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SERIES I: INTEGRATED SERVICES DIGITAL NETWORK

B-ISDN equipment aspects – ATM equipment

Types and general characteristics of ATM equipment

ITU-T Recommendation I.731

(Formerly CCITT Recommendation)

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ITU-T Recommendation I.731

Types and general characteristics of ATM equipment

Summary

This Recommendation describes the types and characteristics of ATM Network Elements (NE) in terms of functional requirements.

Source

ITU-T Recommendation I.731 was revised by ITU-T Study Group 15 (1997-2000) and approved by the World Telecommunication Standardization Assembly (Montreal, 27 September – 6 October 2000).

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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As of the date of approval of this Recommendation, ITU had not 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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Introduction

This Recommendation gives an overview of the functions of ATM equipment, examples of overall characteristics and objectives for ATM network elements.

The general characteristics of ATM equipment may be described by using the functional partitioning of the network element into logical functions linked by internal communications between the functions. A general methodology which may be used to clarify the different types of ATM equipment is also contained in ITU-T I.732.

The grouping of functional functions in accordance with the B-ISDN Protocol Reference Model and the detailed modelling methodology of ITU-T I.326 enables the description of any ATM equipment to the required level of detail.

ITU-T Recommendation I.731

Types and general characteristics of ATM equipment

1 Scope

The purpose of ITU-T I.731 and I.732 is to describe the functional requirements to enable the interoperability between ATM network elements. The detailed functional characteristics of ATM equipment are contained in ITU-T I.732. ITU-T I.731 is more generalized, providing introductions and covering terms and concepts that did not easily fit into the structure of ITU-T I.732. ITU-T I.731 introduces the functional model used in ITU-T I.732 and in other technologies such as SDH and provides an overview of ATM equipment. ITU-T I.731 describes how the functional model can be used to model multipoint communications. This includes how to handle the so-called "channel merging" without corrupting the traffic and without requiring special functions. ITU-T I.731 also provides modelling for OAM applications showing how the various functions in the library can be joined together in different network elements to form an OAM application such as AIS. ITU-T I.731 also describes protection switching of ITU-T I.630 using the functional modelling technique.

This Recommendation is an update to ITU-T I.731/1995 which was the overview companion to ITU-T I.732/1995. This update has resulted in some sections moving from ITU-T I.732.

2 References

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

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

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

[3] ITU-T G.707/Y.1322 (2000), *Network node interface for the Synchronous Digital Hierarchy (SDH)*.

[4] ITU-T G.773 (1993), *Protocol suites for Q-interfaces for management of transmission systems*.

[5] ITU-T G.781 (1999), *Synchronization layer functions*.

[6] ITU-T G.783 (2000), *Characteristics of Synchronous Digital Hierarchy (SDH) equipment functional blocks*.

[7] ITU-T G.784 (1999), *Synchronous Digital Hierarchy (SDH) management*.

[8] ITU-T G.804 (1998), *ATM cell mapping into Plesiochronous Digital Hierarchy (PDH)*.

[9] ITU-T G.805 (2000), *Generic functional architecture of transport networks*.

[10] ITU-T G.806 (2000), *Characteristics of transport equipment – Description methodology and generic functionality*.

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

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

[13] ITU-T I.150 (1999), *B-ISDN asynchronous transfer mode functional characteristics*.

[14] ITU-T I.211 (1993), *B-ISDN service aspects*.

[15] ITU-T I.311 (1996), *B-ISDN general network aspects*.

[16] ITU-T I.321 (1991), *B-ISDN protocol reference model and its application*.

[17] ITU-T I.326 (1995), *Functional architecture of transport networks based on ATM*.

[18] ITU-T I.327 (1993), *B-ISDN functional architecture.*

[19] ITU-T I.356 (2000), *B-ISDN ATM layer cell transfer performance*.

[20] ITU-T I.361 (1999), *B-ISDN ATM layer specification*.

[21] ITU-T I.363 (2000), *B-ISDN ATM Adaptation Layer (AAL) specification*.

[22] ITU-T I.371 (2000), *Traffic control and congestion control in B-ISDN.*

[23] ITU-T I.413 (1993), *B-ISDN user-network interface*.

[24] ITU-T I.432 (1997), *B-ISDN user-network interface – Physical layer specification*.

[25] ITU-T I.555 (1997), *Frame Relaying Bearer Service interworking*.

[26] ITU-T I.580 (1995), *General arrangements for interworking between B-ISDN and 64 kbit/s based ISDN*.

