously CCITT Recommendation)

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ITU-T RECOMMENDATION I.610

B-ISDN OPERATION AND MAINTENANCE PRINCIPLES AND FUNCTIONS

Summary

This Recommendation "B-ISDN operation and maintenance principles and functions" describes the set of functions required to operate and maintain the physical layer and ATM layer aspects of the B-ISDN for permanent, semi-permanent, reserved and on-demand virtual connections.

The functions of the layers above the ATM layer are not considered.

For a detailed description of the maintenance mechanisms and functions at the physical layer, the appropriate ITU-T Recommendations need to be considered depending on the transmission system in use (e.g. SDH, PDH).

For maintenance purposes F4 and F5 flows are defined at the ATM layer covering the VP and VC level, respectively. Both flows are bidirectional and follow the same physical route as the user-data cells, thus constituting an in-band maintenance flow.

Besides the vertical subdivision into F4 and F5 levels a "horizontal" partition also exists: both flows can either cover the entire virtual connection (end-to-end flow) or only parts of the virtual connection (segment flow).

Dedicated OAM cells with pre-assigned VCI and PTI values are used to implement the F4 and F5 flows at segment or end-to-end levels.

This Recommendation specifies the purpose and the realization (using different OAM cell types) of the following functions:

- 1) Fault management, using AIS, RDI, CC and LB cells.
- 2) Performance management, using FPM and BR cells.
- 3) Activation/deactivation of PM and/or CC, using activation/deactivation cells.
- 4) System management cells for use by end-systems only.

In addition, the coding of the APS cell used for providing ATM protection switching is specified.

Source

ITU-T Recommendation I.610 was revised by ITU-T Study Group 13 (1997-2000) and was approved under the WTSC Resolution No. 1 procedure on the 26th of February 1999.

FOREWORD

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In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

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As of the date of approval of this Recommendation, the ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

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Recommendation I.610

B-ISDN OPERATION AND MAINTENANCE PRINCIPLES AND FUNCTIONS

(Geneva, 1991; revised Helsinki, 1993; revised in 1995 and 1999)

1 Scope

The scope of this Recommendation is to identify functions required to operate and maintain the physical layer and ATM layer aspects of the B-ISDN. The functions apply to the Virtual Path (VP) and Virtual Channel (VC) connections that may be routed through the B-ISDN. The mechanisms, functions and protocols as described in this Recommendation apply to all types of ATM connections, i.e. permanent, semi-permanent, reserved and switched virtual connections unless otherwise stated. However, the need for reduced and/or additional Operation and Maintenance (OAM) functionality for switched virtual connections is for further study.

The functions of the layers above the ATM layer are not considered but are for further study.

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.

- ITU-T Recommendation E.164 (1997), *The international public telecommunication numbering plan.*
- CCITT Recommendation G.702 (1988), *Digital hierarchy bit rates.*
- ITU-T Recommendation G.707 (1996), *Network node interface for the Synchronous Digital Hierarchy (SDH).*
- ITU-T Recommendation G.783 (1997), *Characteristics of Synchronous Digital Hierarchy (SDH) equipment functional blocks.*
- ITU-T Recommendation G.784 (1994), *Synchronous Digital Hierarchy (SDH) management.*
- ITU-T Recommendation G.804 (1998), *ATM cell mapping into Plesiochronous Digital Hierarchy (PDH).*
- ITU-T Recommendation G.805 (1995), *Generic functional architecture of transport networks.*
- ITU-T Recommendation G.832 (1998), *Transport of SDH elements on PDH networks: Frame and multiplexing structures.*
- ITU-T Recommendation I.311 (1996), *B-ISDN general network aspects.*
- CCITT Recommendation I.321 (1991), *B-ISDN protocol reference model and its application.*

- ITU-T Recommendation I.326 (1995), *Functional architecture of transport networks based on ATM.*
- ITU-T Recommendation I.356 (1996), *B-ISDN ATM layer cell transfer performance.*
- ITU-T Recommendation I.357 (1996), *B-ISDN semi-permanent connection availability.*
- ITU-T Recommendation I.361 (1999), *B-ISDN ATM layer specification.*
- ITU-T Recommendation I.371 (1996), *Traffic control and congestion control in B-ISDN.*
- ITU-T Recommendation I.432.1 (1999), *B-ISDN user-network interface – Physical layer specification: General characteristics.*
- 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.*
- ITU-T Recommendation I.432.4 (1999), *B-ISDN user-network interface – Physical layer specification: 51 840 kbit/s operation.*
- ITU-T Recommendation I.630 (1999), *ATM protection switching.*
- ITU-T Recommendation I.732 (1996), *Functional characteristics of ATM equipment.*
- ITU-T Recommendation I.751 (1996), *Asynchronous transfer mode management of the network element view.*
- CCITT Recommendation M.20 (1992), *Maintenance philosophy for telecommunications networks.*
- ITU-T Recommendation M.3010 (1996), *Principles for a telecommunications management network.*
- CCITT Recommendation M.3600 (1992), *Principles for the management of ISDNs.*

3 Definitions

This Recommendation defines the following terms:

- 3.1 backward direction:** The backward direction is opposite to the forward direction.
- 3.2 Connection Points (CPs):** (see Note 1 in 3.21) Reference points which are defined along a network connection defined at a given network layer. CPs defined at the ATM layer along a VPC (or VCC) are located at the ingress and egress of an ATM network element (or customer equipment), where VP (or VC) link termination functions operate.
- 3.3 Connection Point Identifier (CPID):** Identifier of a given CP along a VPC or VCC. Different values are intended to be used for identifying the ingress and egress of a given ATM network element.
- 3.4 defect:** (see Note 2 in 3.21) Interruption of the capability of a transport entity (e.g. network connection) to transfer user or OAM information. Examples of defects are loss of signal, LCD, LOC at the VP (or VC) layer.
- 3.5 egress:** The egress point of an ATM network element is illustrated in Figure 0.

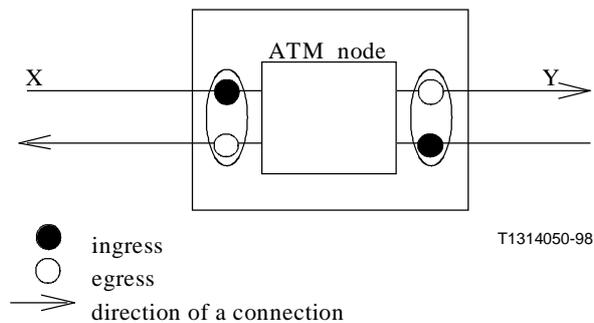


Figure 0/I.610 – Usage of ingress and egress terms in Recommendation I.610

3.6 failure: (see Note 2 in 3.21) Termination of the capability of a transport entity to transfer user or OAM information. A failure can be caused by a persisting defect.

3.7 forward direction: The forward direction is the direction followed by the monitored user cells flow.

3.8 ingress: The ingress point of an ATM network element is illustrated in Figure 0.

3.9 link connection: Definition is provided in Recommendation G.805. As an example, a VP link connection is delimited by the CPs located in two consecutive ATM network elements operating at VP level.

3.10 Maintenance Entity (ME): (see Note 2 in 3.21) MEs are defined at the physical and ATM layers in order to provide the means to detect maintenance events (e.g. defects, failures, performance impairments) occurring within the part of the telecommunication network delimited by the ME boundaries. MEs have an interface with the Telecommunications Management Network (TMN) to convey maintenance information to the Operation System (OS) or to receive maintenance requests from that system.

3.11 matrix connection: (see Note 1 in 3.21) Subnetwork connection delimited, for the ATM layer, by the CPs located at the ingress and egress of an ATM network element.

3.12 network connection: (see Note 1 in 3.21) Transport entity used for transferring user and OAM information between the endpoints of the connection (TCPs).

3.13 OAM flow: Information flow transferred through the network by the means of a dedicated channel supported by specific octets of the transmission systems for the physical layer and by specific ATM cells referred to as OAM cells for the ATM layer.

3.14 segment: Portion of a VPC or a VCC delimited by two CPs referred to respectively as the segment source CP and segment sink CP.

3.15 sink: (see Note 1 in 3.21) Term used, in the context of this Recommendation, to indicate that OAM information is removed (e.g. at the sink trail termination function) from the incoming signal for further processing.

3.16 source: (see Note 1 in 3.21) Term used, in the context of this Recommendation, to indicate that OAM information is added (e.g. at the source trail termination function) to the outgoing signal for further processing downstream (e.g. at the sink trail termination function).

3.17 subnetwork connection: (see Note 1 in 3.21) Transport entity corresponding to a part of a network connection. A subnetwork connection can be subdivided into a concatenation of links and matrix connections. As a special case, a matrix connection corresponds to a single (indivisible) subnetwork connection.

3.18 Termination Connection Point (TCP): (see Note 1 in 3.21) Endpoints of a network connection.

3.19 Trail Termination Function (TTF): (see Note 1 in 3.21) Processing functions that permit to insert, extract and monitor the OAM flows.

3.20 VPC/VCC ME: Maintenance entity delimited by the connection endpoints which are:

- i) the source TCP; and
- ii) the sink TCP.

This ME is a bidirectional entity in the sense that the source TCP for a given direction and the sink TCP for the opposite direction are paired at each end of the ME (the VP/VC trail termination functions are located at those TCPs as defined in Recommendation I.326). This ME is created (respectively deleted) when the VPC/VCC is set up (respectively released).

3.21 VPC/VCC segment ME: Maintenance entity delimited by the segment endpoints which are:

- i) the segment source CP; and
- ii) the segment sink CP.

This ME is a bidirectional entity in the sense that the segment source CP for a given direction and the segment sink CP for the opposite direction are paired at each end of the ME (the VP/VC sub-layer trail termination functions are located at those CPs as defined in Recommendation I.326). This ME is a flexible ME which can be created or deleted following a TMN action. It should be noted that the segment source/sink CP may be adjacent to the source/sink TCP.

NOTE 1 – Recommendation G.805 gives a more general and detailed definition.

NOTE 2 – Recommendation M.20 gives a more general and detailed definition.

4 Abbreviations

This Recommendation uses the following abbreviations:

_A	_Adaptation function (in network functional model)
_C	_Connection function (in network functional model)
_T	_Termination function (in network functional model)
AIS	Alarm Indication Signal
APS	ATM Protection Switching
ATM	Asynchronous Transfer Mode
BEDC	Block Error Detection Code
BIP	Bit Interleaved Parity
B-ISDN	Broadband Integrated Services Digital Network
BLER	BLock Error Result
B-NT(i)	Broadband Network Termination (i = 1 or 2), functional block in the customer access
BR	Backward Reporting
CC	Continuity Check
CLP	Cell Loss Priority

CP	Connection Point
CPID	Connection Point IDentifier
CRC	Cyclic Redundancy Code
ET	Exchange Termination, functional block in the customer access
e-t-e_VC-XX	OAM cell providing the "XX" OAM function for an end-to-end VCC (e.g. e-t-e_VC-AIS, e-t-e_VC-RDI ...)
e-t-e_VP-XX	OAM cell providing the "XX" OAM function for an end-to-end VPC (e.g. e-t-e_VP-AIS, e-t-e_VP-CC ...)
e-t-e_XX	OAM cell providing the "XX" OAM function for an end-to-end VPC or VCC (e.g. e-t-e_AIS, e-t-e_LB ...)
F1	OAM Flows on regenerator section level
F2	OAM Flows on digital section level
F3	OAM Flows on transmission path level
F4	OAM Flow on virtual path level
F5	OAM Flow on virtual channel level
FPM	Forward Performance Monitoring
HEC	Header Error Control
ID	IDentifier
LB	LoopBack
LCD	Loss of Cell Delineation
LLID	Loopback Location IDentifier
LM	Layer Management
LOC	Loss of Continuity (defined at the ATM layer level)
LOM	Loss of Maintenance flow
LOS	Loss of Signal
LT	Line Termination, functional block in the customer access
MCSN	Monitoring Cell Sequence Number
ME	Maintenance Entity
MS	Multiplex-Section (for SDH)
NE	Network Element
NNI	Network-Network Interface
NPC	Network Parameter Control
OAM	Operation And Maintenance
OS	Operation System
PDH	Plesiochronous Digital Hierarchy
PL	Physical Layer
PL-OAM	Physical Layer OAM (cell)

PM	Performance Monitoring
POH	Path OverHead
PRM	Protocol Reference Model
PTI	Payload Type Identifier
RDI	Remote Defect Indication
SDH	Synchronous Digital Hierarchy
seg_VC-XX	OAM cell providing the "XX" OAM function for a VCC segment (e.g. seg_VC-CC, seg_VC-LB ...)
seg_VP-XX	OAM cell providing the "XX" OAM function for a VPC segment (e.g. seg_VP-CC, seg_VP-LB ...)
seg_XX	OAM cell providing the "XX" OAM function for a VPC or a VCC segment (e.g. seg_AIS, seg_LB ...)
SOH	Section OverHead
STM	Synchronous Transfer Mode
T _B	T Reference point for B-ISDN
TCP	Termination Connection Point
TMN	Telecommunications Management Network
TP	Transmission Path
TRCC	Total Received Cell Count
TSTP	Time STamP
TTF	Trail Termination Function
TUC	Total User Cell (number)
UNI	User Network Interface
UPC	Usage Parameter Control
VC	Virtual Channel
VCC	Virtual Channel Connection
VCI	Virtual Channel Identifier
VCL	Virtual Channel Link
VP	Virtual Path
VPC	Virtual Path Connection
VPI	Virtual Path Identifier
VPL	Virtual Path Link

5 OAM principles

The following principles have been considered in specifying the OAM functions of the B-ISDN.

a) *Performance monitoring*

PM is a function which processes user information to produce maintenance information specific to the user information. This maintenance information is added to the user information at the source of a connection/link and extracted at the sink of a connection/link. Analysis of the maintenance event information at the sink of the connection allows estimation of the transport integrity.

b) *Defect and failure detection*

Defect/failures affecting the transport of user information are detected by continuous or periodic checking. As a result, maintenance event information or various alarms will be produced.

c) *System protection*

The effect of a defect on the transport of user information is minimized by blocking or changeover to other entities. As a result the failed entity is excluded from operation.

d) *Defect information*

Defect information is given to other management entities. As a result, alarm indications are given to other management planes. Response to a status report request will also be given.

e) *Fault localization*

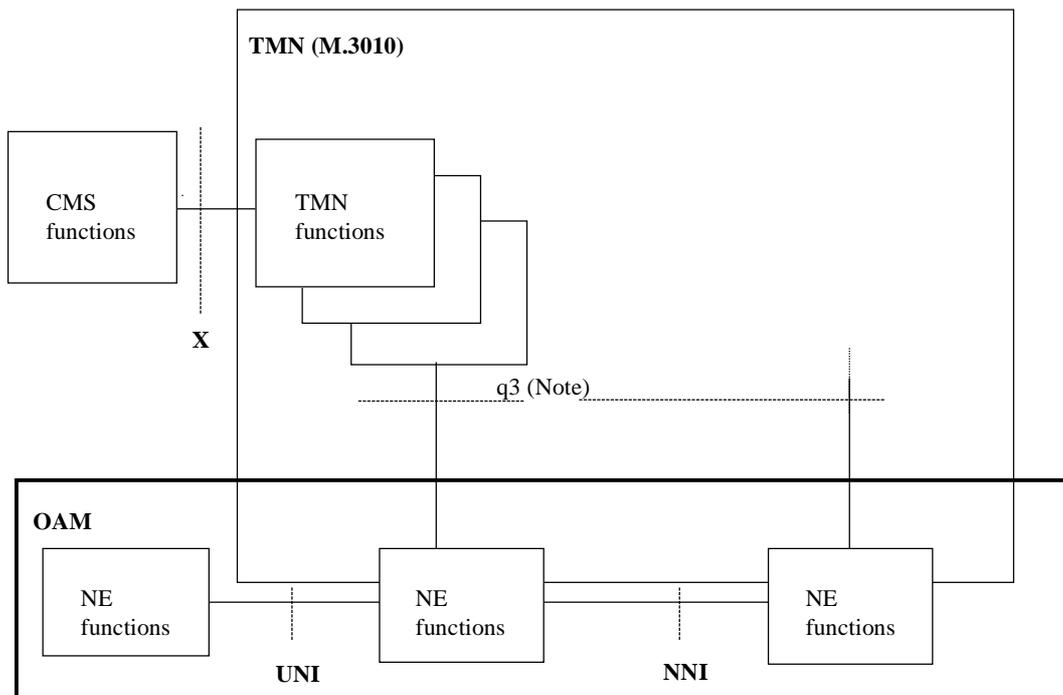
Determination by internal or external test systems of a failed entity if defect information is insufficient.

5.1 Network configuration for maintenance activities

The network configuration for maintenance activities is described in Recommendation M.3600. This configuration is also applicable for the B-ISDN.

5.2 Relation with the Telecommunications Management Network (TMN)

The B-ISDN OAM principles in this Recommendation are intended to be consistent with the TMN principles as defined in Recommendation M.3010. Figure 1 illustrates the relationship of Recommendation M.3010 to TMN.



T1314060-98

NE Network Element
 CMS Customer Management Systems

NOTE – Recommendation I.751 provides the requirements for the q3 interface reference point. It describes the Management Information Base (MIB) to be used between the NE management layer and the NE layer. NE management layer and NE layer are both defined in Recommendation M.3010.

Figure 1/I.610 – B-ISDN OAM relation to TMN

5.3 Management of the information produced by OAM functions

The information produced by OAM functions should be managed so as to provide the appropriate indications to the maintenance staff for maintaining the Quality of Service (QoS) level offered to customers. The OAM functions addressed in this Recommendation are those related to performance and fault management which provide the:

- 1) handling of anomalies and defect indications at the physical and ATM layers;
- 2) assessment of performance at the physical and ATM layers;
- 3) localization of detected failures at the ATM layer.

The information produced should be processed by the management function before being reported by the ATM Network Element (NE) to the local and/or the remote management system as illustrated in Figure 2.

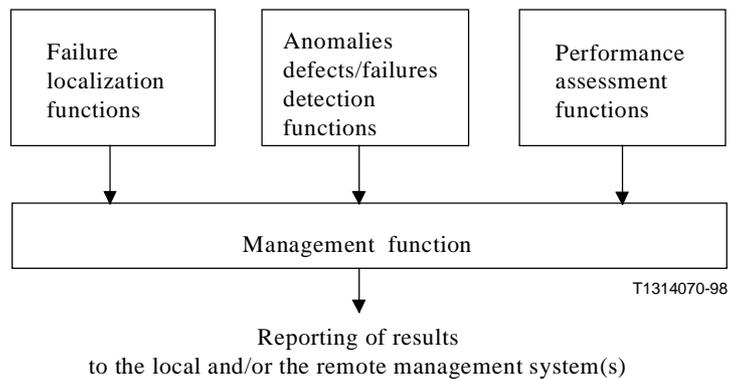


Figure 2/I.610 – Handling of the information produced by OAM functions

The following items give guidance on the main characteristics which should be provided by the management function of the ATM NEs for processing the information produced by the OAM functions:

- A correlation of events should be provided so as to avoid a large number of events to be recorded when a "parent" event causes multiple performance impairment indications at different layers.

As an example a LOS observed in a regenerator section not terminated in an ATM NE may cause a TP-AIS detection at the transmission path endpoint, a LCD and a LOC defect at the ATM layer level. In that case, from a maintenance point of view, only the TP-AIS occurrence has to be stored at the ATM NE level. This function should be provided by declaring as "correlated event" the lowest level event detected. As an example, the LCD defect is a lower level event compared to the detection of VP/VC-AIS cells which in turn is a lower level event compared to a VP/VC LOC defect.

- A check of the persistence of defects should be performed so as to detect defects for which a notification could be sent to the local and/or the remote management system through the TMN.
- Defects and failures should be recorded so as to allow the collection of statistics and the use of thresholding mechanisms to trigger the sending of notifications to the local and/or the remote management system through the TMN.
- Performance outcomes and unavailability state occurrence should be recorded for all physical layer transmission paths and some selected ATM layer connections or connection segments for which a performance assessment is required.

Performance impairments counts during unavailable periods should be excluded (see Note).

As a result threshold crossing in case of an important performance impairment occurrence observed during a given time interval could be notified to the local and/or the remote management system through the TMN. Also performance outcomes statistics may be reported on a periodical or "on demand" basis.

NOTE – Details will be provided in an equipment related Recommendation.

- It should be possible, for the local or remote management systems, to select for each managed maintenance entity the notifications to be sent in case of occurrence of potential notifications issued as a result of a failure detection or a performance impairment.

6 OAM levels and flows

6.1 OAM levels in the B-ISDN

OAM functions in the network are performed on five OAM hierarchical levels associated with the ATM and physical layers of the protocol reference model. The functions result in corresponding bidirectional information flows F1, F2, F3, F4 and F5 referred to as OAM flows (see Figure 3). Not all of these flows need to be present. The OAM functions of a missing level are performed at the next higher level. The levels are as follows:

- *Virtual channel level*: Extends between network elements performing VCC termination functions and is shown extending through one or more VPCs (see also Recommendation I.311).
- *Virtual path level*: Extends between network elements performing VPC termination functions (see Recommendation I.311) and is shown extending through one or more transmission paths.
- *Transmission path level*: Extends between network elements assembling/disassembling the payload of a transmission system and associating it with its OAM functions. Cell delineation and Header Error Control (HEC) functions are required at the endpoints of each transmission path. The transmission path is connected through one or more digital sections.
- *Digital section level*: Extends between section endpoints and comprises a maintenance entity.
- *Regenerator section level*: A regenerator section is a portion of a digital section and as such is a maintenance sub-entity.

This layered concept and the requirements of independence of the layers from each other lead to the following principles. OAM functions related to OAM levels are independent from the OAM functions of other levels and have to be provided at each level. Each level, where OAM functions are required, is able to carry out its own processing to obtain quality and status information.

6.2 Relationship of OAM functions with the B-ISDN models

6.2.1 B-ISDN Protocol Reference Model (PRM)

OAM functions are allocated to the layer management of the B-ISDN protocol reference model (see Recommendations I.321 and I.732).

OAM functions are performed by the layer management. These results may be provided to the plane management or to the adjacent higher layer. Higher layer functions are not necessary to support the OAM of the lower layer.

6.2.2 ATM transport network model

An alternative ATM transport network model described in Recommendation I.326 has been developed using modelling techniques given in Recommendation G.805. It is possible to model the B-ISDN functions using this model. The VC layer network is the client layer of the VP layer network and the VP layer network is the server layer of the VC layer network. The TTFs are responsible for the generation and termination of the trail (i.e. connection endpoint, segment endpoint) related to OAM flows (see Figures IV.1, IV.2). In this Recommendation, a VPC segment endpoint performs VPC segment trail termination and a VPC endpoint performs VP end-to-end trail termination functionality within the VP layer network (refer to Recommendation I.326). Similarly, a VCC segment endpoint performs VCC segment trail termination and a VCC endpoints performs VCC end-to-end trail termination functionality within the VC layer network.

7 Mechanisms to provide OAM flows

7.1 Physical layer mechanisms

The physical layer contains the three lowest OAM levels as outlined in Figure 3. The allocation of the OAM flows is as follows:

- F1: regenerator section level;
- F2: digital section level;
- F3: transmission path level.

The mechanisms to provide OAM functions and to generate OAM flows F1, F2 and F3 will depend on the transport mechanism of the transmission system as well as on the supervision functions contained within the physical layer termination functions of equipments. Three types of transmission can be provided in ATM networks:

- SDH-based transmission systems;
- Cell-based transmission systems;
- PDH-based transmission systems.

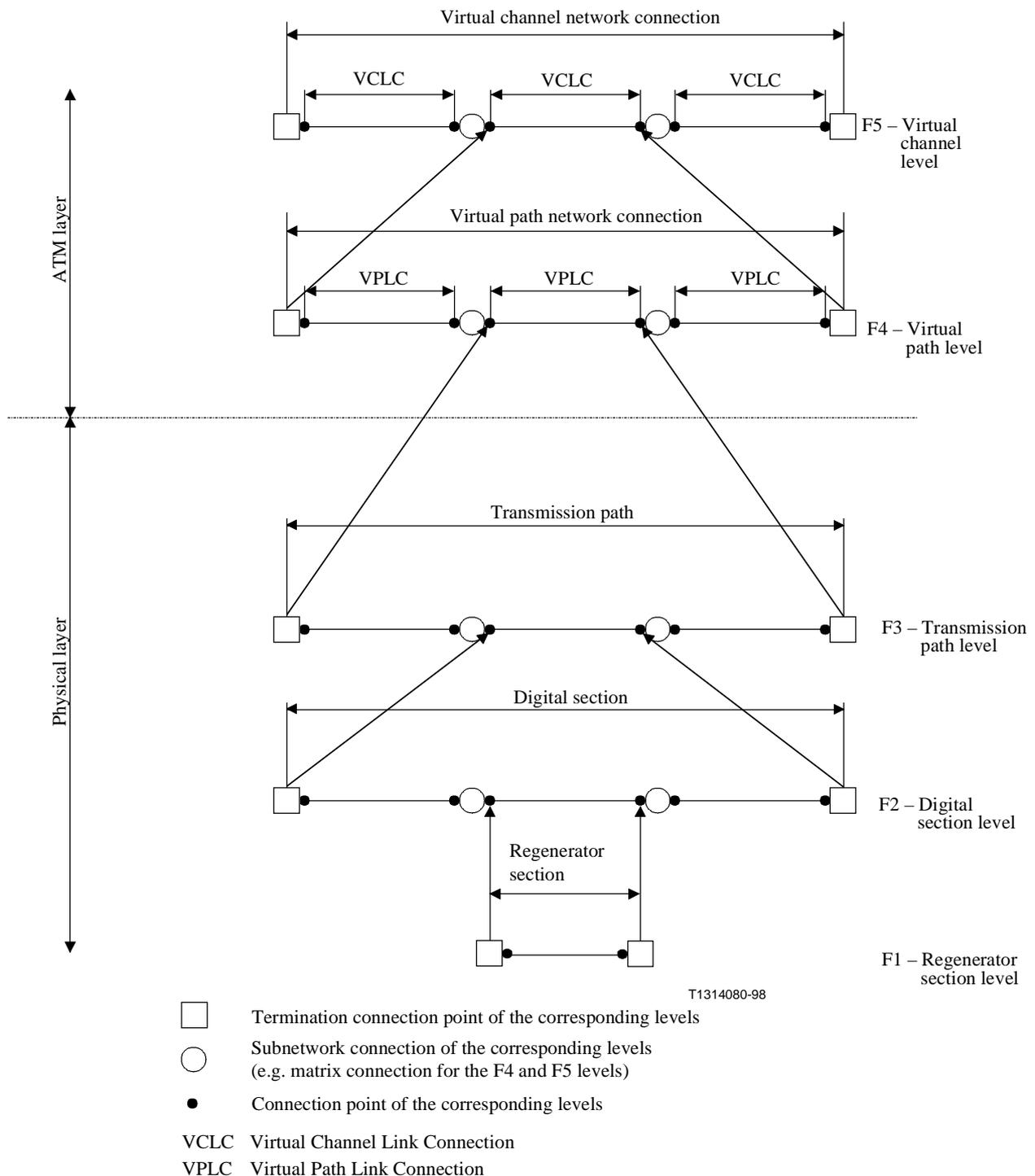


Figure 3/I.610 – OAM hierarchical levels and their relationship with the ATM layer and physical layer

7.1.1 SDH-based transmission systems

Such transmission systems are defined in Recommendations G.707 and G.783. OAM flows F1 and F2 are carried on bytes in the Section Overhead (SOH), flow F3 is carried in the higher order Path Overhead (POH) of the transmission frame. ATM transport may also be supported on lower order paths which support path overheads. These lower order path OAM flows are subsets of the F3 flow.