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

[28] ITU-T I.732 (2000), *Functional characteristics of ATM equipment*.

[29] ITU-T I.751 (1996), *Asynchronous transfer mode management of the network element view*.

[30] ITU-T M.3010 (2000), *Principles for a telecommunications management network.*

[31] ITU-T Q.811 (1997), *Lower layer protocol profiles for the Q3 and X interfaces*.

[32] ITU-T Q.812 (1997), *Upper layer protocol profiles for the Q3 and X interfaces*.

[33] ITU-T Q.2100 (1994), *B-ISDN signalling ATM adaptation layer (SAAL) – Overview description*.

[34] ITU-T Q.2144 (1995), *B-ISDN signalling ATM adaptation layer – Layer management for the SAAL at the network node interface*.

[35] ITU-T Q.2761 (1999), *Functional description of the B-ISDN User Part (B-ISUP) of Signalling System No. 7*.

[36] ITU-T Q.2762 (1999), *General functions of messages and signals of the B-ISDN User Part (B-ISUP) of Signalling System No. 7*.

[37] ITU-T Q.2763 (1999), *Signalling System No. 7 B-ISDN User Part (B-ISUP) – Formats and codes*.

[38] ITU-T Q.2764 (1999), *Signalling System No. 7 B-ISDN User Part (B-ISUP) – Basic call procedures*.

[39] ITU-T Q.2931 (1995), *Digital Subscriber Signalling System No. 2 – User-Network Interface (UNI) layer 3 specification for basic call/connection control*.

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

3 Abbreviations

This Recommendation uses the following abbreviations:

AAL	ATM Adaptation Layer
ABR	Available Bit Rate
ACC	Accounting Management
AEMF	ATM Equipment Management Function
AIS	Alarm Indication Signal
ATM	Asynchronous Transfer Mode
B-ISDN	Broadband Integrated Services Digital Network
B-UNI	Broadband User Network Interface
CAC	Connection Admission Control
CBR	Constant Bit Rate
CDV	Cell Delay Variation
CLR	Cell Loss Ratio
CoF	Coordination Function
CONFIG	Configuration
CTD	Cell Transfer Delay
DBR	Deterministic Bit Rate
ETPI	Equipment Timing Physical Interface
ETS	Equipment Timing Source
FM	Fault Management
FMBS	Frame Mode Bearer Service
HEC	Header Error Control
ISDN	Integrated Services Digital Network
IWF	InterWorking Function
LMI	Layer Management Indication
MCF	Message Communications Function
NE	Network Element
NNI	Network Node Interface
NPC	Network Parameter Control
OAM	Operations And Maintenance
PDH	Plesiochronous Digital Hierarchy
PDU	Protocol Data Unit
PM	Performance Management
QOS	Quality Of Service
RM	Resource Management
SAAL	B-ISDN signalling ATM Adaptation layer

SAP	Service Access Point
SBR	Statistical Bit Rate
SDH	Synchronous Digital Hierarchy
SDU	Service Data Unit
TM	Transmission Media
TMN	Telecommunications Management Network
TP	Transmission Path
UBR	Unspecified Bit Rate
UNI	User Network Interface
UPC	Usage Parameter Control
VBR	Variable Bit Rate
VC	Virtual Channel
VP	Virtual Path

4 Definitions

This Recommendation defines the following terms:

4.1 ATM resource request:

– request to establish or release a given VP or VC connection;

– request for modifying the traffic characteristics of an already established VP or VC connection.

4.2 PVC: traditional ATM Permanent Virtual Connection that is established/released upon a request initiated by a management request procedure (i.e. all nodes supporting the connections need to be instructed by the network management).

4.3 Soft PVC: soft PVC is a Permanent Virtual Connection where the establishment within the network is done by signalling. By configuration, the switching system at one end of the soft PVC (VPC or VCC) initiates the signalling for this.

In addition, this Recommendation uses definitions and terms defined in other ITU-T Recommendations.

5 ITU-T I.732 Annex D formal model

5.1 Symbols and diagrammatic conventions

For a description of the symbols and diagrammatic conventions used in this model refer to ITU-T G.805, G.806, I.322 and I.326.

5.2 Functional modelling rationale

A limited set of atomic functions has been derived by decomposing the digital transport hierarchies to form the library contained within Annex D/I.732 together with ITU-T G.783 for the atomic functions of the Physical Layers. The contents of this library are consistent with the definitions of functions contained in the main body text of ITU-T I.732. In order to be compliant with Annex D/I.732, equipment which contains functionality defined within the Annex D/I.732 should only use the functions as explicitly defined. As technology evolves, new NEs requiring additional atomic functions may be developed.

The specification method is based on functional decomposition of the equipment into atomic and compound functions and a set of rules by which they may be combined. The equipment is then described by its Equipment Functional Specification (EFS) which lists the constituent atomic and compound functions, their interconnection, and any overall performance objectives (e.g. transfer delay, availability, etc.). The underlying principles of functional modelling are given in ITU-T G.806.

The three types of atomic functions (connection, termination and adaptation functions) used in this library are defined in clause 5/G.806.

6 Overview of equipment functions

For the purposes of this Recommendation, ATM equipment is described in terms of the functions of the user plane, control plane, layer management plane and plane management. The transfer functions are common to user plane and control plane.

6.1 Transfer functions

Transfer functions include all functions required for the transport of user, signalling, OAM, and RM information. In accordance with the B-ISDN Protocol Reference Model described in ITU-T I.321 [16], the User Plane functions are layered into those for Physical Layer processing and those for ATM Layer processing.

The transfer functions are further described in ITU-T I.732 [28].

6.2 Layer Management functions

Management information associated with a given transfer layer function is passed to (or received from) the corresponding Layer Management function, e.g. for processing of configuration, fault monitoring, performance monitoring, UPC/NPC. Configuration, performance, fault, and accounting information relating to the corresponding functions may be passed to the AEMF for further processing and/or communication to external network management entities and/or Operating Systems.

Layer Management functions correspond one-to-one with transfer functions and are further described in ITU-T I.732.

6.3 ATM Equipment Management Function (AEMF)

AEMF functions are classified into five areas:

1) configuration management;
2) fault management;
3) performance management;
4) accounting management;
5) security management.

Description of AEMF is found in ITU-T I.751 [29]. It is outside of the scope of this Recommendation which equipment management functions are actually performed in the Network Element and which functions are performed outside the Network Element.

6.4 Message Communications Function

The Message Communications Function (MCF) performs the exchange of AEMF messages with the TMN. It may be based on different protocol stacks. These include:

– X.25 [40] protocol;

– ATM protocol;

– IP protocol.

6.5 Coordination function

Some management functions may require coordination between the relevant Layer Management functions at the different layers. This coordination function is part of the overall Plane Management.

The coordination function processes requests through the Control Plane (C-Plane) and the Management Plane (M-Plane) for network resources and messages between the layer management. It includes:

– Internal communications between layers;

– Fault Management: Consequent Actions and Defect Correlations.

For further description, refer to clause 6/I.732.

6.6 Connection Admission Control (CAC) function

In an ATM NE, a request to establish or release a given VP or VC connection with given bandwidth/QOS parameters may be initiated independently by both the AEMF via the management interface (e.g. Q3) and the Signalling Application. Modification of Bandwidth/QOS parameters may be initiated by the management interface, the Signalling Application or the Resource Management (RM) protocol. The assignment of NE resources to a connection derived from negotiated or renegotiated traffic and QOS parameters is the responsibility of the CAC function in accordance with ITU-T I.371 [22]. The routing functions are therefore not included in the NE level CAC. The CAC algorithm used by the ATM NE is implementation specific.

For further description, refer to clause 7/I.732.

6.7 Signalling Application

NOTE – Other signalling protocols, such as, e.g. P-NNI are for further study.

At the User Network Interface (UNI) the signalling procedures and messages shall be in accordance with ITU-T Q.2931 [39]. The basic set of UNI signalling procedures are defined in ITU-T Q.2931 (B-ISDN Digital Service Signalling System (DSS2), User Network Interface Layer 3 specification for Basic Call/Connection control).

At the Network Node Interface (NNI) the signalling procedures and messages shall be in accordance with ITU-T Q.2761 [35], Q.2762 [36], Q.2763 [37] and Q.2764 [38], that as a set, form the basis for the Broadband ISDN User Part (B-ISUP).

6.8 Timing function

The timing functions deal with the actions required to synchronize the equipment interfaces, either ATM interfaces or non-ATM interfaces, to a clock source (e.g. network, external or internal).

For further description, refer to clause 12.

6.9 Interworking functions

Depending on Service Provider requirements, interworking between ATM based services and other network services may in some instances be supported by the ATM equipment.

For interworking between B-ISDN/ATM and ISDN network elements the Interworking Function (IWF) should be in accordance with ITU-T I.580 [26].