7.1.2 Cell-based transmission systems

Such transmission systems are defined in Recommendations I.432.1, I.432.2 and I.432.4. OAM flows F1 and F3 are carried through maintenance cells at the physical layer using a specific pattern in the header for F1 and F3. F2 flows are not provided, but the associated functions are supported by F3 flows. These cells are not passed to the ATM layer. The occurrence of a PL-OAM cell is determined by the requirements of the supported OAM functions. For each type (F1 and F3) of PL-OAM cell, maximum spacing is applied. If maximum spacing is exceeded, Loss of Maintenance flow (LOM) event will occur.

When transmission path-RDI is sent, the cause of this defect (LCD, LOM, AIS) is indicated in the layer management message.

7.1.3 PDH-based transmission systems

Such transmission systems are defined in Recommendations G.702, G.804 and G.832. Specific means to monitor the section performance (e.g. violation code counting CRC, etc.) are defined within Recommendations G.702, G.804 and G.832. If the ATM layer is supported only on a PDH section, then the G.804 overhead constitutes both F1 and F3 flows (but not F2).

7.2 ATM layer mechanism

The ATM layer contains the two highest OAM levels as outlined in Figure 3. The allocation of the OAM flows is as follows:

- F4: virtual path level;
- F5: virtual channel level.

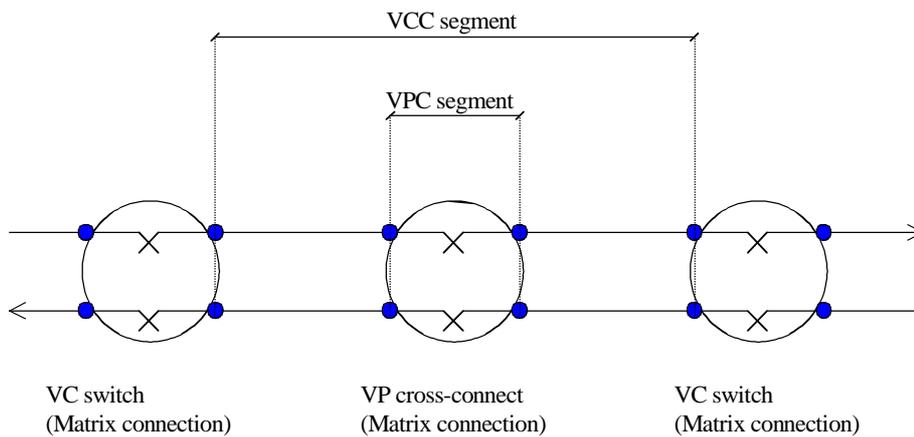
OAM flows are related to bidirectional Maintenance Entities (MEs) corresponding to either the entire ATM VPC/VCC, referred to as the VPC/VCC ME, or to a portion of this connection referred to as a VPC/VCC segment ME.

VPC/VCC segment ME boundaries defined at the VP (or VC) levels are applicable to any type of OAM function (see clause 10) operating at the segment level. The boundaries of a VPC/VCC segment ME shall be defined prior to the use of any type of segment OAM cell.

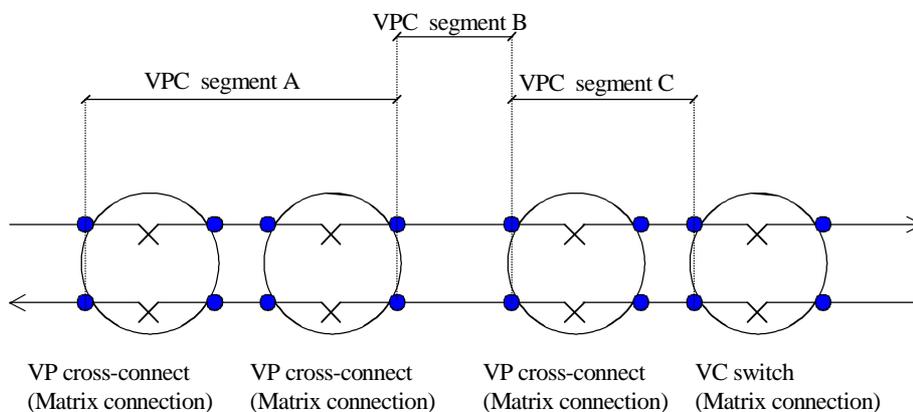
A VPC/VCC segment ME may cover:

- one single VP/VC bidirectional link connection (corresponds to the bidirectional link in-between two consecutive ATM network elements, e.g. cross-connects, switches);
- one single VP/VC bidirectional matrix connection, i.e. a VP/VC bidirectional subnetwork connection delimited by the CPs located at the ingress/egress of an ATM network element;
- a concatenation of VP/VC bidirectional link connections and VP/VC bidirectional matrix connections.

In the remaining part of this Recommendation, a VPC/VCC segment ME is referred to as a VPC/VCC segment. Figure 4 gives some examples of possible segment configurations.



a) Example of a VPC segment covering a single VP bidirectional matrix connection and a VCC segment covering a single VC bidirectional link connection



b) Examples of contiguous VPC segments

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- Termination of the VP/VC links VPLC or VCLC (according to the terminology used in Recs. G.805 and I.326)

Figure 4/I.610 – Examples of possible segment configurations

These OAM flows are provided by special cells dedicated to ATM layer OAM functions for both VCC and VPC. OAM cells are identified by specific values assigned to certain fields in the ATM cell header. In addition, such cells are usable for carrying management information (e.g. activation/deactivation procedures).

7.2.1 F4 flow mechanism

The F4 flow is bidirectional. The OAM cells for both directions of the F4 flow must follow the same physical route so that it is possible for any CP on that connection to correlate the fault and performance information from both directions.

OAM cells of the F4 flow have the same VPI value as the user cells of the VPC thus constituting an in-band flow. OAM cells of the F4 flow are identified by pre-assigned VCI values. The same pre-assigned VCI value shall be used for both directions of the F4 flow.

The OAM cell PTI value which is generated at the source TCP (or source CP) may be set to "000". Intermediate CPs could modify the second bit of this field. However, the PTI field will not be evaluated by the sink TCP (or sink CP) as far as the OAM process is concerned.

At F4 level, the term "user cell" is used for OAM according to the VCI values as shown in Table 1.

There are two kinds of F4 flows, which can simultaneously exist in a VPC. These are:

- *End-to-end F4 flow*: This flow, identified by a standardized VCI (see Recommendation I.361), is used for end-to-end VPC operations communications.
- *Segment F4 flow*: This flow, identified by a standardized VCI (see Recommendation I.361), is used for communicating operations information within the boundaries of the VPC segment.

One or more VPC segments may be defined along a VPC. Neither overlapped nor embedded VPC segments can be defined. For that purpose, it must be ensured that none of the CPs between the source and sink CP of a VPC segment shall be a source or sink CP of another VPC segment of the same connection.

The definition of the span of a VPC segment is not necessarily fixed for the duration of a connection, i.e. the VPC segment may be re-configured as required.

Before any type of VPC segment OAM cells can be used, the endpoints of a VPC segment shall be established.

NOTE – A VPC segment is typically under the control of one Administration or organization; however, it can be extended beyond the control of one Administration/organization by mutual agreement.

End-to-end F4 flows must be terminated at the endpoints of a VPC. Segment F4 flows must be terminated at the CPs terminating a VPC segment. These terminating CPs can be intermediate CPs along the VPC or they can coincide with a VPC endpoint. The F4 flow will be initiated at or after connection set-up. There exist different ways to initiate the F4 flow, i.e. either by the TMN or by OAM function activation procedures.

A source point of a VPC segment shall discard all VPC segment OAM cells coming from the outside of this segment whatever their OAM function type is (see clause 10).

It shall be possible for any CP to be configured as a source/sink of a VPC segment.

Table 1/I.610 – "User cells" at F4 level

VCI	Interpretation	Category
0	Unassigned cell (VPI = 0)	Non-user cell
0	Unused (VPI > 0)	
1	Meta-signalling cell (UNI)	User cell
2	General broadcast signalling cell (UNI)	
3	Segment OAM F4 flow cell	Non-user cell
4	End-to-end OAM F4 flow cell	
5	Point-to-point signalling cell	User cell
6	Resource management cell	Non-user cell
7-15	Reserved for future standardized functions	
16-31	Reserved for future standardized functions	User cell
VCI > 31	Available for user data transmission	

7.2.2 F5 flow mechanism

The F5 flow is bidirectional. The OAM cells for both directions of the F5 flow must follow the same physical route so that it is possible for any CP on that connection to correlate the fault and performance information from both directions.

OAM cells of the F5 flow have the same VPI/VCI values as the user cells of the VCC thus constituting an in-band flow. OAM cells of the F5 flow are identified by pre-assigned PTI values. The same PTI value shall be used for both directions of the F5 flow. The PTI value shall not be modified along the whole connection.

At F5 level, the term "user cell" is used for OAM according to the PTI values as shown in Table 2.

There are two kinds of F5 flows, which can simultaneously exist in a VCC. These are:

- *End-to-end F5 flow*: This flow, identified by a standardized PTI (see Recommendation I.361), is used for end-to-end VCC operations communications.
- *Segment F5 flow*: This flow, identified by a standardized PTI (see Recommendation I.361), is used for communicating operations information within the boundaries of the VCC segment.
- One or more VCC segments may be defined along a VCC. Neither overlapped nor embedded VCC segments can be defined. For that purpose, it must be ensured that none of the CPs between the source and sink CP of a VCC segment shall be a source or sink CP of another VCC segment of the same connection.
- The definition of the span of a VCC segment is not necessarily fixed for the duration of a connection, i.e. the VCC segment may be re-configured as required.
- Before any type of VCC segment OAM cells can be used, the endpoints of a VCC segment shall be established.

NOTE – A VCC segment is typically under the control of one Administration or organization; however, it can be extended beyond the control of one Administration/organization by mutual agreement.

End-to-end F5 flows must be terminated at the endpoints of a VCC. Segment F5 flows must be terminated at CPs terminating a VCC segment. These terminating CPs can be intermediate CPs along the VCC or they can coincide with a VCC endpoint. The F5 flow will be initiated at or after connection set-up. There exist different ways to initiate the F5 flow, i.e. either by the TMN or by OAM function activation procedures.

A source point of a VCC segment shall discard all VCC segment OAM cells coming from the outside of this segment whatever their OAM function type is (see clause 10).

It shall be possible for any CP to be configured as a source/sink of a VCC segment.

Table 2/I.610 – "User cells" at F5 level

PTI code	Interpretation	Category
000	User data cell, congestion not experienced	User cells
001		
010	User data cell, congestion experienced	
011		
100	Segment OAM F5 flow cell	Non-user cells
101	End-to-end OAM F5 flow cell	
110	Resource management cell	
111	Reserved for future standardized functions	

7.3 Association of the OAM mechanisms with the transport functions

Figure 5 gives an example of a VCC supported by all lower network levels according to the techniques described in Recommendation I.311. The associated OAM mechanisms for each level are also shown. The digital section and the regenerator section levels are shown combined under the term "section".

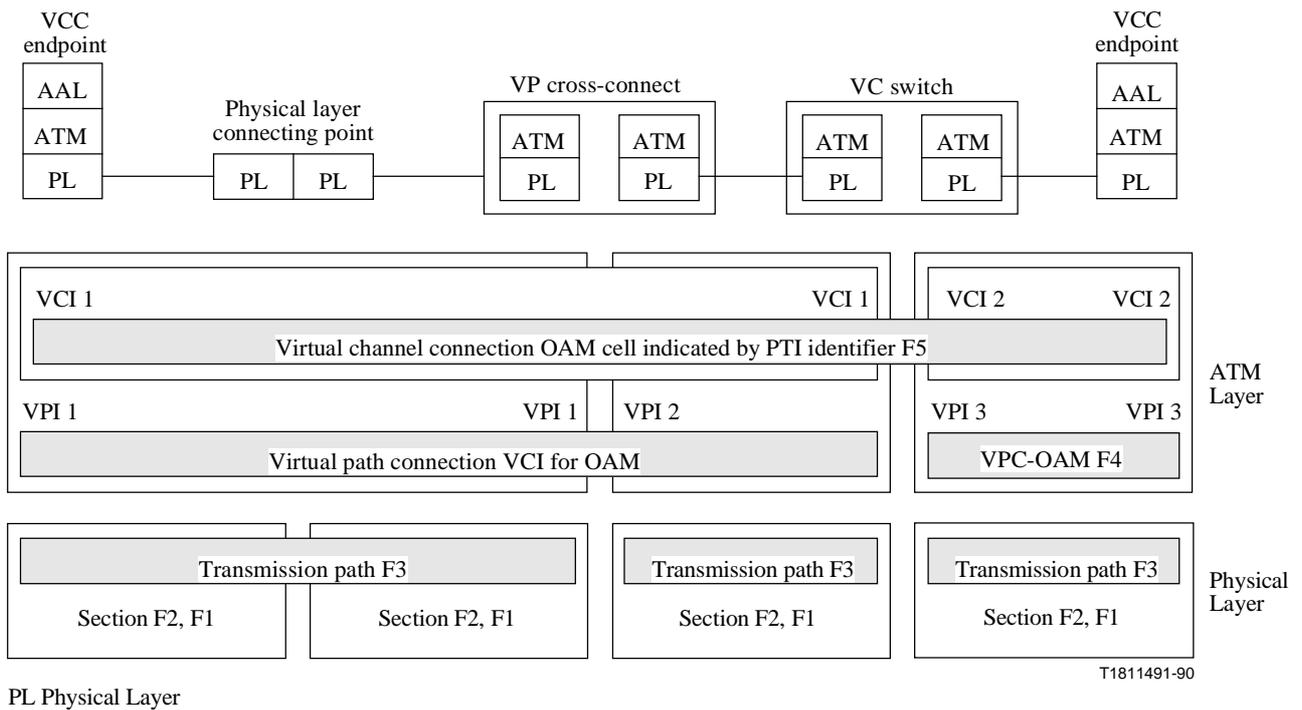


Figure 5/I.610 – Example of mechanisms for OAM flows

8 OAM functions of the physical layer

This clause provides additional information on the OAM flows (F1, F2 and F3) within the physical layer. It is not intended to replace the in-depth physical layer OAM functionality defined in the G-series Recommendations, e.g. for PDH rate interfaces refer to Recommendations G.832 and G.804 and for SDH interfaces refer to Recommendations G.783 and G.784.

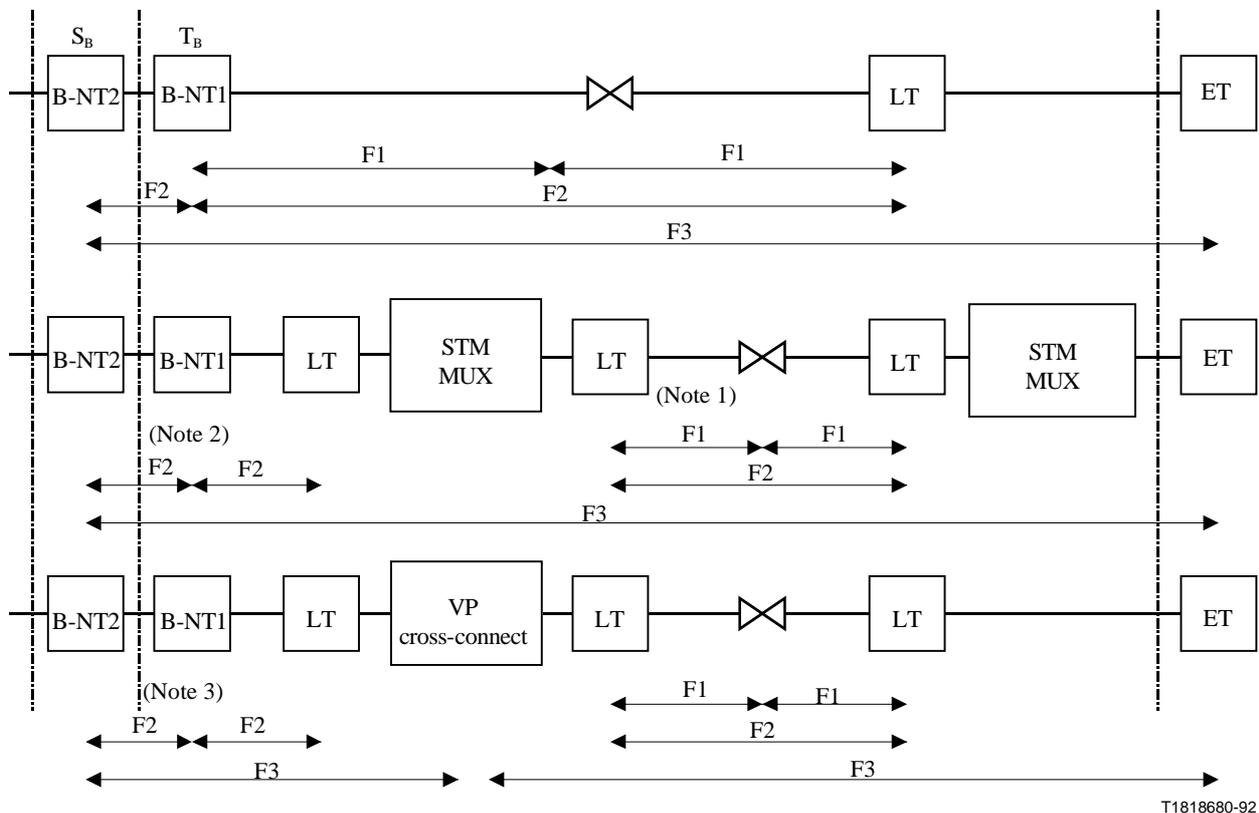
8.1 OAM flows in some physical configurations

Figure 6 illustrates examples of the OAM flows in some physical configurations for the B-ISDN customer access.

8.2 OAM functions

Two types of OAM functions are distinguished:

- 1) *OAM functions supported solely by the flows F1, F2 and F3:*
 - Dedicated to detection and indication of unavailability state.
 - Requiring "real time", defect information transport towards the affected endpoints for system protection.
- 2) *OAM functions with regard to the system management:*
 - Dedicated to performance monitoring or for localization of failed equipment.
 - May be supported by the flows F1 to F3 or by other means, e.g. TMN via the Q-interfaces.



ET Exchange Termination
 LT Line Termination
 STM Synchronous Transfer Mode

NOTE 1 – Depending on the transmission system used (e.g. PDH, SDH, etc.) and its functional implementation (e.g. LT integrated in STM MUX) the related OAM flows may be implemented but not shown.

NOTE 2 – In case of cell-based transmission systems, F2 functions are supported by F3 flows.

NOTE 3 – In case of cell-based transmission system, a F1 flow is provided.

Figure 6/I.610 – Examples of physical configurations and OAM flows at the physical layer

8.2.1 OAM functions supported solely by the flows F1 to F3

OAM functions related to the SDH-based transmission systems can be found in Recommendation G.783.

OAM functions related to the cell-based transmission systems can be found in I.432.x series of Recommendations.

OAM functions related to the PDH-based transmission systems can be found in Recommendations G.804 and G.832.

8.2.2 OAM functions with regard to the system management

For the SDH-based option, examples of these functions are:

- error monitoring at the regenerator section level, allowing the detection of a degraded error performance (optional);
- error monitoring/reporting at the multiplex section level, allowing the detection of a degraded error performance;
- error monitoring/reporting at the transmission path level, allowing the detection of a degraded error performance.

For the cell-based option, examples of these functions are:

- error monitoring/reporting at the regenerator section level, allowing the detection of a degraded error performance;
- error monitoring/reporting at the transmission path level, allowing the detection of a degraded error performance.

For both options, examples of these functions are:

- uncorrectable headers count;
- header error performance monitoring (degraded or not).

8.3 Additional OAM functions

The OAM functions defined in this subclause refer to indications which cannot be handled under the current physical or ATM layers classification. According to G.805 and I.326 terminology, these OAM functions are located in the adaptation function which stands in between the Transmission Path Trail (TPT) and the Virtual Path Link Connection (VPLC) transport entities.

8.3.1 LCD events

Cell delineation, based on the HEC field in the ATM cell header, allows identification of the cell boundaries. When consecutive errors affect the HEC, a LCD defect may be observed. Conditions for declaring a LCD defect are defined in the relevant I.432.x-series Recommendations. The occurrence of LCD defects should be managed.

8.3.2 UNEX events

Cells received at the endpoint of a Transmission Path (TP) with either a non-standardized (i.e. VPI/VCI/PTI combinations not defined in Recommendation I.361) or a non-currently allocated header value should be detected. These cells, referred to as "unexpected VPI/VCI cells", may be observed in case of misrouting due to a failure in an upstream ATM Network Element (NE) or to a human error when setting up a (semi-)permanent VPC/VCC.

The occurrence of these cells should be processed so as to determine the persistence of "unexpected VPI/VCI" values rather than the number of occurrences of such events. This could be achieved by aggregating over a one second period of time the occurrence of cells with an "unexpected VPI/VCI" value. The monitoring of such an event should be provided on a permanent basis for each TP terminated in an ATM NE. This gives rise to a "second with unexpected VPI/VCI cell" (UNEX) event which is obtained only in the absence of Trace Identifier Mismatch (TIM) defect indication (see Note). This permits a fix of a threshold value for the number of "second with unexpected VPI/VCI cell" which is independent of the cell rate of the misrouted connection and therefore to provide management facilities for controlling the time when notifications are sent to the local and/or the remote management systems via the TMN.

NOTE – If "unexpected VPI/VCI cells" are detected together with a TIM defect indication, the counting of UNEX events should be inhibited.

The numbers of UNEX events as well as the VPI/VCI values of the last "unexpected VPI/VCI cell" received should be managed.

9 OAM functions of the ATM layer

9.1 OAM flows in some physical configurations

Figure 7 illustrates the implementation of the OAM flows in some physical configurations for the B-ISDN customer access. The arrow heads show possible flow termination points.

9.2 OAM functions

Table 3 gives an overview of the OAM functions of the ATM layer. Additional functions for testing, fault localization and performance measurement are for further study. Means to detect OAM procedure failures are for further study.

The use of the OAM mechanisms for estimating VPC/VCC outages is outlined in Annex A.

When allocating bandwidth to a VPC/VCC, it is necessary to allocate sufficient bandwidth for the OAM cells in that connection as described in Recommendation I.371.

9.2.1 OAM functions for VPC (F4 flow)

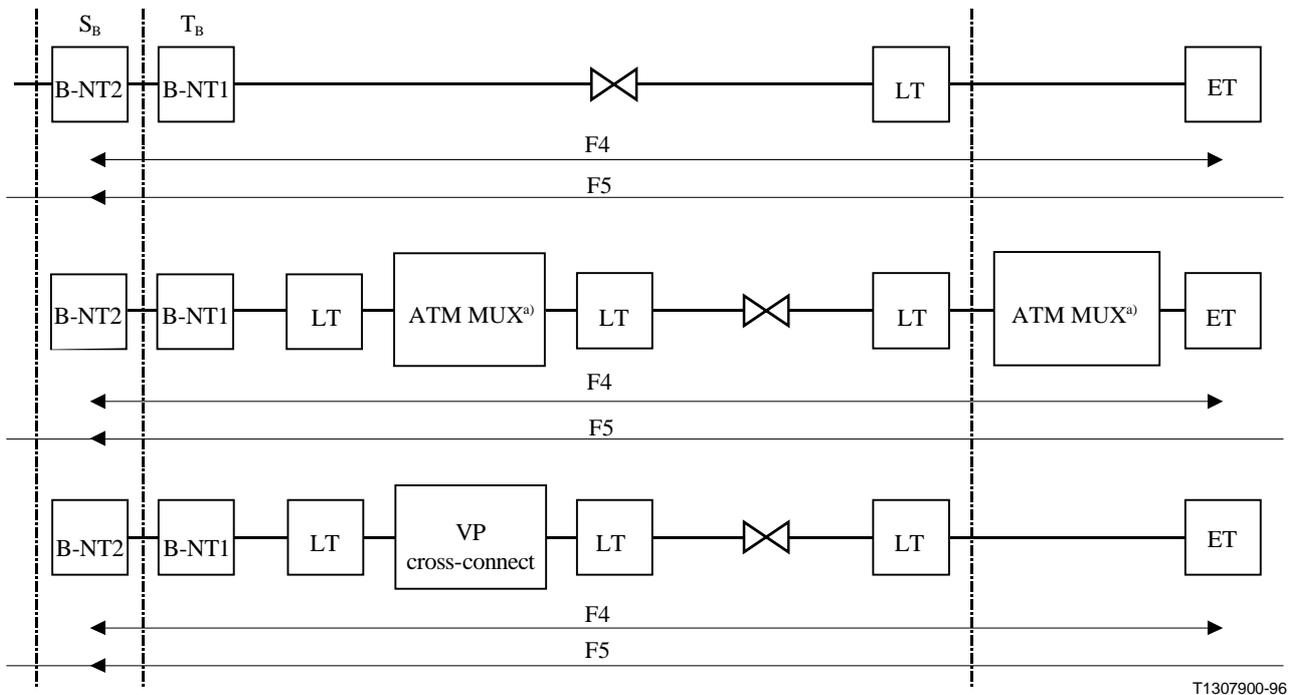
This subclause addresses VP-level fault management and performance management functions.