For interworking between B-ISDN/ATM and Frame Mode Bearer Services (FMBS) the Interworking Function (IWF) should be in accordance with ITU-T I.555 [25].

ATM equipment requirements for interworking between B-ISDN and other network services is for further study.

Two general scenarios for interworking between B-ISDN/ATM and other networks have been identified:

– In one scenario the B-ISDN/ATM network simply encapsulates the higher layer Service or Protocol Data Unit (SDU/PDU) for transparent transport through the B-ISDN.
– In the more complex scenario, the services provided by the other (e.g. FMBS, ISDN, etc.) network is mapped wholly or partially into the B-ISDN/ATM services at the IWF (termed Service Interworking). This requires the IWF to partially or wholly terminate protocol functions.

It is a network option as to which interworking scenario may be supported.

Equipment functional requirements related to these different interworking scenarios are for further study.

7 Connection types and characteristics

7.1 Connection types

ITU-T I.150 [13] describes the rules for making connections from links and describes how unidirectional communication capability can be constructed from a bidirectional connection with asymmetric bandwidth. ITU-T I.326 [17] discusses multipoint connections in ATM. For each of the multipoint connection types a figure is provided giving an example for the connectivity capability. The figures can show network wide connectivity irrespective of the VP or VC layer, in which case the "ellipse" is a node. The figures can also show element wide connectivity irrespective of the VP or VC layer, in which case the "ellipse" is a connection matrix (see Figures 1 to 7).

The defined connection types are:

– point-to-point connection (unidirectional):

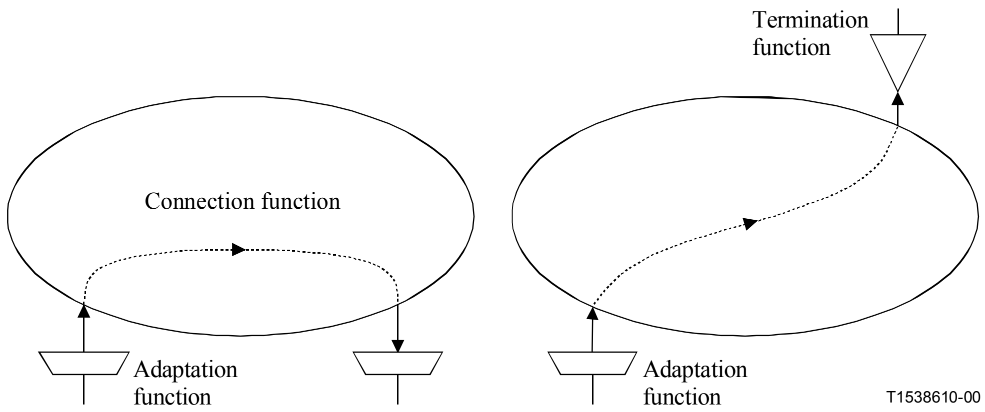

Figure 1/I.731 – Two examples of unidirectional point-to-point connection

– point-to-point connection (bidirectional):

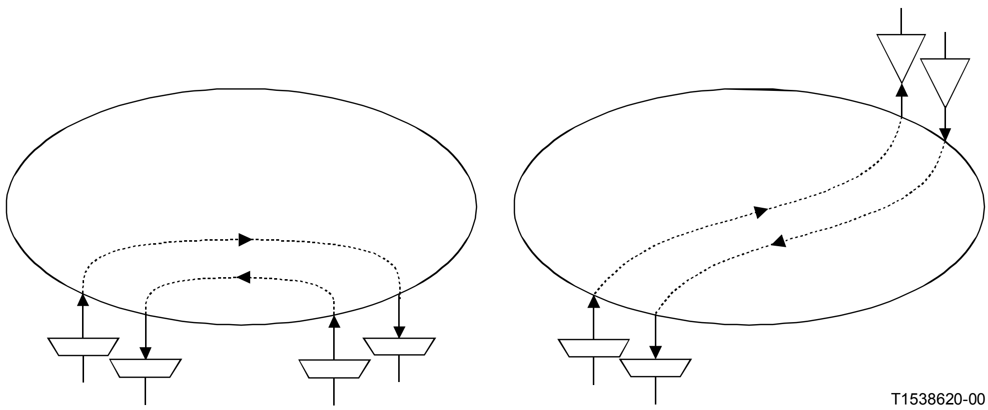

Figure 2/I.731 – Two examples of bidirectional point-to-point connection

– point-to-multipoint connection (unidirectional):

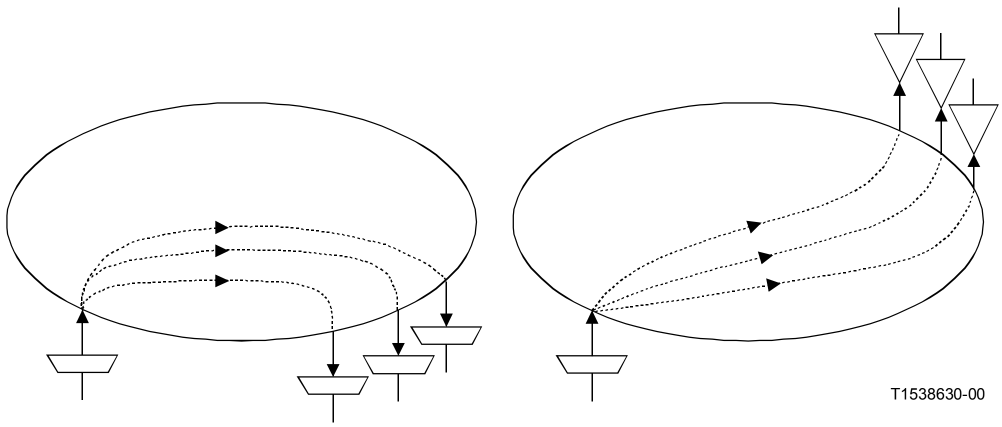

Figure 3/I.731 – Two examples of unidirectional point-to-multipoint connection

– point-to-multipoint connection (bidirectional):

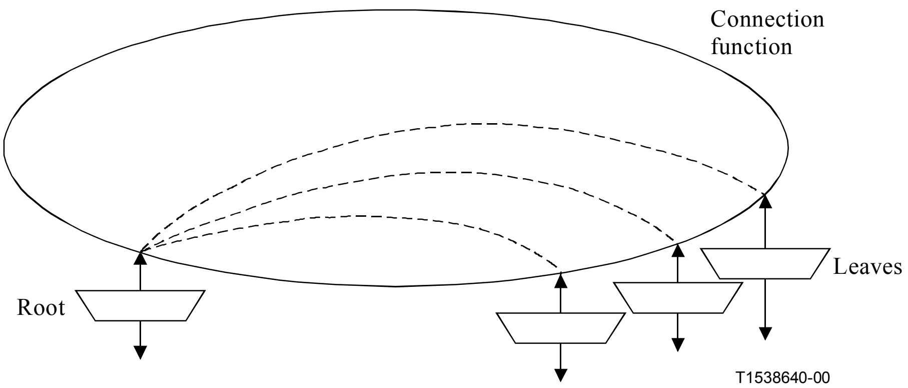

Figure 4/I.731 – Example for bidirectional point-to-multipoint connection

– multipoint-to-point connection (unidirectional):

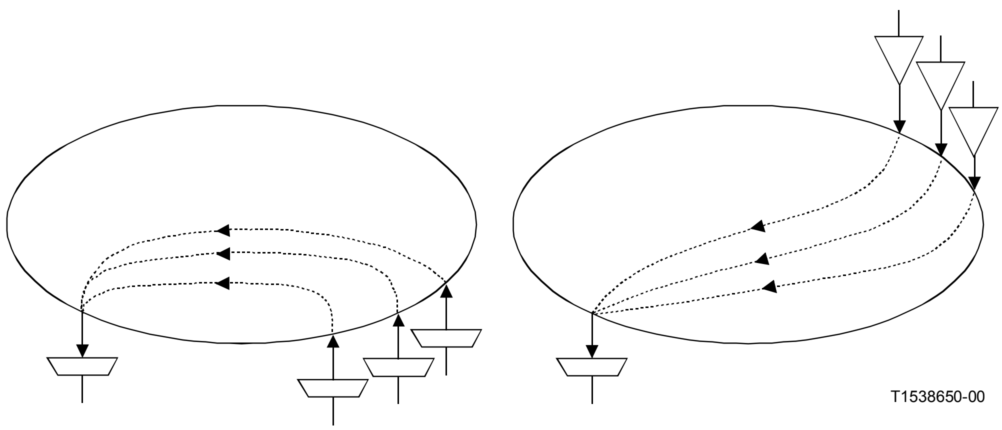

Figure 5/I.731 – Two examples of unidirectional multipoint-to-point connection

– multipoint-to-multipoint connection (unidirectional):