9.2.1.1 Virtual path fault management functions

9.2.1.1.1 VP-AIS and VP-RDI defect indications

VP-AIS and VP-RDI defect indications shall be used for identifying and reporting VPC defects end-to-end.

Seg_VP-AIS and seg_VP-RDI defect indications shall be used for identifying and reporting VPC defects at the segment level.



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^{a)} ATM MUX without VP termination

Figure 7/I.610 – Examples of physical configurations and OAM flows at the ATM layer

Table 3/I.610 – OAM functions of the ATM layer

OAM function	Main application
AIS	For reporting defect indications in the forward direction
RDI	For reporting remote defect indications in the backward direction
CC	For continuously monitoring continuity
LB	For on-demand connectivity monitoring For fault localization For pre-service connectivity verification
FPM	For estimating performance in the forward direction
Backward reporting	For reporting performance estimations in the backward direction
Activation/deactivation	For activating/deactivating PM and CC
System management	For use by end-systems only
APS	For carrying protection switching protocol information

9.2.1.1.1.1 VP-AIS

9.2.1.1.1.1.1 End-to-end VP-AIS

The ATM network element which detects a VPC defect shall generate and send (in the forward direction) e-t-e_VP-AIS cells on all affected active VPCs. e-t-e_VP-AIS cells will be sent upon:

- receiving transmission path defect indications from the physical layer (see Note 1) or;
- detecting LCD in the TP/VP_A function (see Note 2) or;
- detecting LOC at the VP layer at segment sink endpoint (in the VPL_T function).

NOTE 1 – Defect indication conditions are defined in appropriate Recommendations for SDH-, PDH- and cell-based transmission systems (see 7.1).

NOTE 2 – LCD defect is defined in I.432.x-series Recommendations.

e-t-e_VP-AIS cell generation condition – The e-t-e_VP-AIS cells are generated and transmitted as soon as possible after detection of a defect, and are transmitted periodically during the defect condition in order to indicate an interruption of the cell transfer capability at the VP level. The generation frequency of e-t-e_VP-AIS cells is nominally one cell per second and shall be the same for each affected VPC.

e-t-e_VP-AIS cell generation shall be stopped as soon as the defect indications (e.g. transmission path-AIS defect) are removed.

e-t-e_VP-AIS cell detection – The e-t-e_VP-AIS cells are detected at the VPC sink-point. e-t-e_VP-AIS cells may be non-intrusively monitored at CPs along the VPC.

e-t-e_VP-AIS state declaration and release conditions (see Note 3) – The e-t-e_VP-AIS state is declared at the VPC endpoint or intermediate CPs along the VPC (if non-intrusive monitoring is activated) as soon as a e-t-e_VP-AIS cell is received, a transmission path-AIS defect or a VPC defect (e.g. loss of VPC continuity) is detected. The e-t-e_VP-AIS state is released when a user cell (see Table 1) or e-t-e_CC cell is received. If the VPC continuity check function is not activated, the e-t-e_VP-AIS state is also released if e-t-e_VP-AIS cells are absent for nominally 2.5 seconds, with a margin of ± 0.5 seconds.

NOTE 3 – For accurate determination of availability, a problem has been identified when user cells are taken into account for the release condition of the e-t-e_VP-AIS state. A definition of this state that does not give consideration to the presence of user cells is for further study.

9.2.1.1.1.1.2 Segment VP-AIS

Segment VP-AIS is specified as stated below. The use of segment VP-AIS functionality within one network operator domain is a network operator option.

NOTE – The United Kingdom, Netherlands, United States of America and Italy interpret this as meaning that the support of segment VP-AIS functionality is a network operator option.

The ATM network element which detects the VPC defect within an OAM segment shall generate and send (in the forward direction) seg_VP-AIS cells in addition to e-t-e_VP-AIS cells on all affected active VPCs. Segment endpoints (source and sink) and CPs outside of an OAM segment should not generate seg_VP-AIS cells. With regard to generation of seg_VP-AIS cells, each CP can be configured by TMN as either being within a segment (seg_VP-AIS generation activated) or not within a segment (seg_VP-AIS generation deactivated). To assure consistent behaviour of different network elements during setting up of the connection, the default value for each CP of the node is: seg_VP-AIS generation activated.

seg_VP-AIS will be sent when receiving transmission path-AIS defect indications from the physical layer or detecting LCD in the TP/VP_A function. Transmission path-AIS defect indications result from defects observed at the regenerator section, multiplex section or transmission path levels.

seg_VP-AIS cell generation condition – The seg_VP-AIS cells are generated and transmitted as soon as possible after observing a defect indication, and transmitted periodically during the defect condition in order to indicate an interruption of the cell transfer capability at the VPC segment level. The generation frequency of seg_VP-AIS cells is nominally one cell per second and shall be the same for each affected VPC.

seg_VP-AIS cell generation shall be stopped as soon as the defect indications (e.g. transmission path-AIS defect) are removed.

seg_VP-AIS cell detection – The seg_VP-AIS cells are detected and terminated at the VPC segment sink point. Seg_VP-AIS cells may be non-intrusively monitored at CPs along the VPC segment.

9.2.1.1.1.3 Segment sink VP-AIS state

seg_VP-AIS state declaration and release conditions (see Note) – The seg_VP-AIS state is declared at the VPC segment sink point or intermediate CPs along the VPC (if non-intrusive monitoring is activated) as soon as a seg_VP-AIS cell is received, a transmission path-AIS defect or a VPC segment defect (e.g. loss of VPC segment continuity) is detected. The seg_VP-AIS state is released at the segment level when a user cell (see Table 1) or seg_CC cell is received. If VPC segment continuity check function is not activated, the seg_VP-AIS state is also released if seg_VP-AIS cells are absent for nominally 2.5 seconds, with a margin of ± 0.5 seconds.

NOTE – For accurate determination of availability, a problem has been identified when user cells are taken into account for the release condition of the seg_VP-AIS state. A definition of this state that does not give consideration to the presence of user cells is for further study.

9.2.1.1.1.2 VP-RDI

9.2.1.1.1.2.1 End-to-end VP-RDI

e-t-e_VP-RDI is sent to the far-end from a VPC endpoint as soon as it has declared a e-t-e_VP-AIS state.

e-t-e_VP-RDI cell generation condition – The e-t-e_VP-RDI cells are generated and transmitted periodically while the e-t-e_VP-AIS state persists in order to indicate in the backward direction an interruption of the cell transfer capability at the VP level in the forward direction. Generation frequency of e-t-e_VP-RDI cells is nominally one cell per second and shall be the same for all affected VPCs.

e-t-e_VP-RDI cell generation shall be stopped as soon as the e-t-e_VP-AIS state is released.

e-t-e_VP-RDI cell detection – The e-t-e_VP-RDI cells are detected at the VPC endpoint and e-t-e_VP-RDI state is declared after the reception of one e-t-e_VP-RDI cell. E-t-e_VP-RDI cells may be non-intrusively monitored at CPs along the VPC.

e-t-e_VP-RDI state declaration and release conditions – The e-t-e_VP-RDI state is declared at the VPC endpoint as soon as a e-t-e_VP-RDI cell is received at this point. The e-t-e_VP-RDI state is released at the VPC endpoint when no e-t-e_VP-RDI cell is received during a nominally 2.5 seconds period, with a margin of ± 0.5 seconds.

9.2.1.1.1.2.2 Segment VP-RDI

seg_VP-RDI cells are sent to the far-end of the segment from a VPC segment endpoint as soon as it has declared a seg_VP-AIS state.

seg_VP-RDI cell generation condition – The seg_VP-RDI cells are generated and transmitted periodically while the seg_VP-AIS state persists in order to indicate in the backward direction an interruption of the cell transfer capability at the VPC segment level in the forward direction. Generation frequency of seg_VP-RDI cells is nominally one cell per second and shall be the same for all affected VPCs.

seg_VP-RDI cell generation shall be stopped as soon as the seg_VP-AIS state is released.

seg_VP-RDI cell detection – The seg_VP-RDI cells are detected at the VPC segment endpoint and seg_VP-RDI state is declared after the reception of one seg_VP-RDI cell. Seg_VP-RDI cells may be non-intrusively monitored at CPs along the VPC segment.

seg_VP-RDI state declaration and release conditions – The seg_VP-RDI state is declared at the VPC segment endpoint as soon as a seg_VP-RDI cell is received at this point. The seg_VP-RDI state is released at the VPC segment endpoint when no seg_VP-RDI cell is received during a nominally 2.5 seconds period, with a margin of ± 0.5 seconds.

9.2.1.1.2 VPC continuity check

CC can be simultaneously carried out end-to-end or at segment level on a certain number of selected active VPCs per interface (UNI, NNI) in each direction. The value of this number is outside the scope of this Recommendation.

CC can be activated either during connection establishment or at any time after the connection has been established.

Procedures for activation (and associated deactivation) are described in 9.2.3. The possibility to activate CC on all active VPCs and VPC segments remains as an option.

NOTE 1 – Although use of CC is a network operator option, some Administrations considered the ability to activate CC on some or all of the VPCs or VPC segments to be important. This is due to the fact that CC is the only in-service mechanism able to continuously detect for ATM layer defects (as opposed to physical layer defects) in real-time. Also activation of the CC mechanism together with the PM process allows the performance to be assessed only during the available time of the VPC/VPC segment according to Recommendation I.356.

Two alternative mechanisms exist for the insertion of VP-CC cells after the activation of the CC function:

- *Option 1*
VP-CC cells are sent in the forward direction by a VPC source point or a VPC segment source point when no user cells have been sent for a period of nominally 1 second.
NOTE 2 – Option 1 of the CC cell may be used in order to detect LOC defects. However this option should not be used to estimate availability.
- *Option 2*
VP-CC cells are sent repetitively with a periodicity of nominally 1 cell per second independent of the user cells flow.

When the VPC sink-point with CC activated does not receive any user cell or CC cell within a time interval of 3.5 seconds, with a margin of ± 0.5 seconds, it will declare the VP-AIS state due to a LOC defect.

When the VPC segment sink point does not receive any user cell or CC cell (see Table 1) within a time interval of 3.5 seconds, with a margin of ± 0.5 seconds, it will declare a LOC defect and start transmitting e-t-e_VP-AIS cells in the forward direction. However, during a LOC defect, to avoid a duplication of e-t-e_VP-AIS cell flows this segment sink point shall not insert additional e-t-e_VP-AIS cells if it already is receiving and forwarding e-t-e_VP-AIS cells.

NOTE 3 – For accurate determination of availability, a problem has been identified when user cells are taken into account for the declaration of the LOC defect. A definition of this defect that does not give consideration to the presence of user cells is for further study.

9.2.1.1.3 VP loopback capability

9.2.1.1.3.1 General description

The ATM layer loopback capability allows for operations related information to be inserted at one location along a VPC and returned (or looped back) at a different location, without having to take the connection out-of-service. This capability is performed by inserting a LB cell at an accessible point along the VPC (i.e. at an endpoint or any CP) without disrupting the sequence of user cells while minimizing the user cells transfer delay. This cell is looped back at a downstream point according to the information contained in its information field.

9.2.1.1.3.2 Principles of operation

- 1) VP-LB cells can be inserted at CPs (including VPC segment endpoints) and VPC endpoints. The ATM network element that originated the looped cell may optionally remove it, after matching the correlation tag and the source identifier.
- 2) seg_VP-LB cells can be looped back at CPs (including VPC segment endpoints). The ATM network element that looped the seg_LB cell may optionally remove it, after the loop action¹. The use of the LLID is a network operator option for seg_VP-LB cells. The management of the LLID field is described in 10.2.3.
- 3) The waiting time between the transmission of successive LB cells on a connection shall be 5 seconds. The loopback shall be considered unsuccessful if the LB cell is not returned to the originating point within 5 seconds.
- 4) It shall be possible to initiate a loopback without a command from the TMN, e.g. a customer may initiate an end-to-end loopback. This does not preclude the reporting of loopback results to the TMN.
- 5) A means to confirm that loopback is performed at the ATM layer, rather than at the physical layer, is provided by requiring the loopback point to change a field (the loopback indication field – described in 10.2.3) within the LB cell payload. This principle is illustrated in Figure 8. The requirement for the loopback point to change the loopback indication also overcomes the problem of infinite loopback that would otherwise occur with the use of the default (all 1s) LLID.
- 6) e-t-e_VP-LB cells shall not be looped back at CPs.
- 7) Annex C shows the detailed procedures which should be performed when a LB cell is received by a network element.

¹ Some functions associated with the loopback mechanism require that the removal of segment loopback cells (after being looped back at an intermediate CP) is disabled. See details in Annex C and Appendix III.

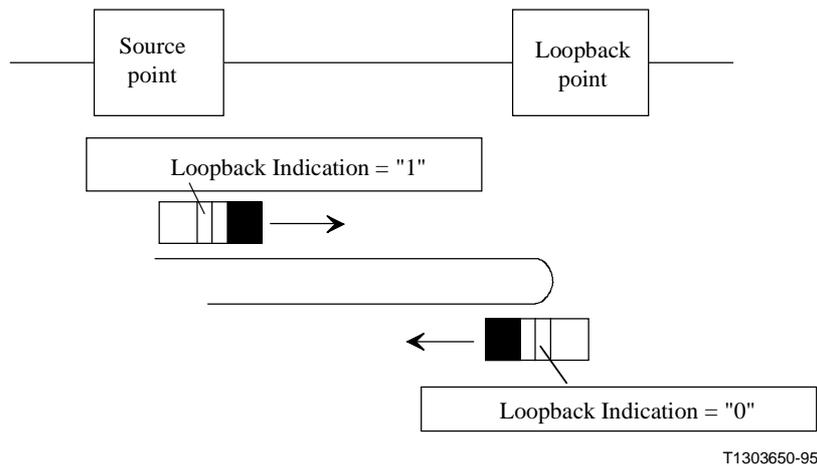


Figure 8/I.610 – The loopback indication function

9.2.1.1.3.3 Loopback applications

The loopback capability supports the applications shown in Figure 9. The applications are limited to the five following cases:

- a) *End-to-end loopback* – A e-t-e_VP-LB cell is inserted by a VPC endpoint, and looped back by the corresponding far-end VPC endpoint.
- b) *Access line loopback* – A seg_VP-LB cell is inserted by the customer or the network, and looped back by the first ATM node in the network or customer equipment respectively. For this application, the VPC segment is defined by mutual agreement.
- c) *Inter-domain loopback* – A seg_VP-LB cell is inserted by one network operator and looped back by the first ATM node in an adjacent network operator domain. For this application, the VPC segment is defined by mutual agreement.
- d) *Network-to-endpoint loopback* – A e-t-e_VP-LB cell is inserted by one network operator, and looped back by the VPC endpoint in another domain.
- e) *Intra-domain loopback* – A seg_VP-LB cell is inserted at a VPC segment endpoint or a CP within the VPC segment, and looped back at a VPC segment endpoint or a CP within the VPC segment. For this application, the use of the LLID is a network operator option.

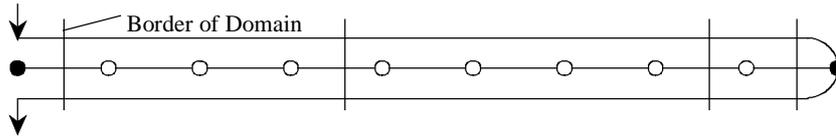
NOTE – A VPC segment may span several network domains, pending on a mutual agreement of all involved Administrations. In this case the resulting monitored portion will be considered as a single domain, and loopback applications e1) and e2) may apply assuming that the seg_VP-LB cell processing options specified in 9.2.1.1.3.2 are compatible in this domain.

9.2.1.2 VP performance management functions

Performance monitoring of a VPC or VPC segment is performed by inserting monitoring cells at the ends of the VPC or VPC segment, respectively. In the procedure supporting this function, forward error detection information (e.g. the error detection code) is communicated by the endpoints using the forward F4 flow based on the FPM cells defined in 10.3. The PM results, on the other hand, are received on the reverse (incoming) F4 flow based on the BR cells defined in 10.3. Note that when monitoring VPCs that are entirely within one span of control or when monitoring VPC segments, the monitoring result may be reported using the reverse F4 flow or via some other means (e.g. TMN).

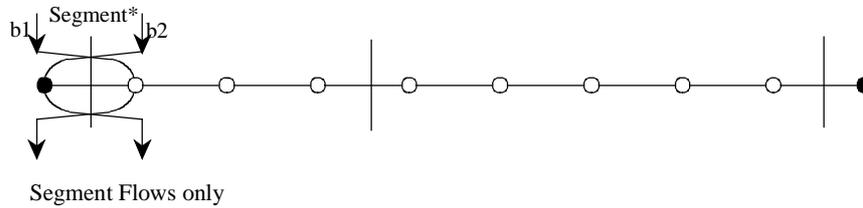
PM shall be done by monitoring blocks of user cells. Table 1 gives the list of cell types which should be considered as "user cell" for VP performance monitoring (i.e. cells which should form part of the monitored cell block at the VP level).

a) End-to-End Loopback

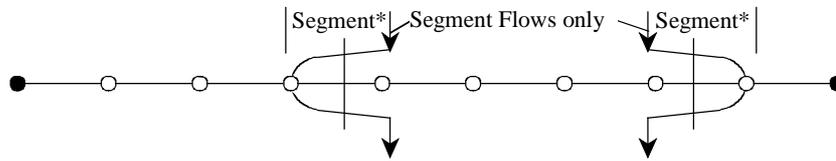


b) Access Line Loopback

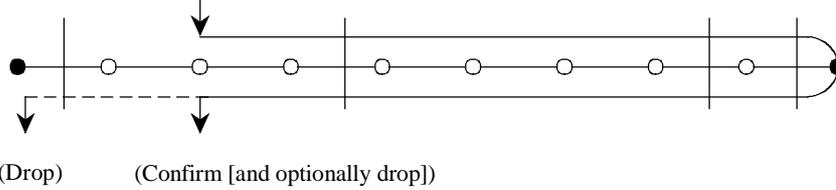
- b1 = Initiated by the Customer
- b2 = Initiated by the Network



c) Inter-Domain Loopback (Initiated by the Network)

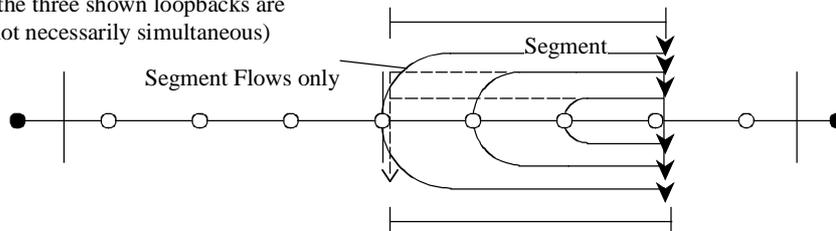


d) Network-to-Endpoint Loopback

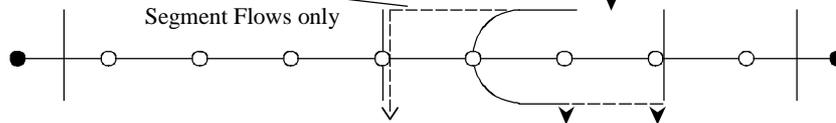


e1) Intra-Domain Loopback (Initiated by the Network)

(the three shown loopbacks are not necessarily simultaneous)



e2)



- * Segment defined by mutual agreement
- Connection Endpoint
- Connecting point or Segment Endpoint

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Figure 9/I.610 – Loopback applications

Whenever PM is performed at the end-to-end or segment level, it is advisable to insure that the corresponding CC mechanism (end-to-end or segment CC, respectively) is activated during the overall performance assessment period. This allows a continuous monitoring of the availability of the VPC or connection portion during that measurement period. CC may be activated either before or when starting the PM process.

A VP-FPM cell insertion request is initiated after every N user cells. The VP-FPM cell is inserted at the first available cell location after the request.

The block size N may have the values 128, 256, 512, 1024, 2048, 4096, 8192, 16 384 and 32 768 (see Table 7). These are nominal block size values, and the actual size of the monitored cell block may vary. The cell block size may vary up to a maximum margin of 50% of the value of N for end-to-end performance monitoring. However, for end-to-end performance monitoring, the monitoring cell must be inserted into the user cells stream no more than N/2 user cells after an insertion request has been initiated. The actual monitoring block size averages out to approximately N cells.

NOTE 1 – Recommendation I.356 shows how to choose the block size N.

To eliminate forced insertions of VP-FPM cells when monitoring VPC segment performance, the actual monitoring block size may be extended until a cell location is available after the insertion request. However, in this case, the actual monitoring block size may not average out to N cells. Forced insertion at the segment level remains as an option.

When forward performance monitoring and backward reporting functions are both activated for a given connection, OAM information related to a given cell block – which is transmitted in the forward direction – has to be carried in both directions by corresponding VP-FPM and VP-BR cells referred to as "paired" OAM cells, i.e. for each correctly received VP-FPM cell a corresponding VP-BR cell shall be issued (see Note 2).

NOTE 2 – A VP-FPM cell is considered to be correctly received if its EDC field (CRC-10) does not detect errors in the payload content.

A VP-BR cell insertion request is initiated after the "paired" VP-FPM cell is correctly received and its content processed. The VP-BR cell shall be then forwarded in the opposite direction, in the first available cell location after the request. The insertion of a VP-BR cell will be forced in case no spare cell location is available before the next VP-FPM cell is received.

The monitoring cell will detect:

- errored blocks;
- loss/mis-insertion of cells within a monitored block of cells.

Other functions (e.g. cell transfer delay) are for further study.

Appendix II provides informative material related to the insertion process applicable to end-to-end or segment performance management cells.

PM can be simultaneously carried out on a certain number of selected VPCs per interface (UNI, NNI). The specification of this number is beyond the scope of this Recommendation.

PM can be activated either during connection establishment or at any time after the connection has been established. Degradation of quality of service experienced by the user due to activation and deactivation should be negligible if resources are properly allocated.

Procedures for activation (and associated deactivation) are described in 9.2.3. Following PM activation, the first VP-FPM or VP-BR cell received is used for initialization only and is not used to update performance parameters.

There may be potential interference between PM and UPC/NPC actions. This is of particular concern in the case that the performance of an inter-operator domain is to be monitored. According to Recommendation I.356, for an International Inter-operator Portion (IIP) cells discarded in the NPC are not considered as performance degradation occurring in this portion. This is more generally true for any connection portion that is delimited by a Measurement Point (MP), adjacent to the UPC/NPC, but upstream this UPC/NPC function. In order to avoid this interference, availability and cell transfer impairments occurring in the UPC/NPC function, if inside an OAM segment, would need to be excluded from the PM results both for the forward and for the backward directions of this PM flow. Solutions to this problem are for further study.

9.2.1.3 VP system management

The VP system management cell type is defined for use by systems to control and maintain various functions at the VP layer. VP system management cells are of the end-to-end type. These OAM cells are inserted/extracted and processed only within the end-user equipment (i.e. within the customer premises) which terminate at both ends the corresponding VPC; they are transparently conveyed on the VPC.

VP system management cells are not defined either between network nodes or between an end-user equipment and a network node.

No segment flow for this function is defined, so that VPC segment OAM cells with this cell type may be used by network element equipment for internal functions (i.e. this cell shall not cross any external interface). Thus no segment for the system management cell type shall be defined in the future.

End-user equipment implementation of the system management cell is optional and is not recommended except for specific applications which are not satisfied by other mechanisms.

9.2.1.4 VP ATM protection switching

The VP-APS cell type is defined for providing ATM protection switching. Further information may be found in Recommendation I.630.

9.2.1.5 Non-intrusive monitoring of VP OAM flows

Non-intrusive monitoring of any type of end-to-end or segment fault and performance management VP OAM flows may be performed at any intermediate point along a VPC. This includes intermediate points within a VPC segment as well as the VPC segment endpoints (see Note).

NOTE – The purpose of the non-intrusive monitoring function is to provide to network providers additional OAM information which cannot be derived from the content of segment OAM flows. As an example, monitoring both the VP-RDI and the corresponding VP-BR flows gives the possibility to assess, from any intermediate point, both the status (available/unavailable) and the end-to-end performance of a VPC. As another example, monitoring non-intrusively the user generated cell flow (monitored cells) and the associated e-t-e_VP-FPM flow in conjunction with the seg_VP-FPM flow established for all network operators' domains can help to localize performance impairments in cases where those impairments are located within the customer network.

Non-intrusive monitoring of VP OAM flows consists of detecting and processing the content of VP OAM cells passing at an intermediate point without modifying the characteristics (e.g. cell content, cell sequence) of the aggregated (OAM & monitored cells) flow observed.

9.2.2 OAM functions for the VCC (F5 flow)

This subclause addresses VC-level fault management and performance management functions.

9.2.2.1 Virtual channel fault management functions

9.2.2.1.1 VC-AIS and VC-RDI defect indication

VC-AIS and VC-RDI defect indications shall be used for identifying and reporting VCC defects end-to-end.

seg_VC-AIS and seg_VC-RDI defect indications shall be used for identifying and reporting VCC defects at segment level.

9.2.2.1.1.1 VC-AIS

9.2.2.1.1.1.1 End-to-end VC-AIS

The ATM network element which detects a VCC defect shall generate and send (in the forward direction) e-t-e_VC-AIS cells on all affected active VCCs. e-t-e_VC-AIS will be sent upon:

- receiving e-t-e_VP-AIS defect indications from the VP level; or
- detecting LOC at the VC layer at segment sink endpoint (in the VCL_T function).

e-t-e_VP-AIS defect indications occur as a result of e-t-e_VP-AIS cells reception, VP LOC, or when receiving transmission path defect indications from the physical layer (see Note 1) or detecting LCD (see Note 2).

NOTE 1 – Defect indication conditions are defined in appropriate Recommendations for SDH-, PDH- and cell-based transmission systems (see 7.1).

NOTE 2 – LCD defect is defined in I.432.x-series Recommendations.

e-t-e_VC-AIS cell generation condition – The e-t-e_VC-AIS cells are generated and transmitted as soon as possible after observing a defect indication, and are transmitted periodically during the defect condition in order to indicate an interruption of the cell transfer capability at the VC level. The generation frequency of e-t-e_VC-AIS cells is nominally one cell per second and shall be the same for each affected VCC.

e-t-e_VC-AIS cell generation shall be stopped as soon as the defect indications (e.g. transmission path-AIS, VP-AIS and loss of VPC continuity) are removed.

e-t-e_VC-AIS cell detection – The e-t-e_VC-AIS cells are detected at the VCC sink-point. e-t-e_VC-AIS cells may be non-intrusively monitored at CPs along the VCC.

e-t-e_VC-AIS state declaration and release conditions (see Note 3) – The e-t-e_VC-AIS state is declared at the VCC endpoint or intermediate CPs along the VCC (if non-intrusive monitoring is activated) as soon as a e-t-e_VC-AIS cell is received, a transmission path-AIS defect, a VPC defect (e.g. VP-AIS, loss of VPC continuity) or a VCC defect (e.g. loss of VCC continuity) is detected. The e-t-e_VC-AIS state is released at the end-to-end level when a valid user cell (see Table 2) or a e-t-e_CC cell is received. If the VCC continuity check function is not activated the e-t-e_VC-AIS state is also released if e-t-e_VC-AIS cells are absent for nominally 2.5 seconds, with a margin of ± 0.5 seconds.

NOTE 3 – For accurate determination of availability, a problem has been identified when user cells are taken into account for the release condition of the e-t-e_VC-AIS state. A definition of this state that does not give consideration to the presence of user cells is for further study.

9.2.2 1.1.1.2 Segment VC-AIS

Segment VC-AIS is specified as stated below. The use of segment VC-AIS functionality within one network operator domain is a network operator option.

NOTE – The United Kingdom, Netherlands, United States of America and Italy interpret this as meaning that the support of segment VC-AIS functionality is a network operator option.

The ATM network element which detects a VCC defect within an OAM segment shall generate and send (in the forward direction) seg_VC-AIS cells in addition to e-t-e_VC-AIS cells on all affected active VCCs. Segment endpoints (source and sink) and CPs outside of an OAM segment should not generate seg_VC-AIS cells. With regard to generation of seg_VC-AIS cells, each CP can be configured by TMN as either being within a segment (seg_VC-AIS generation activated) or not within a segment (seg_VC-AIS generation deactivated). To assure consistent behaviour of different network elements during setting up of the connection, the default value for each connection point of the node is: seg_VC-AIS generation activated.

seg_VC-AIS will be sent when receiving transmission path-AIS defect indications from the physical layer or detecting LCD in the TP/VP_A function or receiving defect indications from the VP level (e.g. e-t-e_VP-AIS or loss of VPC continuity). Transmission path-AIS defect indications result from defects observed at the regenerator section, multiplex section or transmission path levels.

seg_VC-AIS cell generation condition – The seg_VC-AIS cells are generated and transmitted as soon as possible after observing a defect indication, and transmitted periodically during the defect condition in order to indicate an interruption of the cell transfer capability at the VCC segment level. The generation frequency of seg_VC-AIS cells is nominally one cell per second and shall be the same for each affected VCC.

seg_VC-AIS cell generation shall be stopped as soon as the defect indications (e.g. transmission path-AIS defect, VP-AIS and loss of VPC continuity) are removed.

seg_VC-AIS cell detection – The seg_VC-AIS cells are detected and terminated at the VCC segment sink point. seg_VC-AIS cells may be non-intrusively monitored at CPs along the VCC segment.

9.2.2.1.1.1.3 Segment sink VP-AIS state

seg_VC-AIS state declaration and release conditions (see Note) – The seg_VC-AIS state is declared at the VCC segment sink point or intermediate CPs along the VCC segment (if non-intrusive monitoring is activated) as soon as a seg_VC-AIS cell is received, a transmission path-AIS defect, a VPC defect, or a VCC segment defect (e.g. loss of VCC segment continuity) is detected. The seg_VC-AIS state is released at the segment level when a user cell (see Table 2) or seg_CC cell is received. If VCC segment continuity check function is not activated, the seg_VC-AIS state is also released if seg_VC-AIS cells are absent for nominally 2.5 seconds, with a margin of ± 0.5 seconds.

NOTE – For accurate determination of availability, a problem has been identified when user cells are taken into account for the release condition of the seg_VC-AIS state. A definition of this state that does not give consideration to the presence of user cells is for further study.

9.2.2.1.1.2 VC-RDI

9.2.2.1.1.2.1 End-to-end VC-RDI

e-t-e_VC-RDI is sent to the far-end from a VCC endpoint as soon as it has declared a e-t-e_VC-AIS state.

e-t-e_VC-RDI cell generation condition – The e-t-e_VC-RDI cells are generated and transmitted periodically while the e-t-e_VC-AIS state persists in order to indicate in the backward direction an interruption of the cell transfer capability at the VC level in the forward direction. Generation

frequency of e-t-e_VC-RDI cells is nominally one cell per second and shall be the same for all affected VCCs.

e-t-e_VC-RDI cell generation shall be stopped as soon as the e-t-e_VC-AIS state is released.

e-t-e_VC-RDI cell detection – The e-t-e_VC-RDI cells are detected at the VCC endpoint and e-t-e_VC-RDI state is declared after the reception of one e-t-e_VC-RDI cell. E-t-e_VC-RDI cells may be non-intrusively monitored at CPs along the VCC.

e-t-e_VC-RDI state declaration and release condition – The e-t-e_VC-RDI state is declared at the VCC endpoint as soon as a e-t-e_VC-RDI cell is received at this endpoint. The e-t-e_VC-RDI state is released at the VCC endpoint when no e-t-e_VC-RDI cell is received during a nominally 2.5 seconds period, with a margin of ± 0.5 seconds.

9.2.2.1.1.2.2 Segment VC-RDI

seg_VC-RDI cells are sent to the far-end of the segment from a VCC segment endpoint as soon as it has declared a seg_VC-AIS state.

seg_VC-RDI cell generation condition – The seg_VC-RDI cells are generated and transmitted periodically while the seg_VC-AIS state persists in order to indicate in the backward direction an interruption of the cell transfer capability at the VCC segment level in the forward direction. Generation frequency of seg_VC-RDI cells is nominally one cell per second and shall be the same for all affected VCCs.

seg_VC-RDI cell generation shall be stopped as soon as the seg_VC-AIS state is released.

seg_VC-RDI cell detection – The seg_VC-RDI cells are detected at the VCC segment endpoint and seg_VC-RDI state is declared after the reception of one seg_VC-RDI cell. seg_VC-RDI cells may be non-intrusively monitored at CPs along the VCC segment.

seg_VC-RDI state declaration and release conditions – The seg_VC-RDI state is declared at the VCC segment endpoint as soon as a seg_VC-RDI cell is received at this point. The seg_VC-RDI state is released at the VCC segment endpoint when no seg_VC-RDI cell is received during a nominally 2.5 seconds period, with a margin of ± 0.5 seconds.

9.2.2.1.2 VCC continuity check

CC can be simultaneously carried out end-to-end or at segment level on a certain number of selected active VCCs per interface (UNI, NNI) in each direction. The value of this number is outside the scope of this Recommendation.

CC can be activated either during connection establishment or at any time after the connection has been established.

Procedures for activation (and associated deactivation) are described in 9.2.3.

The possibility to activate CC on all active VCCs and VCC segments remains as an option.

NOTE 1 – Although use of CC is a network operator option, some Administrations considered the ability to activate CC on some or all of the VCCs or VCC segments to be important. This is due to the fact that CC is the only in-service mechanism able to continuously detect for ATM layer defects (as opposed to physical layer defects) in real time. Also activation of the CC mechanism together with the PM process allows the performance to be assessed only during the available time of the VCC/VCC segment according to Recommendation I.356.

Two alternative mechanisms exist for the insertion of VC-CC cells after the activation of the continuity check function:

– *Option 1*

VC-CC cells are sent in the forward direction by a VCC source point or a VCC segment source point when no user cells (see Table 2) have been sent for a period of nominally 1 second.

NOTE 2 – Option 1 of the CC cell may be used in order to detect LOC defects. However, this option should not be used to estimate availability.

– *Option 2*

VC-CC cells are sent repetitively with a periodicity of nominally 1 cell per second independent of the user cells flow.

When the VCC sink-point with CC activated does not receive any user cell or CC cell within a time interval of 3.5 seconds, with a margin of ± 0.5 seconds, it will declare the VC-AIS state due to an LOC defect.

When the VCC segment sink-point does not receive any user cell (see Table 2) or CC cell within a time interval of 3.5 seconds, with a margin of ± 0.5 seconds, it will declare an LOC defect and start transmitting e-t-e_VC-AIS cells in the forward direction. However, during an LOC defect, to avoid a duplication of e-t-e_VC-AIS cell flows this VCC segment sink-point shall not insert additional e-t-e_VC-AIS cells if it already is receiving and forwarding e-t-e_VC-AIS cells.

NOTE 3 – For accurate determination of availability, a problem has been identified when user cells are taken into account for the declaration of the LOC defect. A definition of this defect that does not give consideration to the presence of user cells is for further study.

9.2.2.1.3 VC loopback capability

9.2.2.1.3.1 General description

The ATM layer loopback capability allows for operations related information to be inserted at one location along a VCC and returned (or looped back) at a different location, without having to take the connection out-of-service. This capability is performed by inserting a LB cell at an accessible point along the VCC (i.e. at an endpoint or any CP) without disrupting the sequence of user cells while minimizing the user cells transfer delay. This cell is looped back at a downstream point according to the information contained in its information field.

9.2.2.1.3.2 Principles of operation

- 1) VC-LB cells can be inserted at CPs (including VCC segment endpoints) and VCC endpoints. The ATM network element that originated the looped cell may optionally remove it, after matching the correlation tag and the source identifier.
- 2) seg_VC-LB cells can be looped back at CPs (including VCC segment endpoints). The ATM network element that looped the seg_LB cell may optionally remove it, after the loop action¹. The use of the LLID is a network operator option for seg_VC-LB cells. The management of the LLID field is described in 10.2.3.
- 3) The waiting time between the transmission of successive LB cells on a connection shall be 5 seconds. The loopback shall be considered unsuccessful if the LB cell is not returned to the originating point within 5 seconds.
- 4) It shall be possible to initiate a loopback without a command from the TMN, e.g. a customer may initiate an end-to-end loopback. This does not preclude the reporting of loopback results to the TMN.

- 5) A means to confirm that loopback is performed at the ATM layer, rather than at the physical layer, is provided by requiring the loopback point to change a field (the loopback indication field – described later) within the LB cell payload. This principle is illustrated in Figure 8. As discussed in 10.2.3, the requirement for the loopback point to change the loopback indication also overcomes the problem of infinite loopback that would otherwise occur with the use of the default (all 1s) LLID.
- 6) E-t-e_LB cells shall not be looped back at CPs.
- 7) Annex C shows the detailed procedures which should be performed when a LB cell is received by a network element.

9.2.2.1.3.3 Loopback applications

The loopback capability supports the applications shown in Figure 9. The applications are:

- a) *End-to-end loopback* – A e-t-e_VC-LB cell is inserted by a VCC endpoint, and looped back by the corresponding far-end VCC endpoint.
- b) *Access line loopback* – A seg_VC-LB cell is inserted by the customer or the network, and looped back by the first ATM node (operating at the VC level) in the network or customer equipment respectively. For this application, the VCC segment is defined by mutual agreement.
- c) *Inter-domain loopback* – A seg_VC-LB cell is inserted by one network operator, and looped back by the first ATM node (operating at the VC level) in an adjacent network operator domain. For this application, the VCC segment is defined by mutual agreement.
- d) *Network-to-endpoint loopback* – A e-t-e_VC-LB cell is inserted by one network operator, and looped back by the VCC endpoint in another domain.
- e) *Intra-domain loopback* – A seg_VC-LB cell is inserted at a VCC segment endpoint or a CP within the VCC segment, and looped back at a VCC segment endpoint or a CP within the VCC segment. For this application, the use of the LLID is a network operator option.

NOTE – A VCC segment may span several network domains, pending on a mutual agreement of all involved Administrations. In this case the resulting monitored portion will be considered as a single domain, and loopback applications e1) and e2) may apply assuming that the seg_VC-LB cell processing options specified in 9.2.2.1.3.2 are compatible in this domain.

9.2.2.2 VC performance management functions

Performance monitoring of a VCC or VCC segment is performed by inserting monitoring cells at the ends of the VCC or VCC segment, respectively. In the procedure supporting this function, forward error detection information (e.g. the error detection code) is communicated by the endpoints using the forward (outgoing) F5 flow based on the FPM cells defined in 10.3. The PM results, on the other hand, are received on the reverse (incoming) F5 flow based on the BR cells defined in 10.3. Note that when monitoring VCCs that are entirely within one span of control or when monitoring VCC segments, the monitoring result may be reported using the reverse F5 flow or via some other means (e.g. TMN).

PM shall be done by monitoring blocks of user cells. Table 2 gives the list of cell types which should be considered as "user cell" for VC performance monitoring (i.e. cells which should form part of the monitored cell block at the VC level).

Whenever PM is performed at the end-to-end or segment level, it is advisable to insure that the corresponding CC mechanism (end-to-end or segment CC, respectively) is activated during the overall performance assessment period. This allows a continuous monitoring of the availability of

the VCC or connection portion during that measurement period. CC may be activated either before or when starting the PM process.

A VC-FPM cell insertion request is initiated after every N user cells. The VC-FPM cell is inserted at the first available cell location after the request.

The block size N may have the values 128, 256, 512, 1024, 2048, 4096, 8192, 16 384 and 32 768 (see Table 7). These are nominal block size values, and the actual size of the monitored cell block may vary. The cell block size may vary up to a maximum margin of 50% of the value of N for end-to-end PM. However, for end-to-end PM, the monitoring cell must be inserted into the user cells stream no more than N/2 user cells after an insertion request has been initiated. The actual monitoring block size averages out to approximately N cells.

NOTE 1 – Recommendation I.356 shows how to choose the block size N.

To eliminate forced insertions of VC-FPM cells when monitoring VCC segment performance, the actual monitoring block size may be extended until a cell location is available after the insertion request. However, in this case, the actual monitoring block size may not average out to N cells. Forced insertion at the segment level remains as an option.

When forward performance monitoring and backward reporting functions are both activated for a given connection, OAM information related to a given cell block – which is transmitted in the forward direction – has to be carried in both directions by corresponding VC-FPM and VC-BR cells referred to as "paired" OAM cells, i.e. for each correctly received VC-FPM cell a corresponding VC-BR cell shall be issued (see Note 2).

NOTE 2 – A VC-FPM cell is considered to be correctly received if its EDC field (CRC-10) does not detect errors in the payload content.

A VC-BR cell insertion request is initiated after the "paired" VC-FPM cell is correctly received and its content processed. The VC-BR cell shall then be forwarded in the opposite direction, in the first available cell location after the request. The insertion of a VC-BR cell will be forced in case no spare cell location is available before the next VC-FPM cell is received.

The monitoring cell will detect:

- errored blocks;
- loss/mis-insertion of cells within a monitored block of cells.

Other functions (e.g. cell transfer delay) are for further study.

Appendix II provides informative material related to the insertion process applicable to end-to-end or segment performance management cells.

PM can be simultaneously carried out on a certain number of selected VCCs per interface. The specification of this number is beyond the scope of this Recommendation.

PM can be activated either during connection establishment or at any time after the connection has been established. Degradation of quality of service experienced by the user due to activation and deactivation should be negligible if resources are properly allocated.

Procedures for activation (and associated deactivation) are described in 9.2.3. Following PM activation, the first VC-FPM or VC-BR cell received is used for initialization only and is not used to update performance parameters.

There may be potential interference between PM and UPC/NPC actions. This is of particular concern in the case that the performance of an inter-operator domain is to be monitored. According to Recommendation I.356, for an International Inter-operator Portion (IIP) cells discarded in the NPC are not considered as performance degradation occurring in this portion. This is more generally true

for any connection portion that is delimited by a Measurement Point (MP), adjacent to the UPC/NPC, but upstream this UPC/NPC function. In order to avoid this interference, availability and cell transfer impairments occurring in the UPC/NPC function, if inside an OAM segment, would need to be excluded from the PM results both for the forward and for the backward directions of this PM flow. Solutions to this problem are for further study.

9.2.2.3 VC system management

The VC system management cell type is defined for use by systems to control and maintain various functions at the VC layer. VC system management cells are of the end-to-end type. These OAM cells are inserted/extracted and processed only within the end-user equipment (i.e. within the customer premises) which terminate at both ends the corresponding VCC; they are transparently conveyed on the VCC.

VC system management cells are not defined either between network nodes or between an end-user equipment and a network node.

No segment flow for this function is defined, so that VCC segment OAM cells with this cell type may be used by network element equipment for internal functions (i.e. this cell shall not cross any external interface). Thus no VCC segment for the system management cell type shall be defined in the future.

End-user equipment implementation of the system management cell is optional and is not recommended except for specific applications which are not satisfied by other mechanisms.

9.2.2.4 VC ATM protection switching

The VC-APS cell type is defined for providing ATM protection switching. Further information may be found in Recommendation I.630.

9.2.2.5 Non-intrusive monitoring of VC OAM flows

Non-intrusive monitoring of any type of end-to-end or segment fault and performance management VC OAM flows may be performed at any intermediate point along a VCC. This includes intermediate points within a VCC segment as well as the VCC segment endpoints (see Note).

NOTE – The purpose of the non-intrusive monitoring function is to provide to network providers additional OAM information which cannot be derived from the content of segment OAM flows. As an example, monitoring both the VC-RDI and the corresponding VC-BR flows gives the possibility to assess, from any intermediate point, both the status (available/unavailable) and the end-to-end performance of a VCC. As another example, monitoring non-intrusively the user generated cell flow (monitored cells) and the associated e-t_e_VC-FPM flow in conjunction with the seg_VC-FPM flow established for all network operators' domains can help to localize performance impairments in cases where those impairments are located within the customer network.

Non-intrusive monitoring of VC OAM flows consists of detecting and processing the content of VC OAM cells passing at an intermediate point without modifying the characteristics (e.g. cell content, cell sequence) of the aggregated (OAM & monitored cells) flow observed.

9.2.3 Activation/deactivation procedures

The following procedures are identical at both the VP and VC level.

PM and CC can be activated either during connection/segment establishment or at any time after the connection/segment has been established. Such activation (and associated deactivation) is initiated either by the TMN or the end-user. After the TMN or the end-user has requested activation/deactivation of PM or CC, an initialization procedure is needed between the two endpoints of the connection (or connection segment) to properly initialize the OAM process. Specifically, this initialization procedure serves the following purposes:

- To coordinate the beginning or end of the transmission and downstream reception of OAM cells used to monitor performance or check continuity.
- To establish agreement on the type of monitoring to be performed (i.e. FPM only or both FPM and the associated BR) and to specify the block size (as recommended in Recommendation I.356) and the direction of transmission for PM activation requests.

The initialization procedure is performed by either:

- a) using activation/deactivation OAM cells as illustrated in Figures 10 and 11 for activation and deactivation, respectively; or
- b) entirely via TMN as described below.

The detailed specification of the activation/deactivation OAM procedure a) is given in Annex B.

For the case where PM or CC is to be established on a connection or connection segment with endpoints contained in a single administrative domain, the OAM function activation and deactivation may be also entirely carried out by the TMN. In this case, the following information is necessary from the TMN:

- 1) Identification of the specific connection or connection segment on which PM or CC activation/deactivation is desired.
- 2) The direction of action.
- 3) The type of monitoring process to be activated (i.e. FPM only or both FPM and the associated BR) at a given segment or connection sink endpoint (i.e. at the receiving side).
- 4) For PM activation requests, one (and only one) block size must be specified for the forward direction. No block size is reported for the backward direction.

For the case where the connection or connection segment crosses an administrative boundary, PM or CC activation and deactivation may in special cases be also entirely carried out by the TMN. This, however, requires mutual agreement and TMN coordination among network providers and end-users as applicable.

In both cases above, the TMN is responsible for coordinating the connection or connection segment endpoints' activities. Therefore, it is necessary that actions be completed one direction at a time.

As an example of this procedure, activation of a bidirectional PM on connection A-B may be carried out by the following four steps:

In the A to B direction:

- Endpoint B is commanded to activate the sink-process of the PM function.
- Endpoint A is commanded to activate the source-process of the PM function.

In the B to A direction:

- Endpoint A is commanded to activate the sink-process of the PM function.
- Endpoint B is commanded to activate the source-process of the PM function.

Deactivation of the PM function for connection A-B would follow these steps in reverse order.

As another example of this procedure, activation of a bidirectional CC on connection A-B may be carried out by the following four steps:

In the A to B direction:

- Endpoint A is commanded to activate the source-process of the CC function.
- Endpoint B is commanded to activate the sink-process of the CC function.

In the B to A direction:

- Endpoint B is commanded to activate the source-process of the CC function.
- Endpoint A is commanded to activate the sink-process of the CC function.

Deactivation of the CC function for connection A-B would follow these steps in reverse order.

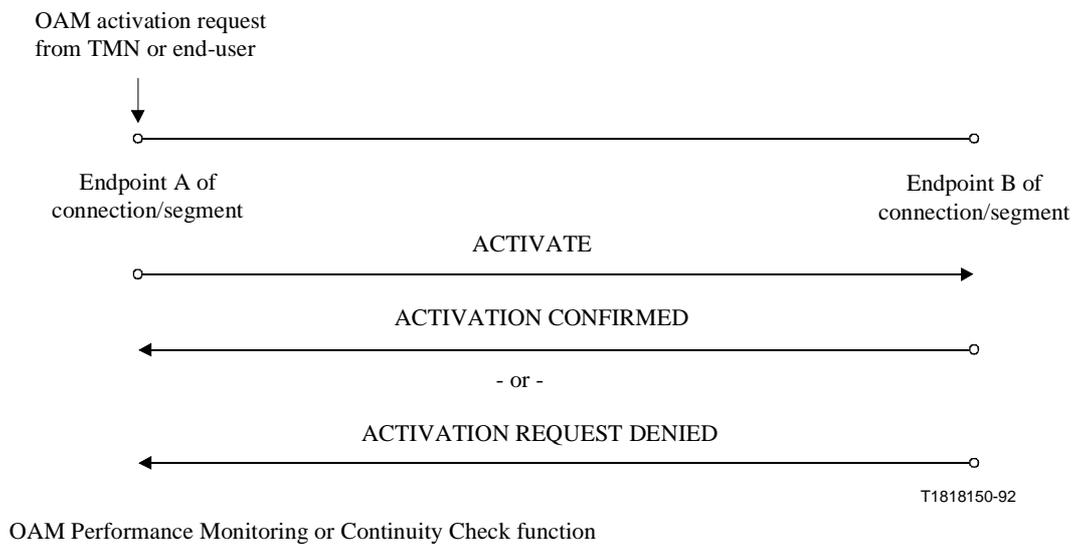


Figure 10/I.610 – Initialization procedure for PM or CC activation via activation OAM cells

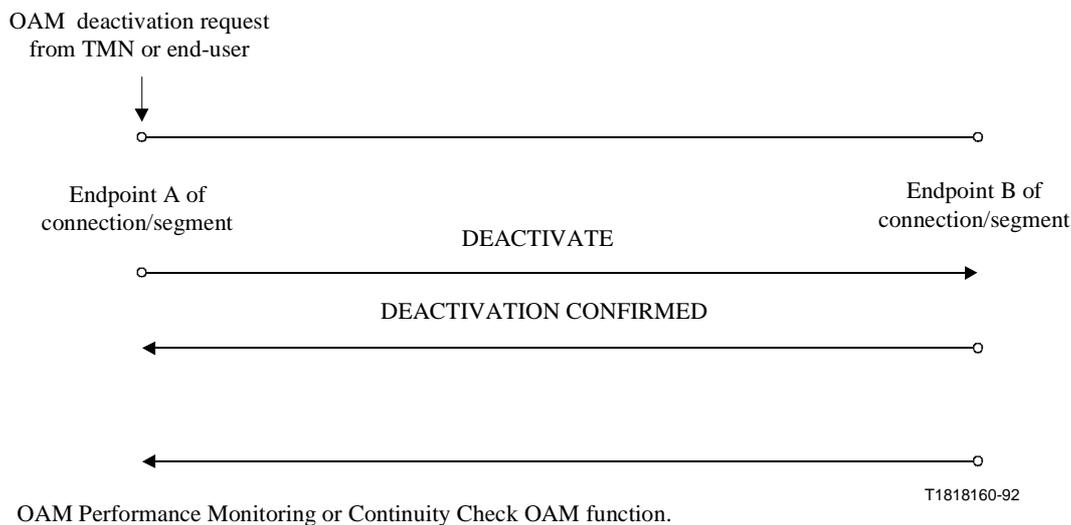


Figure 11/I.610 – Initialization procedure for PM or CC deactivation via deactivation OAM cells

10 ATM layer OAM cell format

The ATM layer OAM cells contain fields common to all types of OAM cells (see Table 4) as well as specific fields for each type of OAM cell. The coding principles for currently unused common and specific fields are (except when stated otherwise):

- Currently unused OAM cell information field octets are coded 0110 1010 ('6A'H).
- Currently unused OAM cell information field bits (incomplete octets) are coded all zero.

The currently unused octets and bits are not to be checked by the receiver for conformance to this coding rule. A CP (which is not also a segment endpoint) shall transparently transfer all OAM cells regardless of the encoding within a given field (except possibly for the case of LB cells, see 9.2.1.1.3.2 and 9.2.2.1.3.2).

Further enhancements to this Recommendation should ensure that equipment supporting lower versions has no compatibility problems related to the content of OAM cells. That is, functions and encodings of defined fields shall not be redefined in the future.

However, currently unused fields and code points may be defined in future releases of this Recommendation and are therefore reserved.

For the purpose of this Recommendation, the leftmost bit is the most significant bit and transmitted first.

Table 4/I.610 – OAM Type and function type identifiers

OAM type	Coding	Function type	Coding
Fault management	0001	AIS	0000
	0001	RDI	0001
	0001	CC	0100
	0001	LB	1000
Performance management	0010	FPM	0000
	0010	Backward reporting	0001
APS Coordination protocol	0101	Group protection	0000
		Individual protection	0001
Activation/deactivation	1000	FPM and associated BR	0000
	1000	CC	0001
	1000	FPM	0010
System management	1111	(Note)	(Note)
NOTE – Not to be standardized by this Recommendation.			

10.1 Common OAM cell fields

All ATM layer OAM cells will have the following common fields (see Figure 12):

- 1) *Header* – Details of this field are in Recommendation I.361. For F4 flow identification, two pre-assigned VCIs are used to distinguish OAM cells for VPCs and VPC segments. These two values are defined in Recommendation I.361. For F5 flow identification, two PTI values are used to distinguish OAM cells for VCCs and VCC segments. These two values are defined in Recommendation I.361.
- 2) *OAM cell type (4 bits)* – This field indicates the type of management function performed by this cell, e.g. fault management, performance management, and activation/deactivation.
- 3) *OAM function type (4 bits)* – This field indicates the actual function performed by this cell within the management type indicated by the OAM cell type field.
- 4) *Reserved field for future use (6 bits)* – One possible use of these bits is an OAM protocol version indication. As long as the coding scheme of this field is not defined, it shall be encoded as all "0"s.
- 5) *Error detection code (10 bits)* – This field carries a CRC-10 error detection code computed over the OAM cell information field excluding the EDC field. It shall be the remainder of the division (modulo 2) by the generator polynomial of the product of x^{10} and the content of the OAM cell information field (namely OAM type, function type, function specific field, reserved field, excluding the EDC field) (374 bits). Each bit of the concatenated field mentioned above is considered as a coefficient (modulo 2) of a polynomial of degree 373 using the first bit as coefficient of the highest order term. The CRC-10 generating polynomial is:

$$G(x) = 1 + x + x^4 + x^5 + x^9 + x^{10}$$

The result of the CRC calculation is placed with the least significant bit right justified in the CRC field. See Appendix I for examples of CRC-10 values.

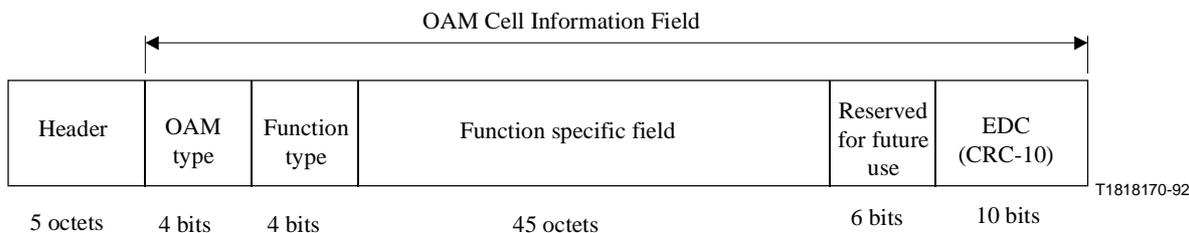


Figure 12/I.610 – Common OAM Cell Format

VP OAM cells are detected through the following procedure (no specific ordering is implied):

- Check of the VCI value to determine if it is a segment OAM cell (VCI = 3) or an end-to-end OAM cell (VCI = 4).
- Check of the OAM type and function type value according to Table 4 to determine the type of OAM cell received.
- Check of the error detection code field value according to 10.1, [item 5], to determine if the received OAM cell is valid. Any invalid OAM cell should not be further processed.

VC OAM cells are detected through the following procedure (no specific ordering is implied):

- Check of the PTI value to determine if it is a segment OAM cell (PTI = 4) or an end-to-end OAM cell (PTI = 5).
- Check of the OAM type and function type value according to Table 4 to determine the type of OAM cell received.
- Check of the error detection code field value according to 10.1, [item 5], to determine if the received OAM cell is valid. Any invalid OAM cell should not be further processed.

Some OAM cells contain specific fields to carry location IDentifiers (ID) information. Different address (location) formats can be used, they are identified by the first octet at the start of the location ID field. Table 5 provides the coding structure according to the location identifier type.

Table 5/I.610 – Coding structures of location identifiers

Location identifier type (octet #1 of the location ID field)	Coding structure (octet #2 to 16 of the location ID field – see Note)
0000 0000	No specific coding structure defined, the remaining octets are coded all zeros
0000 0001	Country code + network ID + operator specific information i) octets #2 to #5 are used to carry the country code + network ID information These 4 octets should be BCD coded. The country code should be set up according to Recommendation E.164 ii) octets #6 to 16 are used to carry operator specific information These 11 octets should be binary coded
0000 0010	Country code + network ID i) octets #2 to #5 are used to carry the country code + network ID information These 4 octets should be BCD coded. The country code should be set up according to Recommendation E.164 ii) octets #6 to 16 are coded as '6A'H
0000 0011	Partial NSAP based coding structure (description of the coding structure is for further study)
1111 1111	No specific coding structure defined, the remaining octets are coded all ones
'6A'H	No specific coding structure defined, the remaining octets are coded all '6A'H
Other code points	Reserved for future use
NOTE – To assure interoperability between different equipment, every octet of this location field needs to be coded so as to avoid the use of "padding octets" which could be different from one equipment to another.	

10.2 Specific fields for fault management cell

The function type field for fault management applications will be used to identify the following possible functions: AIS, RDI, CC, and LB. Further specifications of cells carrying these functions are provided in the subclauses that follow.

10.2.1 AIS/RDI fault management cell

The function specific fields for AIS/RDI fault management cells are illustrated in Figure 13. They are defined as follows:

- 1) *Defect Type (8 bits)* – As an option, this field may be used to indicate the nature of the reported defect.

Examples for these defect types are:

- defect not specified;
- defect in the VP/VC layer in which the OAM flow is transmitted;
- defect in the layer which supports the layer in which the OAM flow is transmitted (lower layer defect).

An additional distinction can be made to indicate whether the defect occurs in-service or out-of-service. Additional detailed defect information and the coding of the defect type field is for further study.

As long as the coding scheme of this field is not defined, it shall be encoded '6A'H.

- 2) *Defect Location (16 octets)* – As an option, this field may be used to carry information about the defect location. For an AIS cell this field indicates the location which generates the AIS cell. For an RDI cell this field contains the same location identifier as which was received in the corresponding AIS cell.

As long as the coding scheme of this field is not defined, it shall be encoded '6A'H.

Defect type (Optional)	Defect location (Optional)	Reserved for future use ('6A'H)
1 octet	16 octets	28 octets

Figure 13/I.610 – Specific fields for AIS/RDI fault management cell

10.2.2 Continuity check fault management cell

There are currently no fields that are specific to the continuity check function, and hence the function specific field is encoded '6A'H. However, Appendix V gives informative material on a possible future use of the first 25 octets.

10.2.3 Loopback cell

The function specific fields for LB cells are illustrated in Figure 14. They are defined as follows:

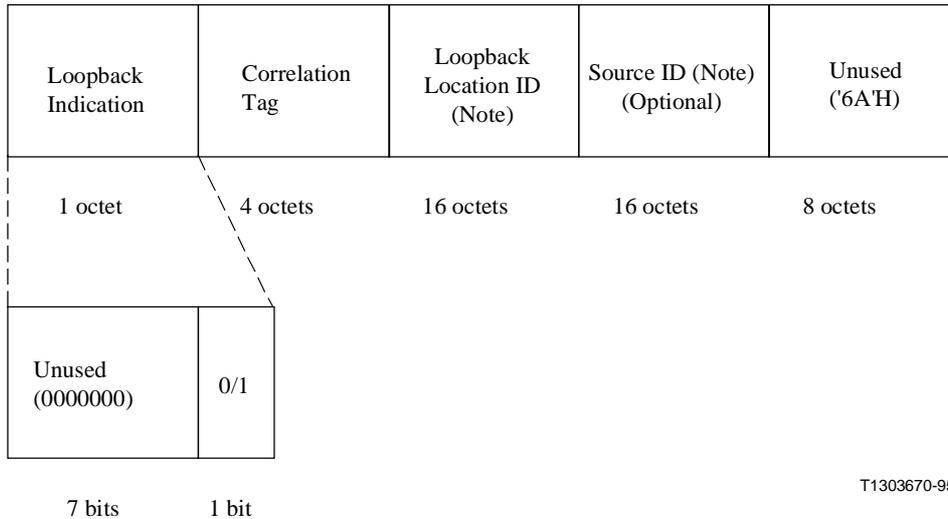
- *Loopback indication field (1 octet)*: The least significant bit of this field provides a boolean indication as to whether or not the cell has already been looped back. The field confirms that the loopback has occurred at the ATM layer and avoids the problem of infinite loopback that would otherwise occur when the default (all 1s) loopback location ID field is used. The source point encodes this field as 00000001. The loopback point changes the encoding to 00000000.
- *Correlation tag field (4 octets)*: A correlation tag is generated for each loopback process so nodes can correlate loopback commands with loopback responses. That is, the correlation tag in a response must match the correlation tag in the associated command. Consecutively generated correlation tags should be different, in order to correctly correlate commands with responses.
- *LLID field (16 octets)*: For the incoming LB cell (LI = 1), the content of this field identifies the CP along the virtual connection or connection segment where the loopback is to occur. Table 5 provides the coding structure for this field.
 - *All 1s* – Represents the endpoint. This is the segment endpoint for segment loopback and the connection endpoint for end-to-end loopback.
 - *All 0s* – Represents all CPs for which the LLID option is enabled. This includes the segment endpoint. It is only applicable to seg_LB cells.
 - *'6A'H* – Does not represent any specific CP and thus no loopback shall be performed.
 - *All other values* – Indicates the specific CP where the loopback is to occur.

For backwards compatibility with the '95 version of Recommendation I.610, all octets of the LLID shall be set to the same value as in the address type field when using the all 1s, all 0s, or '6A'H value.

For the "returned" LB cell (LI = 0), this field is filled with the identifier of the particular CP where the loopback occurred.

- *Source ID field (16 octets)*: The use of this field is optional and identifies the source originating the LB cell. Table 5 provides the coding structure for this field.

Annex C shows the detailed procedures which should be performed when a LB cell is received by a network element.



NOTE – Values (except for default all 1s) are not subject to standardization and encoding of non-default values is optional.

Figure 14/I.610 – Specific fields for loopback cell

10.3 Specific fields for performance management cell

The function type field for performance management applications will be used to identify the following possible functions: forward monitoring and backward reporting. When forward monitoring and backward reporting functions are both activated, for a given connection FPM and BR cells are referred to as "paired" OAM cells.

10.3.1 Forward performance monitoring cell

The function specific fields for FPM cells are illustrated in Figure 15. They are defined as follows:

- 1) *Monitoring Cell Sequence Number (MCSN/FPM) (8 bits)* – This sequence number field indicates the current value of a running counter modulo 256 of the FPM cell sequence. Independent counters are used at both ends of the connection/segment for the paired FPM and BR cells.
- 2) *Total User Cell number related to the CLP₋₀₊₁ user cells flow (TUC₋₀₊₁) (16 bits)* – This field indicates the current value of a running counter related to the total number (modulo 65 536) of transmitted user cells (i.e. CLP = 0 + 1), when the FPM cell is inserted.

NOTE 1 – At the transmitting side (where OAM cells are inserted), the difference between two consecutive TUC values represents then the number of user cells included between two FPM cells sent consecutively. This corresponds to the size of the block of user cells on which performance is estimated.

- 3) *Total User Cell number related to the CLP₋₀ user cells flow (TUC₋₀) (16 bits)* – The use of this field is similar to the use of the TUC₋₀₊₁ field. It is related to the transmitted user cells with a CLP value equal to "0".

- 4) *Block Error Detection Code related to the CLP₋₀₊₁ user cells flow (BEDC₋₀₊₁) (16 bits)* – This field carries the even parity BIP-16 (see Note 2) error detection code computed over the information fields of the block of user cells (i.e. CLP = 0 + 1) after the transmission of the last FPM cell.

NOTE 2 – Bit interleaved parity-X (BIP-X) code is defined as a method of error monitoring. With even parity, an X-bit code is generated by the transmitting equipment over a specific portion of the signal in such a manner that the first bit of the code provides even parity over the first bit of all X-bit sequences in the covered portion of the signal, the second bit provides even parity over the second bit of all X-bit sequences within the specific portion, etc. Even parity is generated by setting the BIP-X bits so that there is an even number of 1s in each of all monitored partitions of the signal including the BIP-X (a monitor partition of the signal is built by all bits which are in the same bit position within the X-bit sequences in the covered portion of the signal).

- 5) *Time STamp (TSTP) (32 bits)* – As an option this field may be used to represent the time at which the FPM cell was inserted. The coding of this field requires further study. As long as the coding scheme of this field is not defined, it shall be encoded all 1s since '6A'H might be a valid time stamp value.

MCSN /FPM	TUC ₋₀₊₁	BEDC ₋₀₊₁	TUC ₋₀	TSTP (Optional)	Reserved for future use ('6A'H)
8 bits	16 bits	16 bits	16 bits	32 bits	34 octets

Figure 15/I.610 – Specific fields for the FPM cell

10.3.2 Backward reporting cell

The function specific fields for BR cells are illustrated in Figure 16. They are defined as follows:

- 1) *Monitoring Cell Sequence Number (MCSN/BR) (8 bits)* – This sequence number field indicates the current value of a running counter, modulo 256, of the BR cell sequence. Independent counters are used at both ends of the connection/segment for the paired FPM and BR cells.
- 2) *Total User Cell number related to the CLP₋₀₊₁ user cells flow (TUC₋₀₊₁) (16 bits)* – This field contains the TUC₋₀₊₁ value copied from the paired FPM cell.
NOTE 1 – At the transmitting side, the difference between two consecutively transmitted TUC values represents then the number of user cells included between two consecutively received FPM cells. This set of cells corresponds to one block of user cells if FPM cells are received in sequence (MCSN values are consecutive) or to several blocks in case of lost FPM cells.
- 3) *Total User Cell number related to the CLP₋₀ user cells flow (TUC₋₀) (16 bits)* – This field contains the TUC₋₀ value copied from the paired FPM cell.
- 4) *Time STamp (TSTP) (32 bits)* – As an option this field may be used to represent the time at which the BR cell was inserted. The coding of this field requires further study. As long as the coding scheme of this field is not defined, it shall be encoded all 1s since '6A'H might be a valid time stamp value.
- 5) *Reported Monitoring Cell Sequence Number (RMCSN) (8 bits)* – This field contains the MCSN/FPM value copied from the paired FPM cell.
- 6) *Severely Errored Cell Block Count (SECBC) (8 bits)* – This field indicates the current value of a running counter, modulo 256, of the number of SECB experienced by the connection on the opposite direction. This value is obtained by processing of the paired FPM cell.

- 7) *Total Received Cell Count related to the CLP₀ user cells flow (TRCC₀) (16 bits)* – This field carries the current value of a running counter related to the total number (modulo 65 536) of received user cells (CLP = 0), read when a FPM cell is received.

NOTE 2 – If CLP = 0 cells are "tagged" (i.e. changed to CLP = 1, see Recommendation I.371) the computed number for CLP = 0 lost/mis-inserted cells may be misleading.

- 8) *Block Error Result (BLER₀₊₁) (8 bits)* – This field carries the number of errored parity bits detected by the BIP-16 code of the paired FPM cell. This number is only inserted in the corresponding BR cell if the following two conditions are met:

- The number of user data cells (i.e. CLP = 0 + 1) between the last two FPM cells equals the difference between the TUC of the last two FPM cells.
- The MCSN of the last two FPM cells are sequential.

Otherwise the field shall be encoded as all 1s.

- 9) *Total Received Cell Count related to the CLP₀₊₁ user cells flow (TRCC₀₊₁) (16 bits)* – The use of this field is similar to the use of the TRCC₀ field.

NOTE 3 – At the transmitting point (where BR cells are inserted), the difference between two consecutively transmitted TRCC₀₊₁ values represents then the number of user cells received between the two last received FPM cells. At the receiving side where BR cells are evaluated, the following calculations can be performed on two consecutively received BR cells:

- a) Calculate the difference (modulo 65 536) between two consecutively received TRCC₀₊₁ fields;
- b) Calculate the difference (modulo 65 536) between two consecutively received TUC₀₊₁ fields.

The difference [b) – a)] estimates the number of lost cells (positive result), or the number of mis-inserted cells (negative result); a zero result is interpreted as no lost/mis-inserted cells.

MCSN /BR	TUC ₀₊₁	Reserved for future use ('6A'H)	TUC ₀	TSTP (Optional)	Reserved for future use ('6A'H)	RMCSN	SECBC	TRCC ₀	BLER ₀₊₁	TRCC ₀₊₁
8 bits	16 bits	16 bits	16 bits	32 bits	27 octets	8 bits	8 bits	16 bits	8 bits	16 bits

Figure 16/I.610 – Specific fields for the BR cell

10.4 Specific fields for activation/deactivation cell

The function type field for activation/deactivation applications will be used to identify the following possible function:

- PM activation/deactivation; and
- CC activation/deactivation.

The function specific fields for activation/deactivation cells are illustrated in Figure 17. They are defined as follows:

Message ID	Directions of action	Correlation tag	PM block size A-B	PM block size B-A	Reserved for future use ('6A'H)
6 bits	2 bits	8 bits	4 bits	4 bits	336 bits

Figure 17/I.610 – Specific fields for activation/deactivation cell

- 1) *Message ID (6 bits)* – This field indicates the message ID for activating or deactivating specific VPC/VCC OAM functions. Code values for this field are shown in Table 6.
- 2) *Correlation Tag (8 bits)* – A correlation tag is generated for each message so nodes can correlate commands with responses. That is, the correlation tag in a response must match the correlation tag in the associated command. Consecutively generated correlation tags should be different, in order to correctly correlate commands with responses.
- 3) *Direction(s) of Action (2 bits)* – This field identifies the direction(s) of transmission to activate/deactivate OAM function. The A-B and B-A notation is used to differentiate between the direction of transmission away or towards the activator/deactivator, respectively. This field value is used as a parameter for the ACTIVATE and DEACTIVATE messages. This field shall be encoded as 01 for B-A, 10 for A-B, 11 for two-way action, and 00 (default value) when not applicable.
- 4) *PM Block Size A-B (4 bits)* – This field specifies the A-B block size for forward performance monitoring required by the activator for the performance monitoring function. Currently defined code values for this field are shown in Table 7. This field value is used as a parameter for the ACTIVATE and ACTIVATION CONFIRMED messages. The default value for this field shall be 0000 for all other messages and when activating/deactivating CC.
- 5) *PM Block Size B-A (4 bits)* – This field specifies the B-A block size required by the activator of the forward performance monitoring function. It is encoded and used in the same manner as the block size A-B field.

Table 6/I.610 – Message ID values

Message	Command/response	Coding
ACTIVATE	Command	000001
ACTIVATION CONFIRMED	Response	000010
ACTIVATION REQUEST DENIED	Response	000011
DEACTIVATE	Command	000101
DEACTIVATION CONFIRMED	Response	000110

Table 7/I.610 – PM block size encoding

Message type	PM block Size	Coding
Other	Unused (Note)	0000
ACTIVATE and ACTIVATE CONFIRMED for PM	32 768	0111
	16 384	1011
	8 192	0011
	4 096	0101
	2 048	1001
	1 024	0001
	512	0010
	256	0100
	128	1000
NOTE – The 65 536 PM block size is not currently defined since using such a value would require to adapt the algorithm defined in Figure C.4/I.356, which is designed to handle the case of a single FPM lost cell.		

10.5 Specific fields for system management cell

The use of the function specific fields is out of the scope of this Recommendation.

10.6 Specific fields for APS cell

The function specific field for APS is defined in Recommendation I.630.

ANNEX A

Guidance on estimating VPC/VCC outages

This material may be developed further in Recommendation I.357 in the future.

Recommendation I.357 defines the availability criteria for ATM connections based on the SES_{ATM} event. The means by which this event is estimated in-service depends on which OAM flows are activated on the connection. That is:

- 1) FPM and CC flows.
- 2) FPM flow only (see Note).
- 3) CC flow only.
- 4) No CC or FPM flows.

NOTE – A FPM flow without an associated CC flow is not recommended for availability estimation.

Note that only option 2 of the CC cell (i.e. a CC cell is sent with a periodicity of nominally 1 cell per second independently of user cells) is used for in-service estimation of availability.

Each case has an associated level of accuracy in the estimation of the SES_{ATM} event. It should be noted that out-of-service measurement provides the greatest accuracy, but this is not considered here.

Table A.1 provides guidance on how to estimate near-end SES_{ATM} whilst the connection is in-service. In the case of segment-level availability estimation, references to FPM, CC and AIS cells in the table should be interpreted as segment OAM cells. Similarly, for end-to-end availability estimation, the same references should be interpreted as end-to-end OAM cells.

Table A.1/I.610 – Near-end SES_{ATM} estimation rules for various OAM-flow options

FPM	CC	Near-end SES _{ATM} if
Yes	Yes	CLR > 1/1024 (Note) <u>OR</u> SECBR > 1/32 (Note) <u>OR</u> No CC cell received <u>OR</u> ≥ 1 AIS cell
Yes	No	CLR > 1/1024 (Note) <u>OR</u> SECBR > 1/32 (Note) <u>OR</u> ≥ 1 AIS cell
No	Yes	No CC cell received <u>OR</u> ≥ 1 AIS cell
No	No	≥ 1 AIS cell
NOTE – CLR/SECBR estimation is obtained from the FPM cell.		

Recommendation I.357 states that a bidirectional connection or connection portion is unavailable if either direction is unavailable. This means that if a PM flow is enabled, processing of near-end I.356 parameters must be inhibited when either direction of the connection is unavailable. Therefore, there must also be a method of estimating far-end SES_{ATM} events in order to determine if the far-end direction is unavailable. The guidance on how to estimate far-end SES_{ATM} events is under study.

ANNEX B

SDLs for activation/deactivation using OAM cells

This annex provides a detailed specification for the activation/deactivation procedures of PM and CC functions using OAM cells. The following description is given for PM but is also applicable to the CC function.

B.1 Figure B.1 shows the state diagram for the activation/deactivation of PM. The states referenced in this Figure are:

B.1.1 Ready state

The PM process is not activated on an ATM connection.

B.1.2 Wait-activate-confirm state (abbreviated as WAIT_ACT_CON)

Activation of the PM process on an ATM connection has been requested by the local system management, an activate_PM message has been sent, and the corresponding response from the peer layer management entity has not arrived yet. This state only exists in systems that originate the activation of the PM process (i.e. the activator). During this state, in case where PM was activated from B towards A (node A being the activator, see 10.4), the local system (at node A) shall be prepared to process entering FPM cells coming from the peer layer management entity (at node B). In this case, if necessary, the local system (at node A) shall also be able to generate BR cells.

NOTE – For the specific case where CC was activated from A towards B (node A being the activator, see 10.4), the local system (at node A) shall start to generate CC cells according to the rules indicated in 9.2.1.1.2 and 9.2.2.1.2.

B.1.3 Wait-activate-response state (abbreviated as WAIT_ACT_RES STATE)

An activate_PM message from a peer layer management entity has been received, the request to activate the PM process on an ATM connection has been indicated to the local system management, and the corresponding response from the system management has not been received yet. This state only exists in systems that receive requests from peer layer management entity to activate the PM process.

B.1.4 Active state

The PM process is activated on an ATM connection.

B.1.5 Wait-deactivate-confirm state (abbreviated as WAIT_DEACT_CON)

Deactivation of the PM process on an ATM connection has been requested by the local system management, a deactivate_PM message has been sent, and the corresponding response from the peer layer management entity has not arrived yet. This state only exists in systems that originate the deactivation of the PM process (i.e. the deactivator). During this state, in case where PM was activated from B towards A (node A being the deactivator, see 10.4), the local system (at node A) shall still be prepared to process entering FPM cells coming from the peer layer management entity (at node B). In this case, if necessary, the local system (at node A) shall also still be able to generate BR cells.

NOTE – For the specific case where CC was activated from A towards B (node A being the deactivator, see 10.4), the local system (at node A) shall still generate CC cells according to the rules indicated in 9.2.1.1.2 and 9.2.2.1.2.

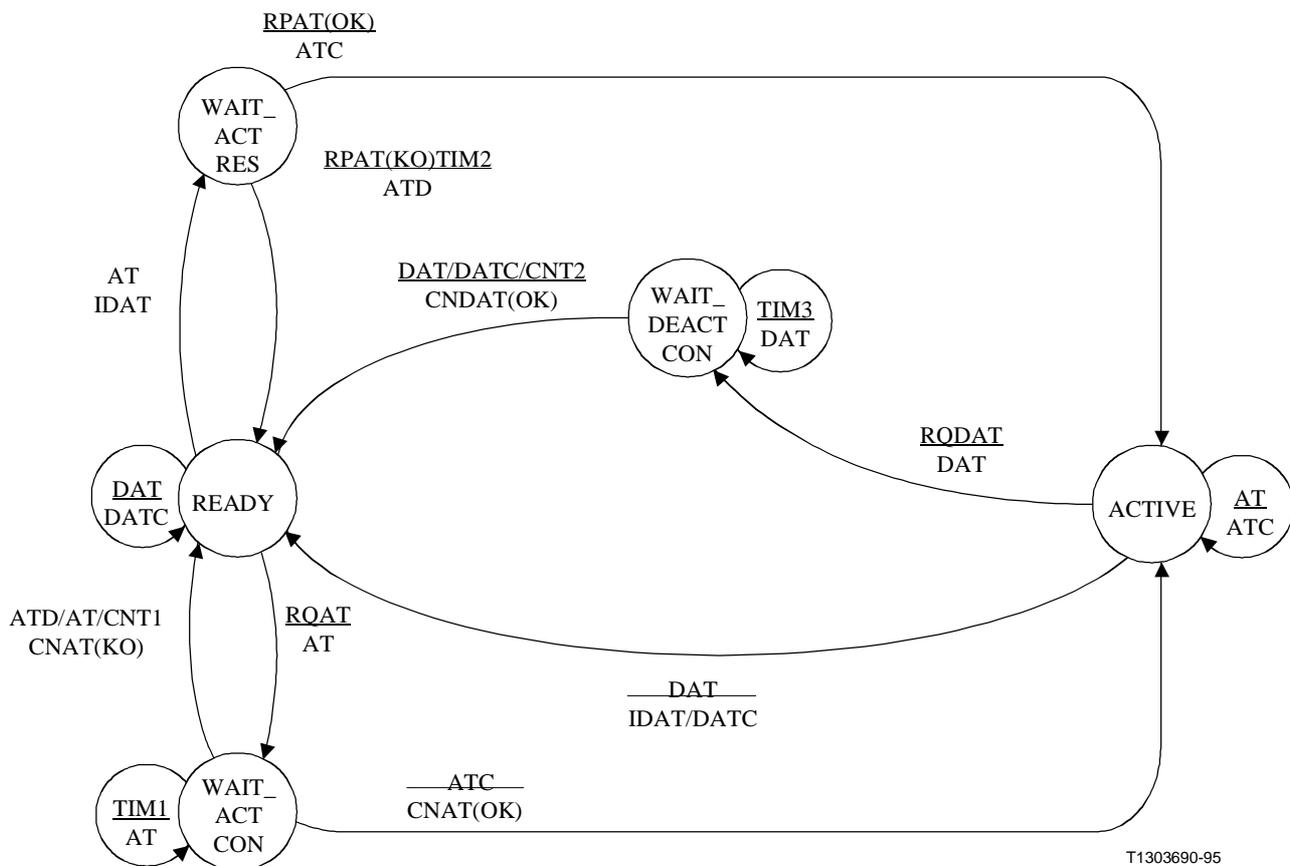
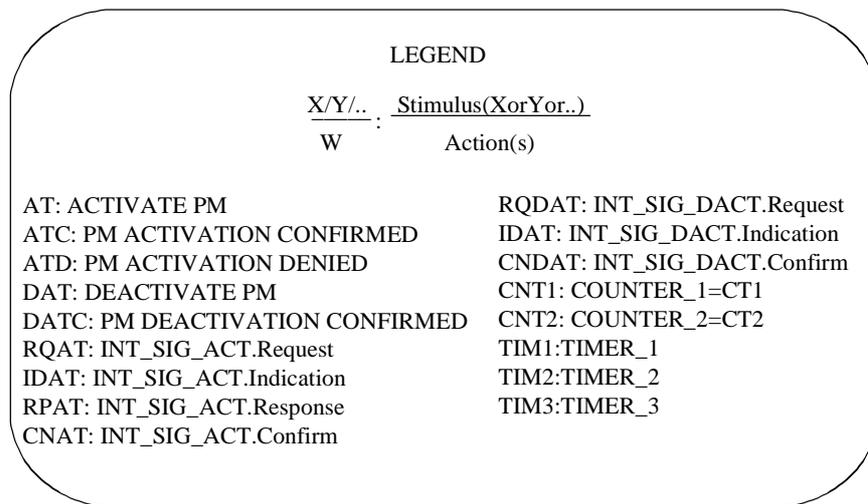


Figure B.1/I.610 – State diagrams

B.2 For the description of the procedure, a minimal set of internal signals exchanged between ATM layer management and plane management are required. For the activation case, a relation of these internal signals is:

- INT_SIG_ACT.Request (parameters): The plane management requests for the activation of the PM functions. Parameters are left for further study.
- INT_SIG_ACT.Indication (parameters): The ATM layer management indicates to the plane management the arrival of a request for the activation of PM functions. Parameters are left for further study.

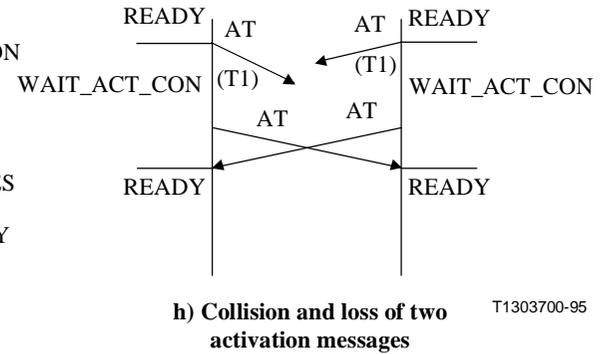
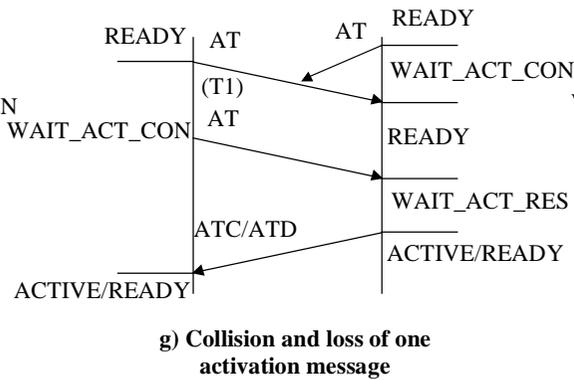
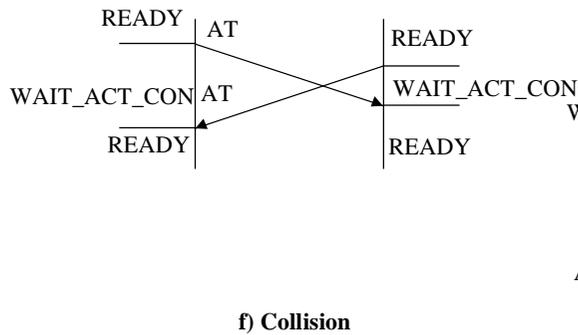
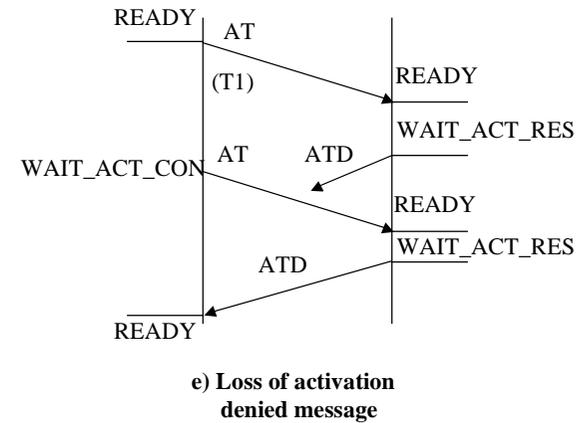
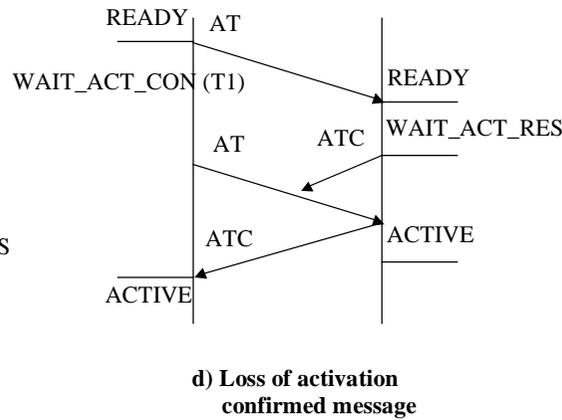
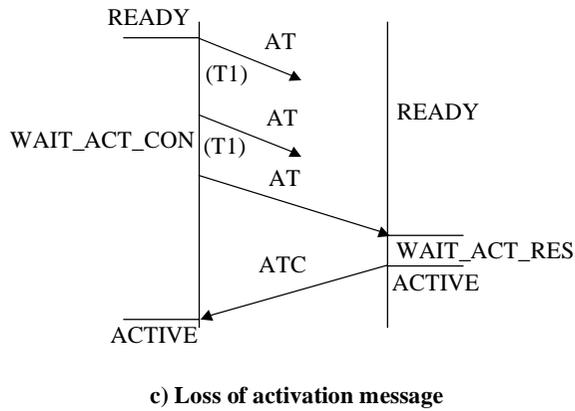
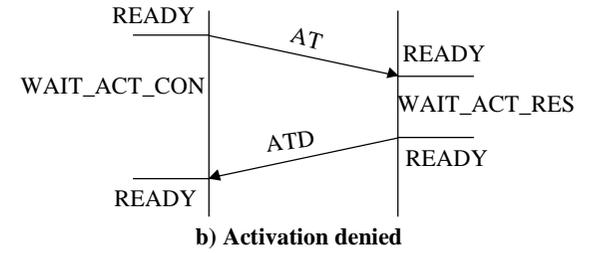
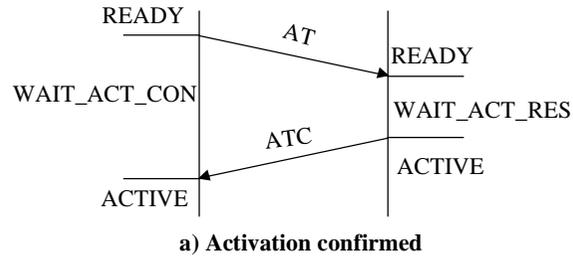
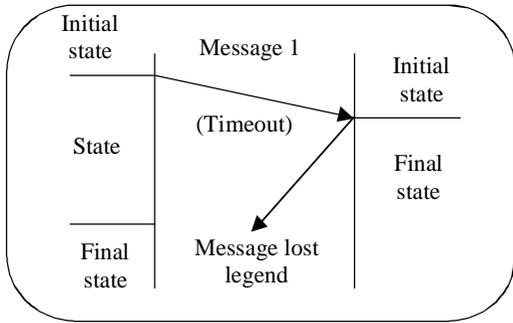
- INT_SIG_ACT.Response (Response, other_parameters): The plane management replies to the ATM layer management. The parameter response indicates the acceptance (if Response = OK) or rejection (if Response = KO) of the requested activation. Other parameters are for further study.
- INT_SIG_ACT.Confirm (Response, other_parameters): The ATM layer management confirms to the plane management the acceptance (Response = OK) or rejection (Response = KO) by the peer entity of the requested activation. Other parameters are for further study.

For the deactivation case a similar set of internal signals is required, the names of these internal signals are :

- INT_SIG_DEACT.Request, INT_SIG_DEACT.Indication, INT_SIG_DEACT.Response and INT_SIG_DEACT.Confirm: The meaning of each one of these signals is similar to the meaning of the corresponding signals for the activation case.

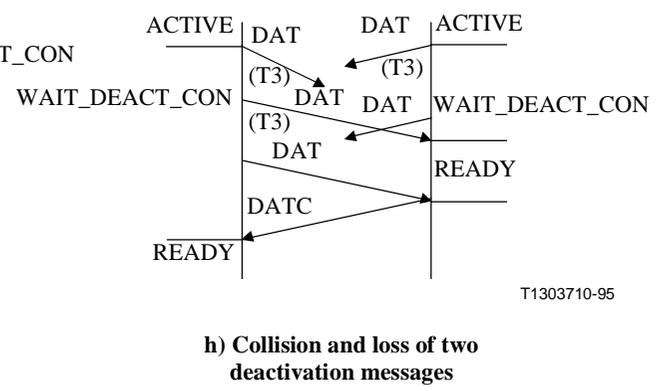
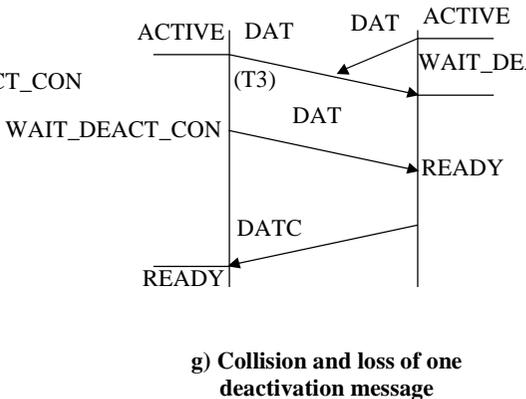
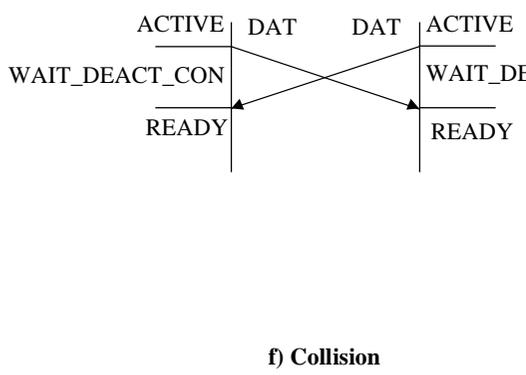
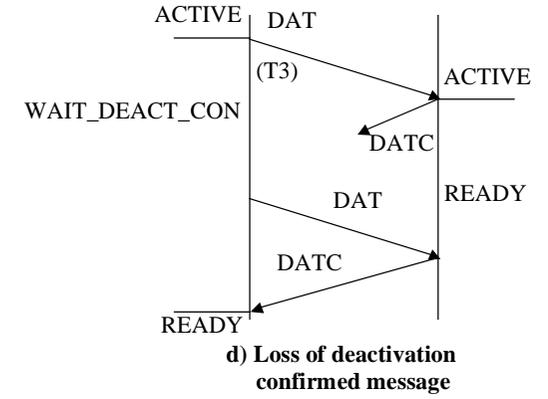
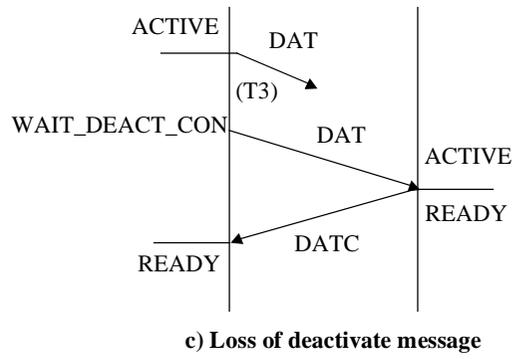
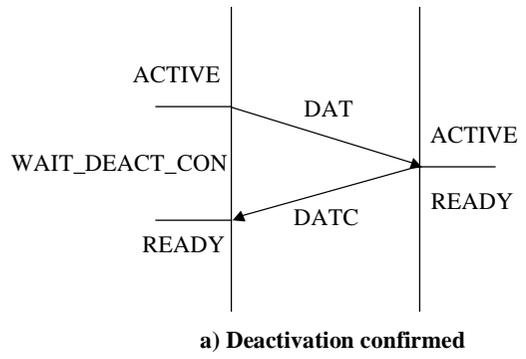
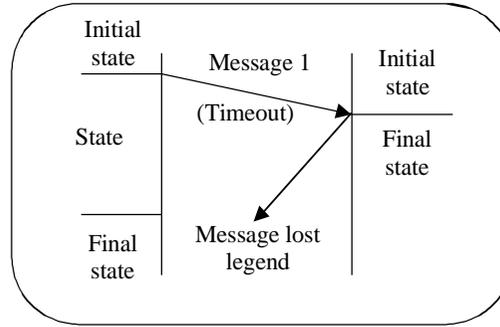
B.3 Examples of protocol operation for the activation case are included in the time flow diagrams of Figure B.2. The first two diagrams [a) and b)] describe the error free protocol operation mode. The next three [c), d) and e)] describe the protocol operation when some errors are detected. Finally, the diagrams [f), g) and h)] describe the collision case.

Similar examples for the deactivation case are included in Figure B.3.



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Figure B.2/I.610 – Activation: examples of protocol operation



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Figure B.3/I.610 – Deactivation: examples of protocol operation

B.4 SDL diagrams concerned with the proposed procedures are included in Figure B.5. In the diagrams, a reference to some variables is made. The meaning of each of these variables is:

- T1 This constant is used to initialize the timer_1 when it is started. T1 is the minimum waiting time for the response from the peer entity (in case of receiving a request to activate the PM process from system management). The value of T1 is ≥ 5 seconds. This value is greater than the round trip delay plus the processing time (whose maximum value is T2) at the peer entity to generate the corresponding response. In case of message loss, this constant also indicates the elapsed time between the generation of two consecutive activate_PM messages.
- T2 This constant is used to initialize the timer_2 when it is started. T2 is the minimum waiting time for the response from the system management (in case of receiving an activate_PM message). The value of T2 is ≤ 2 seconds.
- T3 This constant is used to initialize the timer_3 when it is started. T3 is the minimum waiting time for the response from the peer entity (in case of receiving a request to deactivate the PM process from system management). The value of T3 is ≥ 5 seconds. This value is greater than the round trip delay plus the processing time at the peer entity to generate the corresponding response. In case of message loss, this constant also indicates the elapsed time between the generation of two consecutive deactivate_PM messages.
- CT1 This constant is used to initialize the counter_1 when it is started. CT1 is the maximum number of attempts to send activate_PM messages. $CT1 \geq 3$.
- CT2 This constant is used to initialize the counter_2 when it is started. CT2 is the maximum number of attempts to send deactivate_PM messages. $CT2 \geq 3$.
- Timer_1 This variable represents the remaining time of a T1 time interval. This timer is used when the activation/deactivation process is in wait-activate-confirm state.
- Timer_2 This variable represents the remaining time of a T2 time interval. This timer is used when the activation/deactivation process is in wait-activate-response state.
- Timer_3 This variable represents the remaining time of a T3 time interval. This timer is used when the activation/deactivation process is in wait-deactivate-confirm state.
- Counter_1 This variable represents the number of attempts to send activate_PM when the activation/deactivation process is in wait-activate-confirm state.
- Counter_2 This variable represents the number of attempts to send deactivate_PM when the activation/deactivation process is in wait-deactivate-confirm state.

Finally, the key symbols used for the SDL² diagrams are included in Figure B.4.

While the activation/deactivation procedure is in ready state, the following operations take place [see Figure B.5 (sheet 1 of 5)]:

- 1) Upon receiving an activate_PM: Send a PM activation request indication to system management, start the timer_2, and go to wait-activate-response state.
- 2) Upon receiving a PM activation request from system management: Start the timer_1, send to peer entity activate_PM with a correlation_tag, direction and block_size conveyed from system management, set counter_1 to 1, and go to wait-activate-confirm state.

² In the internal signals are also included the timers previously referenced. Remainder signals are related with the peer entity communication.

- 3) Upon receiving a deactivate_PM: Send to peer entity PM_deactivation_confirmed, and stay in Ready state.

While the activation/deactivation procedure is in wait-activate-response state, the following operations take place [see Figure B.5 (sheet 2 of 5)]:

- 1) If system management rejects this request or the timer_2 expired: Stop timer_2, send to peer entity PM_activation_denied, and go to Ready state.
- 2) If system management accepts this request: Stop timer_2, send to peer entity PM_activation_confirmed; activate the PM process; and go to active state.

While the activation/deactivation procedure is in wait-activate-confirm state, the following operations take place [see Figure B.5 (sheet 3 of 5)]:

- 1) Upon receiving a PM_activation_confirmed: Stop the timer_1; activate the PM process; send PM activation-success confirmation to system management, and go to active state.
- 2) Upon receiving a PM_activation_denied or an activate_PM, or upon expiration of timer_1 and counter_1 is greater than or equal to CT1: Stop timer_1, send a PM activation-failure indication to system management, and go to ready state.
- 3) Upon expiration of the timer_1 (T1 time period) and counter_1 is less than CT1: Increment counter_1 by 1, start the timer_1, send to peer entity activate_PM with a correlation_tag, direction and block_size conveyed from system management, and stay in wait-activate-confirm state.

While the activation/deactivation procedure is in active state, the following operations take place [see Figure B.5 (sheet 4 of 5)]:

- 1) Upon receiving a PM deactivation request from system management: Send deactivate_PM with a correlation_tag and direction conveyed from system management, start the timer_3, set counter_2 to 1 and go to wait-deactivate-confirm state.
- 2) Upon receiving a deactivate_PM: Send a PM deactivation request indication to system management, send to peer entity PM_deactivation_confirmed, and go to ready state.
- 3) Upon receiving an activate_PM: Send to peer entity PM_activation_confirmed; and stay in active state.

While the activation/deactivation procedure is in wait-deactivate-confirm state, the following operations take place [see Figure B.5 (sheet 5 of 5)]:

- 1) Upon receiving a PM_deactivation_confirmed, a deactivate_PM, or if timer_3 is expired and if counter_2 is greater than or equal to CT2: Stop the timer_3; send PM deactivation-success confirmation to system management, deactivate the PM process; and go to ready state.
- 2) Upon expiration of the timer_3 (T3 time period) and counter_2 is less than CT2: Increment counter_2 by 1, start the timer_3, send to peer entity deactivate_PM with a correlation_tag and direction conveyed from system management and stay in wait-activate-confirm state.

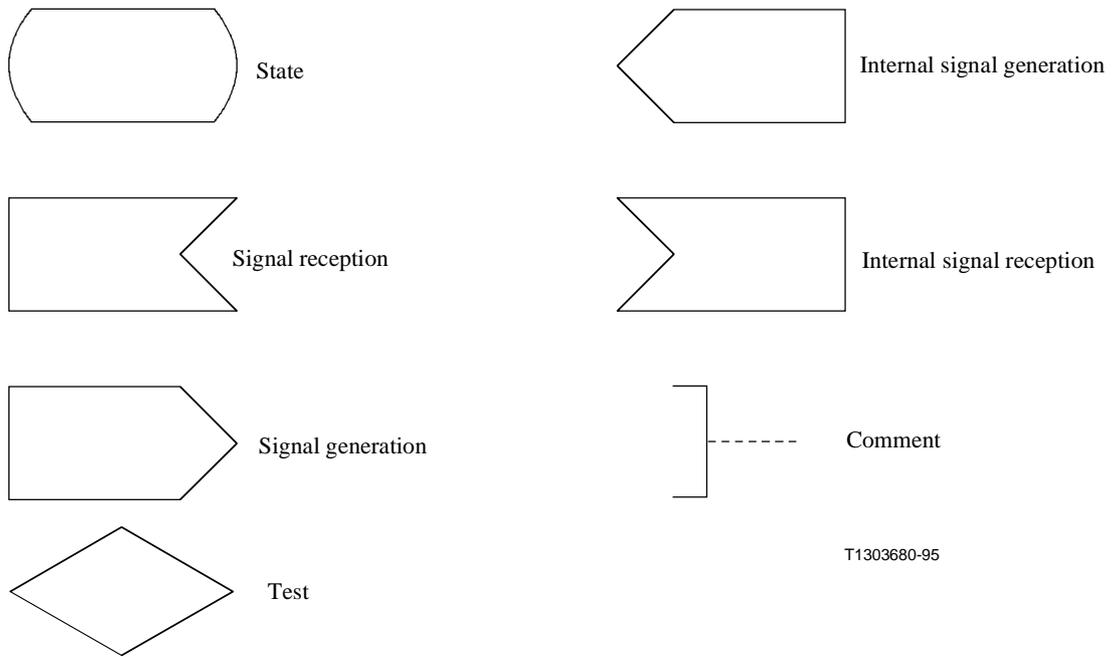
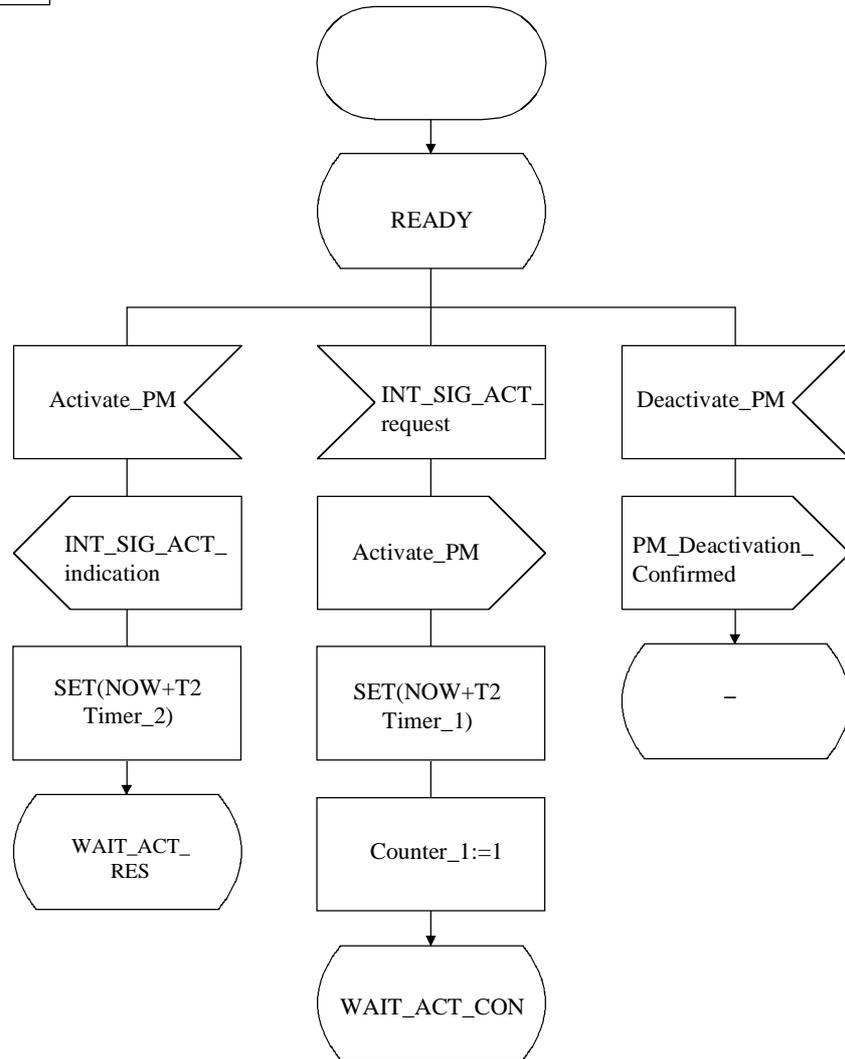


Figure B.4/I.610 – Keys used in the SDL diagrams

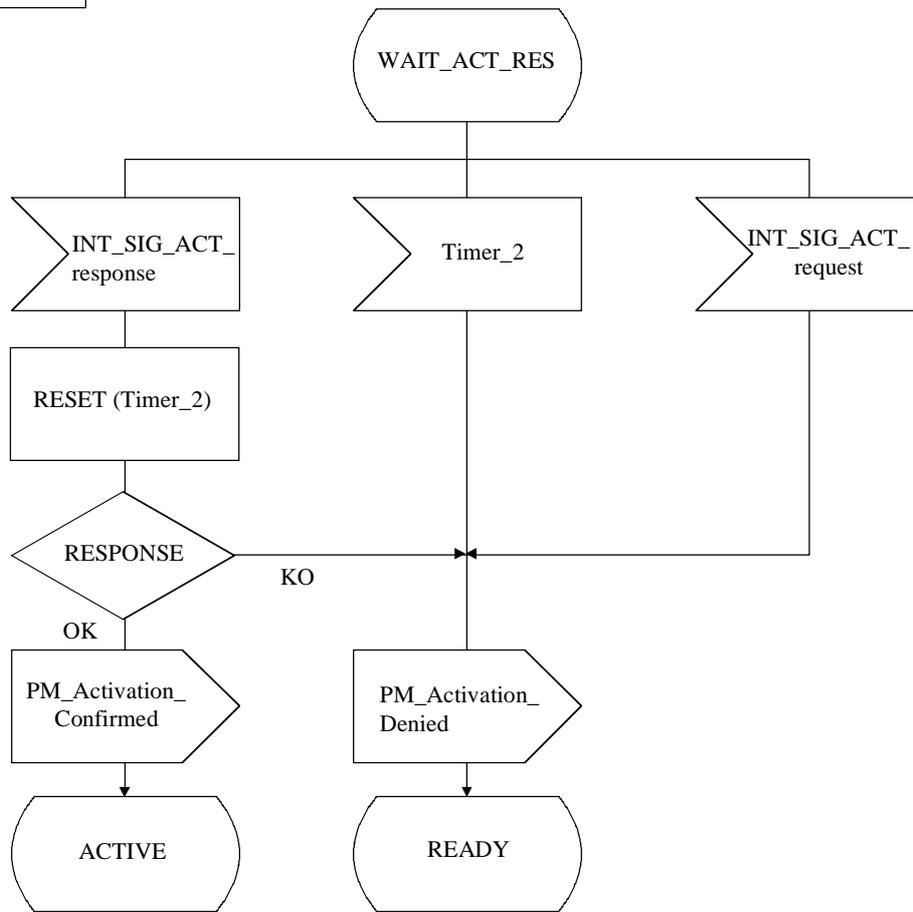
(1,1);
SIGNALSET



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Figure B.5/I.610 – SDL diagrams (sheet 1 of 5)

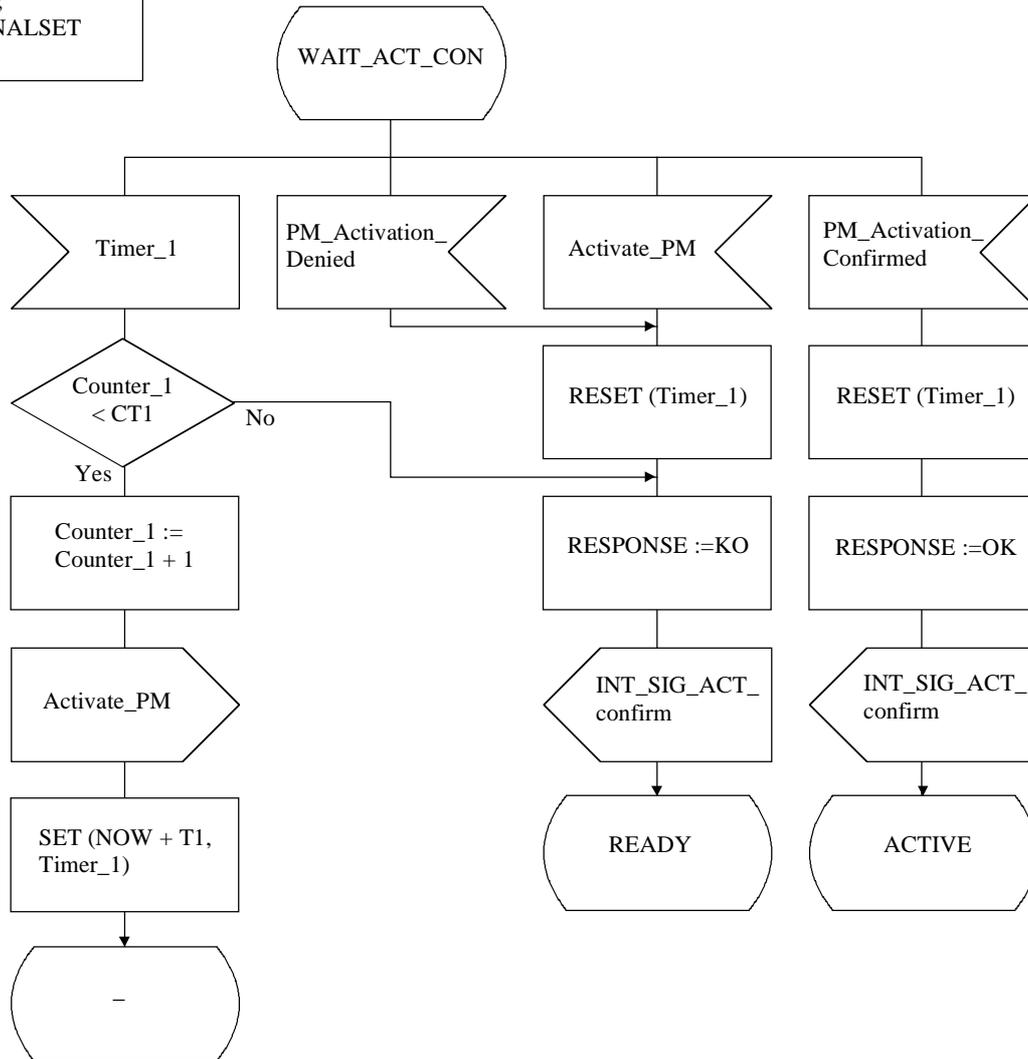
(1,1);
SIGNALSET



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Figure B.5/I.610 – SDL diagrams (sheet 2 of 5)

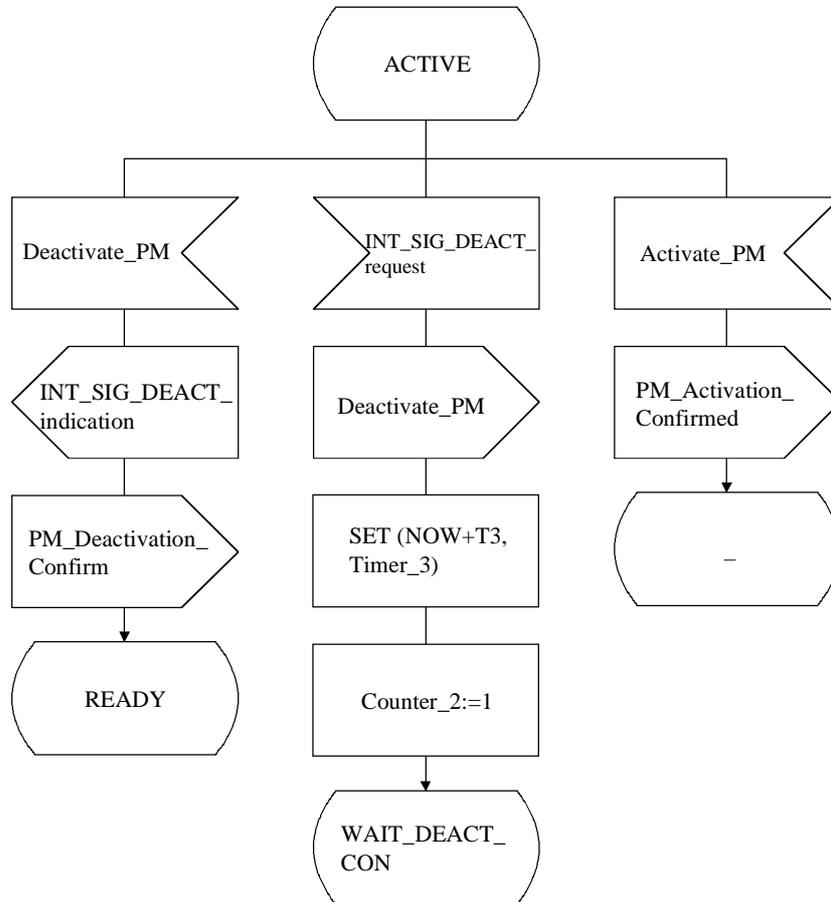
(1,1);
SIGNALSET



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Figure B.5/I.610 – SDL diagrams (sheet 3 of 5)

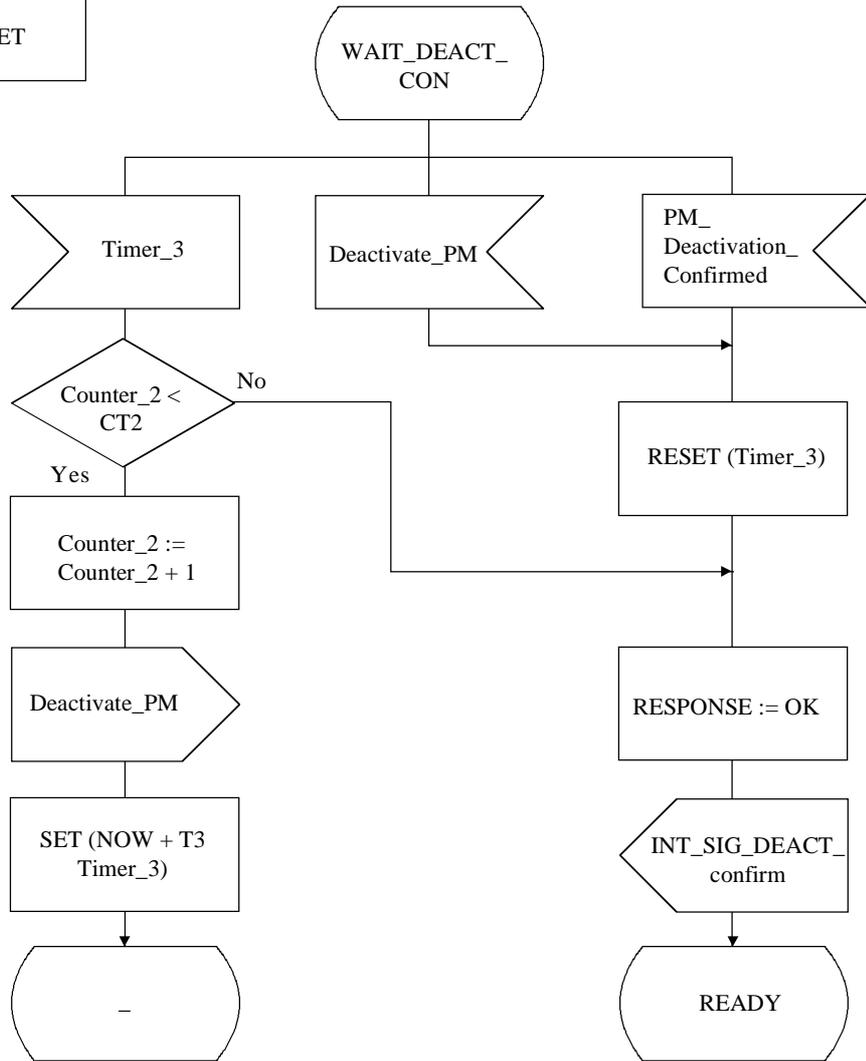
(1,1);
SIGNALSET



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Figure B.5/I.610 – SDL diagrams (sheet 4 of 5)

(1,1);
SIGNALSET



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Figure B.5/I.610 – SDL diagrams (sheet 5 of 5)

ANNEX C

Procedures to be performed when receiving LB cells

Figure C.1 provides the procedures to be performed when receiving e-t-e_LB or seg_LB cells at a segment endpoint, a connection endpoint, or at any intermediate Connection Point (CP). The procedure uses the concept of LB state which is defined as follows:

- A CP shall enter the LB state as soon as either a seg_LB or an e-t-e_LB cell is forwarded from this CP [cell sent with LB Indication field (LI) = 1].
- At a CP the LB state is defined for a given type of loopback procedure which is characterized by both the type of LB cells used (i.e. seg_LB or e-t-e_LB) and the direction of sending (i.e. towards the outside or the inside of a network element). Therefore it should be possible to manage four LB states simultaneously at a given CP.
- Exit from this state shall occur after a waiting time of 6 seconds \pm 1 second.
- While in the LB state for a given type of loopback procedure, a CP shall not initiate another loopback procedure of the same type.

The following requirements constitute the detailed procedure which applies to seg_LB and e-t-e_LB cells.

The main features of the loopback procedure are the following:

C.1 Case of seg_LB cells

- i) Bounds of a segment shall be defined prior to the use of any seg_LB cells.
- ii) Seg_LB cells can be issued from the segment source endpoint or from any CP within a segment.
- iii) The content of the incoming seg_LB cells shall be analysed at all crossed CPs for which the LLID option is enabled. The content of the incoming seg_LB cells shall always be analysed at the sink/source segment endpoints. Analysing an incoming seg_LB cell shall be a non-intrusive process. The following analysis shall be performed:
 - if the Loopback Indication field (LI) of the incoming seg_LB cell is equal to "1" (in which case this cell is referred to as a "parent cell"), then two cases have to be considered:
 - if the LLID value matches either the ID of the CP (referred to as the CPID), or the all "0"s value or the default all "1"s value (this applies only in the case of loopback at a segment endpoint), then a seg_LB cell (referred to as the "returned" seg_LB cell) shall be transmitted in the opposite direction from the CP which received the "parent" seg_LB cell (see Note 1 in C.2) within a time that insures that the cell is returned to the originator before the 5 seconds minimum waiting time expiration. As an option, the "parent" seg_LB cell may be extracted if its LLID field value is not equal to the default all "0"s value [see also item iv)]. The "returned" seg_LB cell shall have its specific fields filled as follows:
 - LI is set to "0";
 - Correlation tag is set to the value of the corresponding field of the "parent" seg_LB cell;

Optional source ID field is set to the value of the corresponding field of the "parent" seg_LB cell if the CP supports the Source ID option. How to handle the source ID field in case the CP does not support the source ID option is for further study.

LLID is set to the value of the CPID (ID of the CP which returns the LB cell);

Unused octets are set to '6A'H.

– otherwise no "returned" seg_LB cell is produced.

- if the LI field of the incoming seg_LB cell is equal to "0", then two cases have to be considered:

– the CP is in the "LB state" in which case the correlation tag (and optionally the source ID) of the incoming seg_LB cell shall be analysed so as to check whether the loopback was performed or not. If the loopback is performed (see Note 2 in C.2), then the "incoming" seg_LB cell may optionally be extracted and the value of the LLID field of the "returned" seg_LB cell shall be stored in the ATM Network Element (NE) for further processing;

– otherwise no further analysis is performed.

iv) All types of seg_LB cells (LI = "1" or "0") shall be removed at the segment sink endpoint.

C.2 Case of e-t-e_LB cells

i) E-t-e_LB cells can be issued from a connection source endpoint or any CP (including segment endpoints) along the connection.

ii) The content of the incoming e-t-e_LB cells shall be analysed at all crossed CPs, segment and connection endpoints. Analysing an incoming e-t-e_LB cell shall be a non-intrusive process. The following analysis shall be performed:

- if the Loopback Indication field (LI) of the incoming e-t-e_LB cell is equal to "1" (in which case this cell is referred to as a "parent cell"), then the cell has to be processed according to the following procedure:

– If the e-t-e_LB cell is received at a connection endpoint, two cases have to be considered:

- if the LLID value matches either the CPID or the default all "1"s value, then an e-t-e_LB cell (referred to as the "returned" e-t-e_LB cell) shall be transmitted in the opposite direction from the connection endpoint which received the "parent" e-t-e_LB cell (see Note 1) within a time that ensures that the cell is returned to the originator before the 5 seconds minimum waiting time expiration. The "returned" e-t-e_LB cell shall have its specific fields filled as follows:

LI is set to "0";

Correlation tag is set to the value of the corresponding field of the "parent" e-t-e_LB cell;

Optional source ID field is set to the value of the corresponding field of the "parent" e-t-e_LB cell if the connection endpoint supports the source ID option. How to handle the source ID field in case the connection endpoint does not support the source ID option is for further study;

LLID is set to the value of the CPID (ID of the CP which returns the LB cell);

Unused octets are set to '6A'H.

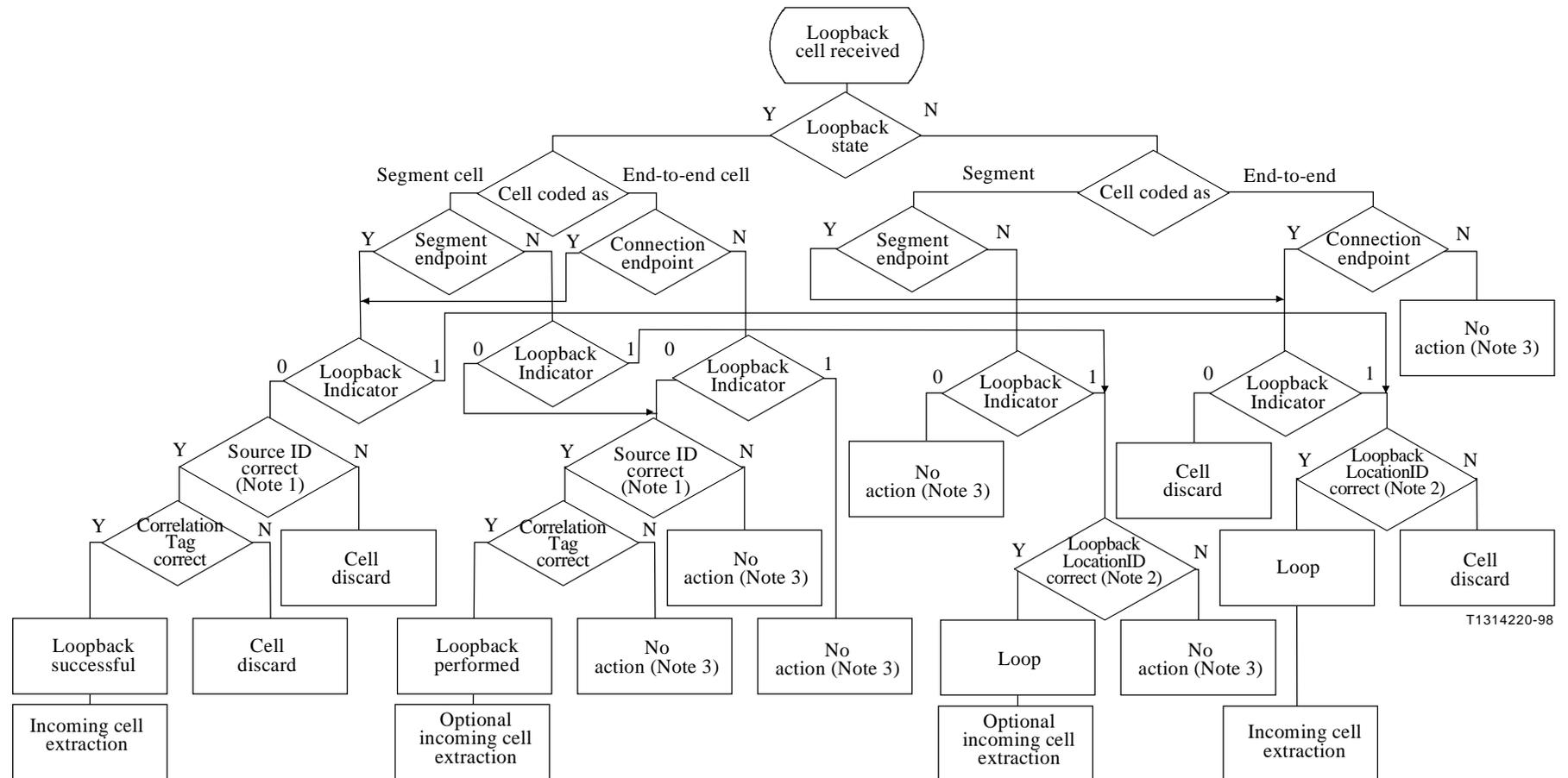
- otherwise no "returned" e-t-e_LB cell is produced.

- If the e-t-e_LB cell is received at an intermediate CP, then no "returned" e-t-e_LB cell is produced.
- if the LI field of the incoming e-t-e_LB cell is equal to "0", then two cases have to be considered:
 - the CP, segment endpoint or connection endpoint is in the "LB state" in which case the correlation tag (and optionally the source ID) of the incoming e-t-e_LB cell shall be analysed so as to check whether the loopback was performed or not. If the loopback is performed (see Note 2), then the value of the LLID field of the "returned" e-t-e_LB cell shall be stored in the ATM NE for further processing. As an option, the incoming e-t-e_LB cell may be removed at an intermediate CP (this includes segment endpoints) in case of a performed loopback;
 - otherwise no further analysis is performed.

iii) All types of e-t-e_LB cells (LI="1" or "0") shall be removed at the connection endpoint.

NOTE 1 – This corresponds to the "LOOP" action mentioned in the diagram provided in Figure C.1.

NOTE 2 – This corresponds to the "LOOPBACK PERFORMED" action mentioned in the diagram provided in Figure C.1.



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Diagram notations:

Cell coded as:

seg_LB or e-t-e_LB cells are considered.

Loopback indicator:

LI = 1 or 0 in the case where the cell was already looped back.

Correlation tag correct:

This is obtained when the correlation tag value of the "returned" LB cell (LI = 0) matches the correlation tag value of the "parent" LB cell (i.e. forwarded from the CP with LI = 1).

Loopback location ID correct:

This is obtained when the LLID value of the "parent" LB cell matches either the CPID, the default all "1"s value (in the case of segment endpoint), or in the case of LB cells in any part of a segment, the all "0"s value.

LB performed:

This is obtained when "returned" LB cells are received with a correct correlation tag at a given CP while this CP is in the "LB state". How to handle the resulting information requires further study.

NOTE 1 – If the optional source ID field is not used, this decision should be skipped and continued direction "Y".

NOTE 2 – If the Loopback Location ID option is not enabled by the TMN, then the LLID field is not examined at an intermediate CP and this decision should be set to direction "N". Same decision applies also in the case where an intermediate CP does not support Loopback functions.

NOTE 3 – No action : no returned LB cell is produced, the incoming LB cell is not extracted and is transparently transferred through the CP.

Figure C.1/I.610

APPENDIX I

Examples of OAM cell error detection codes

I.1 This appendix provides two examples of the 10-bit CRC Error Detection Field (EDC) calculated for an RDI cell and a LB cell, respectively.

Example 1 – RDI cell

The cell type is "0001", the function type is "0001", and the next 45 octets are all coded as 6A hexadecimal. The reserved field consists of six "0" bits. The calculated CRC-10 is AF hexadecimal (i.e. "00 1010 1111"). The 48-octet information field is transmitted as:

11	6A											
6A												
6A												
6A	00	AF										

Example 2 – LB cell

The cell type is "0001", the function type is "1000", the loopback indication is "00000001", the correlation tag is AA hexadecimal, the loopback ID is all ones and the source ID is 6A hexadecimal. The calculated CRC-10 is 2AC hexadecimal (i.e. "10 1010 1100"). The 48-octet information field is transmitted as:

18	01	AA	AA	AA	AA	FF						
FF	6A	6A										
6A												
6A	02	AC										

APPENDIX II

This appendix contains informative material related to the insertion process applicable to end-to-end or segment performance management cells.

II.1 Processes applicable to forward performance monitoring cells

The insertion of those OAM cells could be performed according to one of the following processes.

II.1.1 Forced insertion

This process is applicable to e-t-e_FPM cells and could be used also for the seg_FPM cells.

Figure II.1 shows the relationship between the insertion requests, produced every N user cells, and the actual insertion of the FPM cells in the case of the "forced insertion" process. In this Figure, events No. 1, 3, 5 and 7 represent the time of the insertion requests while events No. 2, 4, 6 and 8 represent the time of the corresponding actual insertion.

Events No. 2 and 6 correspond to a "normal" insertion, i.e. immediately after the insertion request, in the first free cell location.

Event No. 4 corresponds to a "forced" insertion, i.e. immediately after $N + N/2$ user cells have been received, in the first cell location. In this case, user cells may experience some additional delay.

Event No. 8 corresponds to a "delayed" insertion, i.e. immediately after $N + x$ user cells have been received in the first free cell location ($x < N/2$).

The resulting block sizes are then equal to $(N + N/2)$ for block A, $(N - N/2)$ for block B and $(N + x)$ for block C. Block sizes may vary in the range $[N/2, 3N/2]$ and the average block size is roughly equal to N .

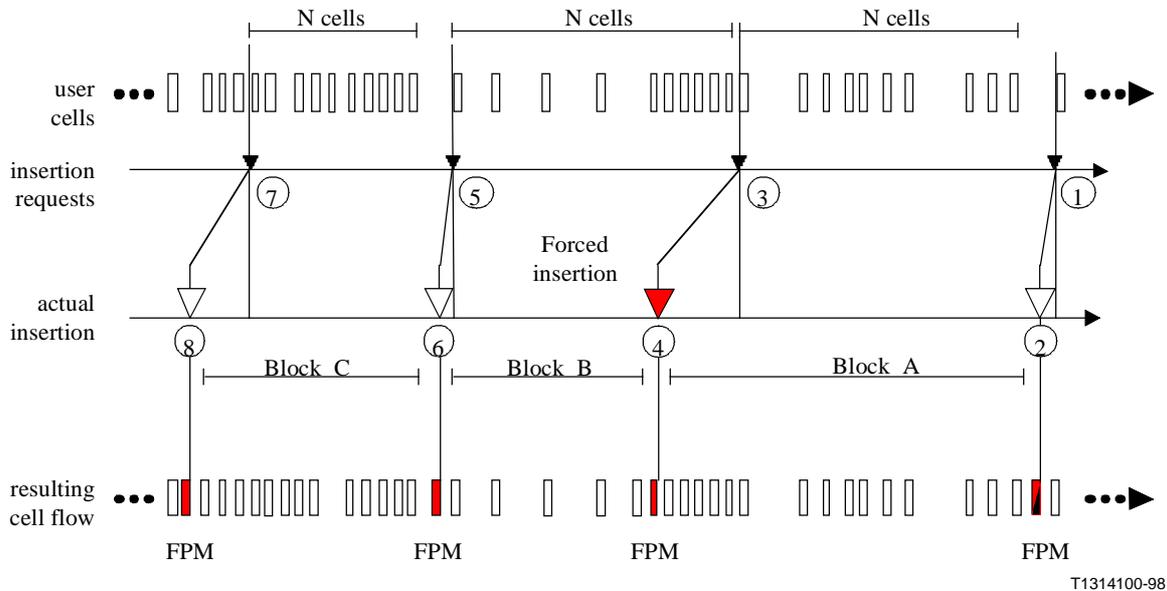


Figure II.1/I.610 – Forced insertion case for e-t-e_FPM or seg_FPM cells

II.1.2 Non forced insertion

This process could be used only for seg_FPM cells.

Figure II.2 shows the relationship between the insertion requests and the actual insertion of the seg_FPM cells in the case of the "forced insertion" process. Insertion requests are produced after N user cells observed since the last forwarded seg_FPM cell.

In this Figure, events No. 1, 3 and 5 represent the time of the insertion requests while events No. 2, 4 and 6 represent the time of the corresponding actual insertion.

Event No. 2 corresponds to a "normal" insertion, i.e. immediately after the insertion request in the first free cell location.

Events No. 4 and 6 correspond to "delayed" insertions, the insertion is performed in the first free cell location after the insertion request.

The resulting block sizes are not limited in principle, the average block size is greater than or equal to N .

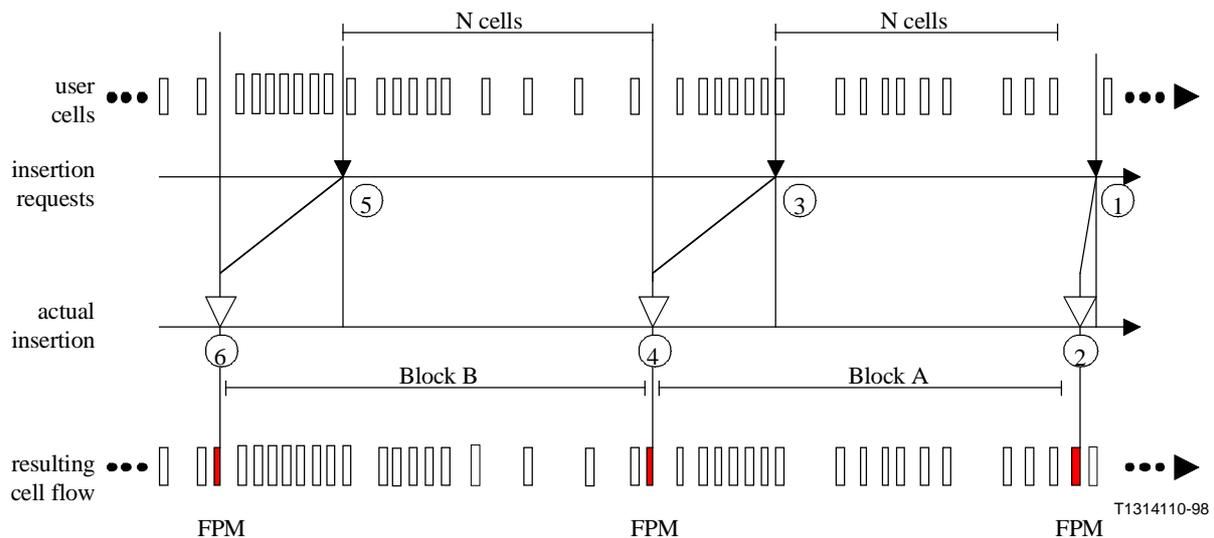


Figure II.2/I.610 – Non forced insertion case for seg_FPM cells

II.2 Process applicable to backward reporting cells

The insertion of those OAM cells could be performed according to one of the following processes.

II.2.1 Forced insertion

This process is used for seg_BR cells or e-t-e_BR cells.

Figure II.3 shows the relationship between the arrival time of FPM cells and the actual insertion of the BR cells in the opposite direction. Insertion requests of BR cells are produced after a FPM cell has been correctly received and its content processed.

In this Figure, events No. 1, 3 and 5 represent the time of the BR cell insertion requests while events No. 2, 4 and 6 represent the time of the corresponding actual insertion.

Event No. 2 corresponds to a "normal" insertion, i.e. immediately after the insertion request in the first free cell location.

Event No. 6 corresponds to "delayed" insertion. A forced insertion is illustrated by event No. 4.

It should be noted that this insertion method may produce at most a clump of two BR cells. Also, in some cases, the forced insertion of a BR cell could be coincident with the forced insertion of a FPM cell on the same direction of the VPC/VCC. The priority scheme between the two forced insertion actions is not considered in this appendix but needs to be solved at the ATM equipment level.

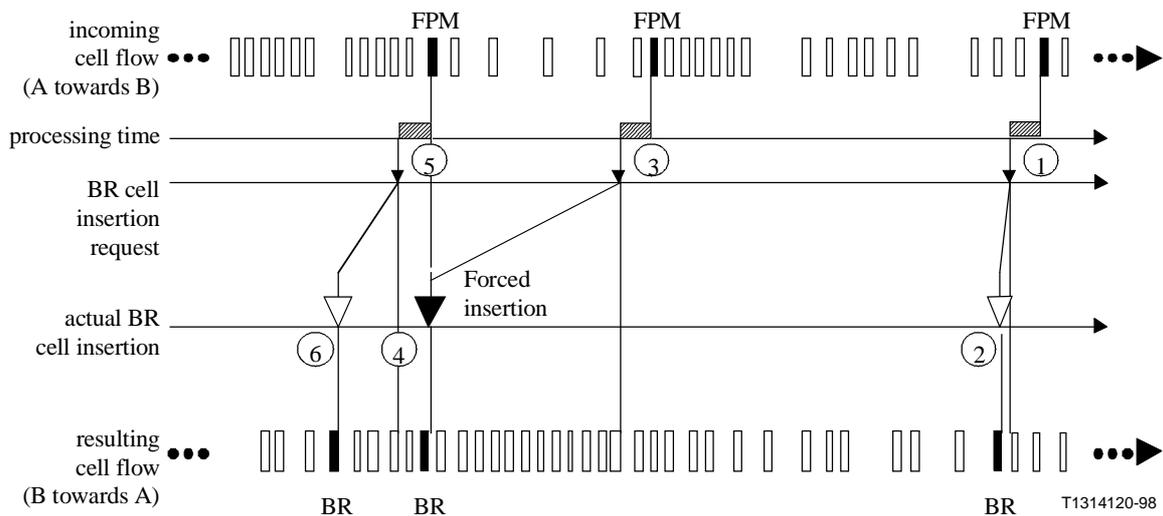


Figure II.3/I.610 – Insertion mechanism for e-t-e_BR or seg_BR cells

II.2.2 Non forced insertion

For further study.

APPENDIX III

Use of segment loopback cells for localizing failures

This appendix contains informative material on how to use seg_LB cells for localizing failures which may occur at the ATM layer level. While failures occurring at the transmission layer level are intended to be localized with the OAM procedures inherent to the physical layer, the techniques described in this appendix could be also used for that purpose.

III.1 Description of failure types which may be observed at the ATM layer level

The three following main categories of failures are considered in this appendix :

- a) LOC;
- b) misroutings;
- c) unintended connection branches.

Failure categories b) and c) are supposed to affect the two directions of the VPC/VCC. In case of a unidirectional VPC/VCC, the reverse direction carries only the OAM cells (i.e. in particular the "returned" seg_LB cells).

If in absence of failure the "normal" cell flow corresponds to cells transferred from A towards B with a correct VPI/VCI translation, the above-mentioned failure categories correspond then to the following cases (see Figure III.1):

Type a) failure

The "normal" cell flow is interrupted. Absence of user cells and CC cells (in case this mechanism is activated) is observed at B while user cells or CC cells are present at A.

Type b) failure

The "normal" cell flow is misrouted. Cells are transferred from A towards C (instead of B).

Type c1) failure

Some or all the cells of the "normal" cell flow are duplicated and wrongly directed towards C while the "normal" cell flow is transferred from A towards B.

Type c2) failure

Mis-inserted cells are added to the "normal" flow. A mixed cell flow is issued from B (i.e. the cells of the "normal" flow plus those transferred from C towards B).

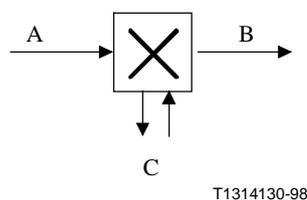


Figure III.1/I.610 – Failure types at the ATM layer level

NOTE – Specific failure types depend also on network element architecture and particular conditions in which the failure takes place (e.g. misrouting of only one direction due to corruption of a translation and routing table). Further analysis is required for fault localization in these cases.

III.2 Loopback techniques applicable for segment loopback cells

III.2.1 Basic principle of the single loopback technique

A seg_LB cell is issued from any source point within a segment (in particular the segment endpoint) and looped back at a single CP where the LLID value matches the CPID value as illustrated in Figure III.2. For each seg_LB cell issued, one seg_LB cell is returned if the failure is not located between the source point of the seg_LB cell and the loopback point. By modifying the LLID value on a step per step basis and monitoring the "returned" seg_LB cells, it is possible to localize type a) or b) failures as illustrated in III.3.1.1.

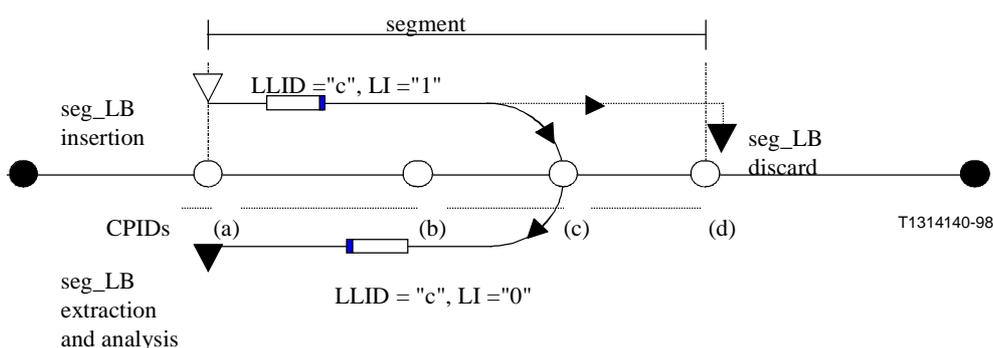


Figure III.2/I.610 – Basic principle of the single loopback technique

III.2.2 Basic principle of the multiple loopback technique

A seg_LB cell is issued from a segment endpoint with a LLID value equal to all "0"s and looped back at all CPs within the segment (this LLID value being a "universal address"). For each seg_LB cell issued, one seg_LB cell is returned by each CP within the segment portion in-between the source point of the seg_LB cell and the failure location (see Figure III.3). By monitoring the LLID values of the multiple "returned" seg_LB cells, it is possible to localize type a), b), c1) and c2) failures as illustrated in III.3.1.2.

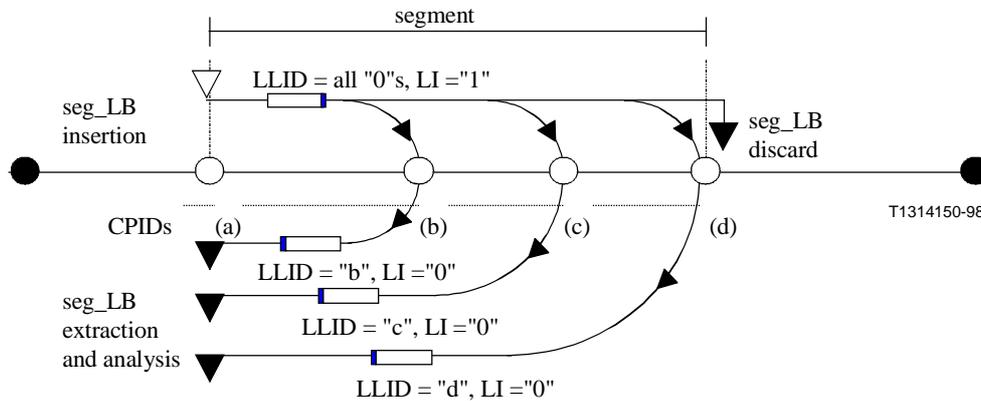


Figure III.3/I.610 – Basic principle of the multiple loopback technique

III.3 Examples of use of segment loopback cells for localizing failures occurring at the VP/VC layer levels

III.3.1 Case of Point-to-Point VPC/VCC

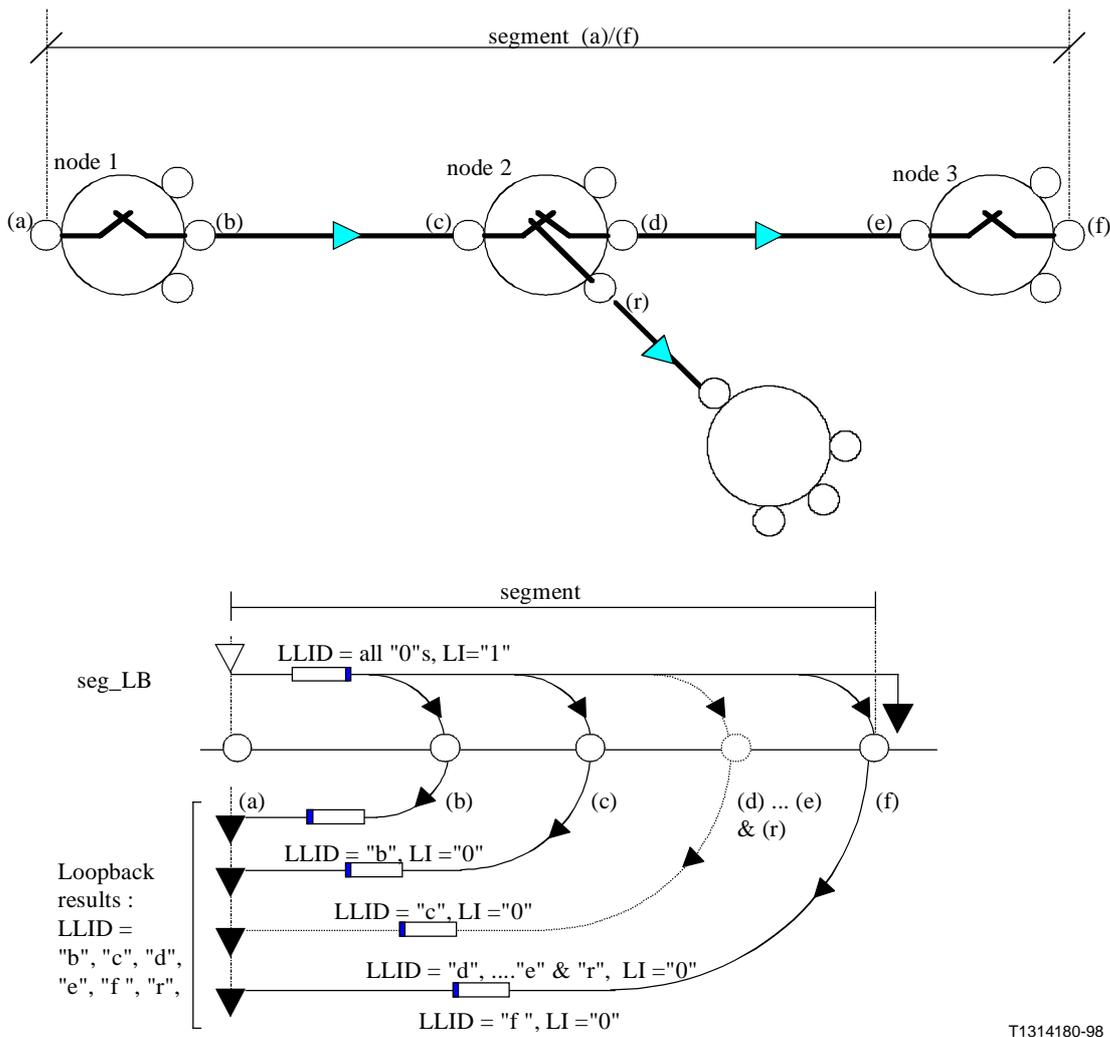
III.3.1.1 Use of the single loopback technique

In case of a type a) failure affecting node 2, its localization using the single loopback technique requires the sending of at least two (or three) seg_LB cells for the example given in Figure III.4. The result obtained from the third loopback test allows confirmation that the failure is actually located in-between CPIDs (c) and (d), i.e. within node 2.

III.3.1.2 Use of the multiple loopback technique

It should be noted that while this is not illustrated in this subclause, the multiple loopback technique is adapted to localize type a) and b) failures.

In case of a type c1) failure affecting node 2, its localization using the multiple loopback technique requires the sending of a single seg_LB cell. For the example given in Figure III.6. The results obtained consist in seven "returned" seg_LB cells for one seg_LB cell issued. By analysing the LLID values of the "returned" seg_LB cells, it follows that the failure is located in-between CPIDs (c) and (d), i.e. within node 2, and that an unintended branch exists between CPIDs (c) and (r).

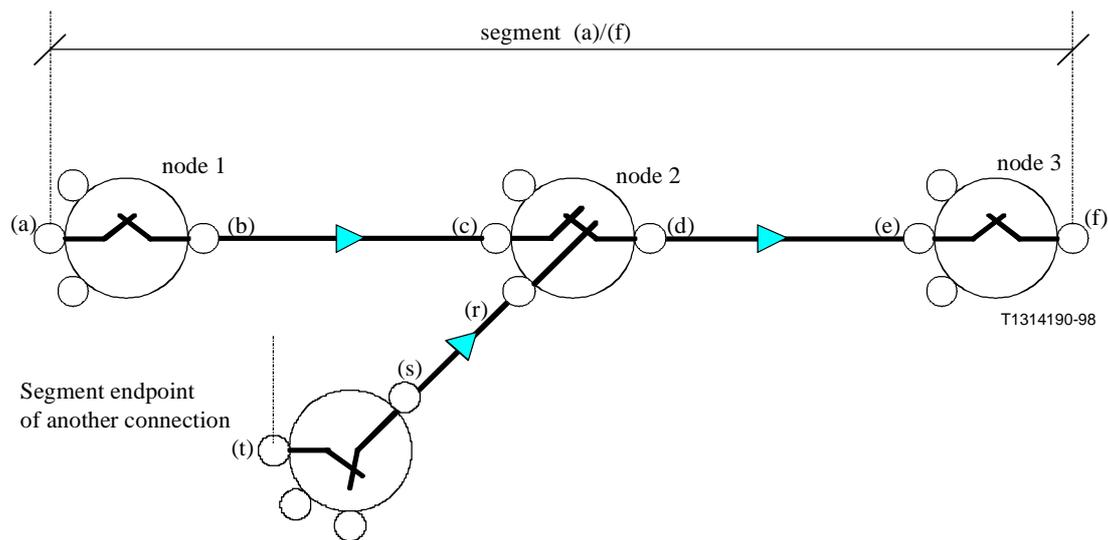


NOTE – In this example, it is assumed that the LLID option is enabled for all CPs including those outside the segment.

Figure III.6/I.610 – Example of use of the multiple loopback technique for a type c1) failure

In case of a type c2) failure affecting node 2 (see Figure III.7), its localization using the multiple loopback technique is performed similarly to the previous case: the seg_LB cell with LLID all "0"s is sent from CPID (f) instead of CPID (a). Since the failure is assumed to affect both directions, the failure in the (f) towards (a) direction is then a type c1) failure.

It should be noted that a complete check of the connectivity in-between two segment endpoints could be performed by initiating a multiple loopback procedure from both segment endpoints.



NOTE – In this example, it is assumed that the LLID option is enabled for all CPs including those outside the segment.

Figure III.7/I.610 – Example of use of the multiple loopback technique for a type c2) failure

III.3.2 Case of point-to-multipoints VPC/VCC

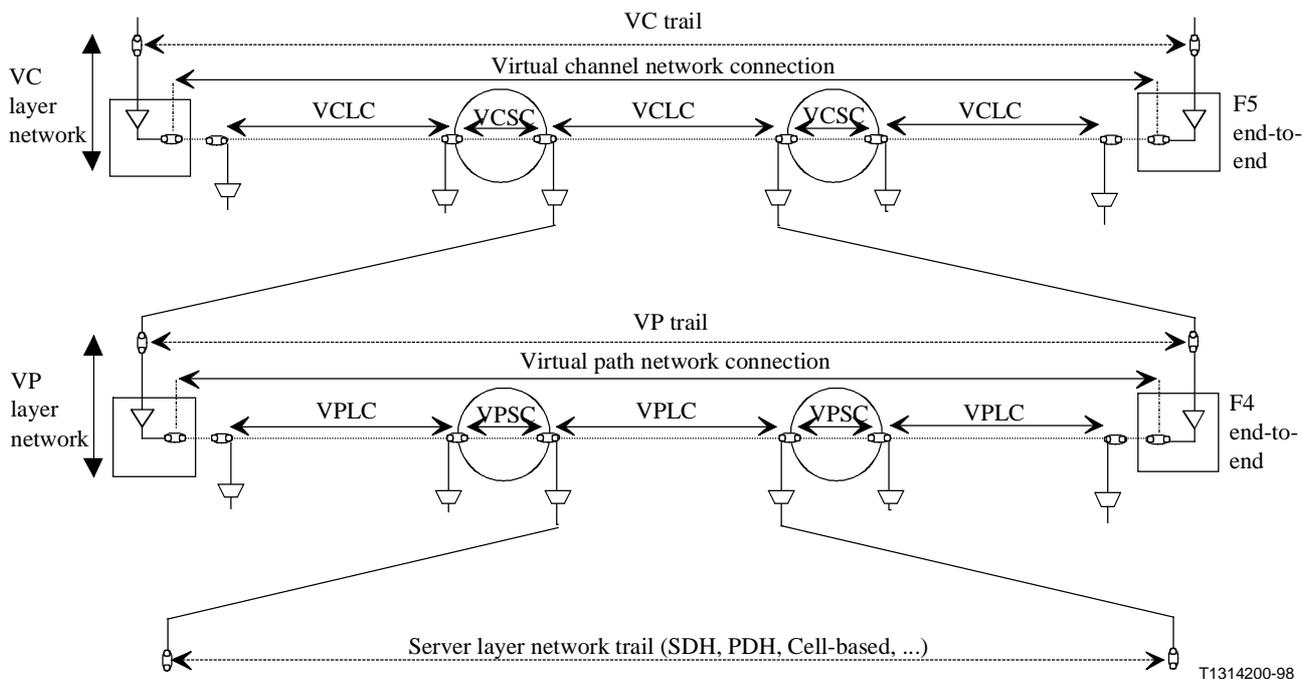
For further study.

APPENDIX IV

OAM hierarchical levels and their relationship with the functional model of G.805

In the functional model (I.326), transport and OAM layer management processing is allocated to so called transport functions (see 6.2.2). The location of the transport functions is indicated in Figure IV.1. Figure IV.1 is an extension of Figure 3.

Figure IV.1 illustrates end-to-end OAM allocation to I.326 transport functions. Segment OAM allocation to transport functions is illustrated in Figure IV.2 which is an extension of Figure 4 [item b)]. When a CP is provisioned as a segment endpoint, segment adaptation and segment trail termination functions are included in the connection. The segment trail termination function is responsible for the generation and termination of segment OAM flows.



▽ Trail termination function (see G.805/I.326)

▤ Adaptation function (see G.805/I.326)

⊙ Connection point (see G.805/I.326)

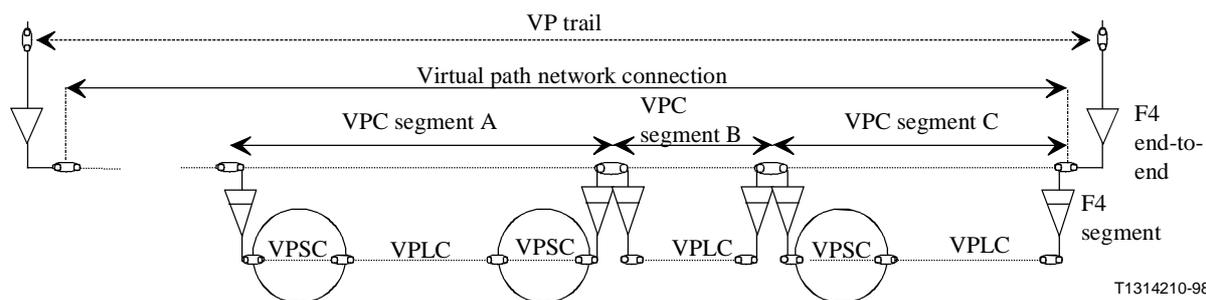
VCLC Virtual Channel Link Connection (see G.805/I.326)

VCSC Virtual Channel Subnetwork Connection (see G.805/I.326)

VPLC Virtual Path Link Connection (see G.805/I.326)

VPSC Virtual Path Subnetwork Connection (see G.805/I.326)

Figure IV.1/I.610 – F5 and F4 OAM hierarchical levels and their relationship with I.326 ATM transport functions



▽ Trail termination function (see G.805/I.326)

▤ Adaptation function (see G.805/I.326)

⊙ Connection point (see G.805/I.326)

VCLC Virtual Channel Link Connection (see G.805/I.326)

VCSC Virtual Channel Subnetwork Connection (see G.805/I.326)

VPLC Virtual Path Link Connection (see G.805/I.326)

VPSC Virtual Path Subnetwork Connection (see G.805/I.326)

Figure IV.2/I.610 – Example of VPC segments configuration and their relationship with I.326 ATM transport functions

APPENDIX V

Use of an ID in the segment CC cell

This appendix contains informative material on the possible use of a source ID in the seg_CC cell. Examples of practical applications are given which demonstrate the benefits of using this function, including the ability to detect connectivity problems in the ATM layer.

V.1 Basic concepts

When there is misconfiguration in the ATM layer, resulting in either mis-delivery of a cell stream to a third party, or unintended merging of cells from multiple sources, it is important that an operator can detect the fault quickly.

At the point of connection set-up, an operator can carry out a limited set of out-of-service tests to verify that connectivity is correct. In particular, LB cells can be used to provide a level of assurance before the connection is handed over to the customer. From this point onwards, however, the operator will need to rely on in-service tools to detect subsequent connectivity failures. If this is not achievable, operators will find themselves being informed of failures by customers – but this is undesirable.

This Recommendation defines the FPM and BR cells for in-service estimation of cell transfer performance according to Recommendation I.356. Whilst this tool is suitable for detecting impairments resulting from physical layer disturbances, or cell loss due to congestion for example, it is not optimized for detection of connectivity problems in the ATM layer. In fact, the PM tool will not detect certain misrouting scenarios, e.g. mis-delivery of a cell stream to a third party.

An alternative tool which may be used is the CC cell. However, considering that there is no information carried in the CC payload, which means that misconnectivity cannot be detected in most cases, it has been suggested that inclusion of an ID in the CC cell would provide a powerful in-service means of detecting connectivity failures, since the embedded information would effectively serve as a path trace. The ID would unambiguously identify the associated segment source point.

V.2 Defect conditions

In addition to the LOC defect, a new defect would be defined to cater for instances when CC cells, with an unexpected ID, arrive at a segment endpoint. The defect, which would identify a trace identifier mismatch condition, would require a suitable algorithm which checks for persistency of the fault condition before declaring the defect. Likewise, a persistency check would be required before the defect can be cleared.

V.3 CC ID source/sink functions

Currently, CC source and sink functions are coupled, i.e. activating a segment CC flow automatically invokes the CC function at the segment sink point. In the case of CC plus ID, it has been suggested that source and sink functions can be decoupled, i.e. the act of *sourcing* CC plus ID cells within a segment would not automatically imply that the segment sink point must process incoming CC cells. The rationale for this is that in order to detect a connectivity failure, for example when an "offending" cell stream is incorrectly merged into another stream, CC plus ID must already be present in the "offending" stream. Therefore, without any *a priori* knowledge of which connections will be affected by such a failure, the conclusion is that CC plus ID should be generated on the majority of (if not all) connections. However, sink processing would only be required on "important" connections, i.e. those which an operator wishes to protect with automatic detection capability in the

event of a connectivity failure. Therefore, it should be possible to decouple enhanced CC source and sink functions.

V.4 SES_{ATM} estimation

The CC plus ID cell (based on option 2) for CC generation can be used as an additional input for in-service estimation of SES_{ATM} events.

V.5 Backwards compatibility

There are no issues foreseen with backwards compatibility since the current CC cell has no codings defined in the function-specific field.

V.6 Connection identification for the purposes of through-path monitoring

If connections have CC plus ID cells, there would now be a possible method for rapidly identifying the ingress/egress points of the connection within an operators domain, for example for the purposes of through-path monitoring.

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