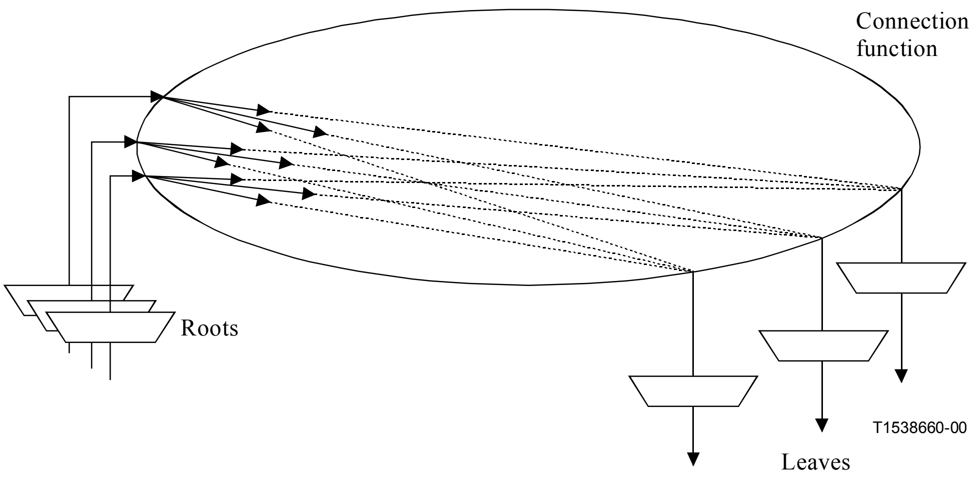

Figure 6/I.731 – Example for unidirectional multipoint-to-multipoint connection

– multipoint-to-multipoint connection (bidirectional):

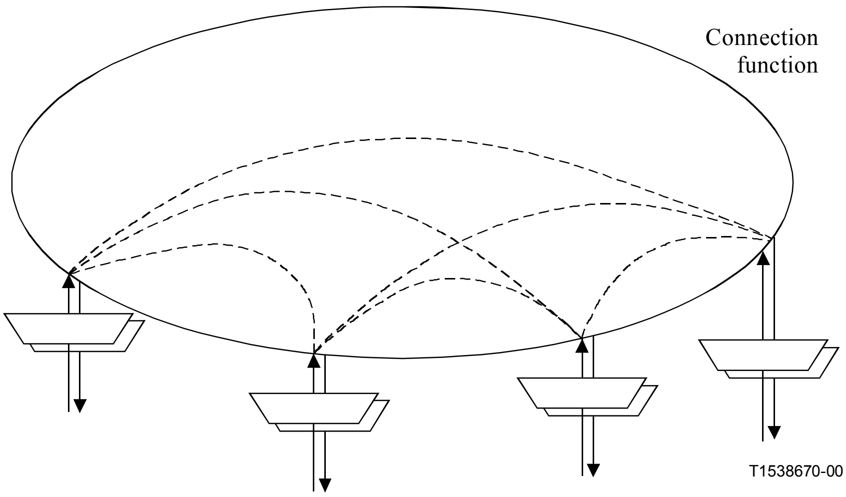

Figure 7/I.731 – Example for bidirectional multipoint-to-multipoint connection

7.1.1 Point-to-point connections

A description of bidirectional point-to-point connections is for further study.

The requirement for unidirectional point-to-point connections is for further study.

7.1.2 Point-to-multipoint connections

7.1.2.1 Overview

Point-to-multipoint connections interconnect multiple connection endpoints by using a tree topology as shown in Figures 3 and 4. Thereby, one endpoint (called root node) sends cells which are copied at the tree's intermediate vertices and sent directly to all other endpoints (called leaf nodes). Each leaf node can send cells directly to the root node, but leaf nodes cannot communicate directly among each other. Depending on the bandwidth allocated in root-to-leaf and in leaf-to-root direction, point-to-multipoint connections can be unidirectional or bidirectional. Bidirectional point-to-multipoint connections (also called composite connections according to ITU-T I.326 [17]) can be symmetrical or asymmetrical. It may be necessary to send cell copies to each interface connected to the NE (full multipoint according to ITU-T I.326).

7.1.2.2 Definitions

To support the defined multipoint connection types, two ATM layer connection functions, namely ATM cell multicast and ATM channel merging, are defined.

7.1.2.2.1 ATM cell multicast

ATM cell multicast implies copying of cells from one root and routing of the cell copies to multiple destinations, called leaves.

Figure 8 shows the different options for ATM cell multicast, which are distinguished by the destinations of the cell copies.

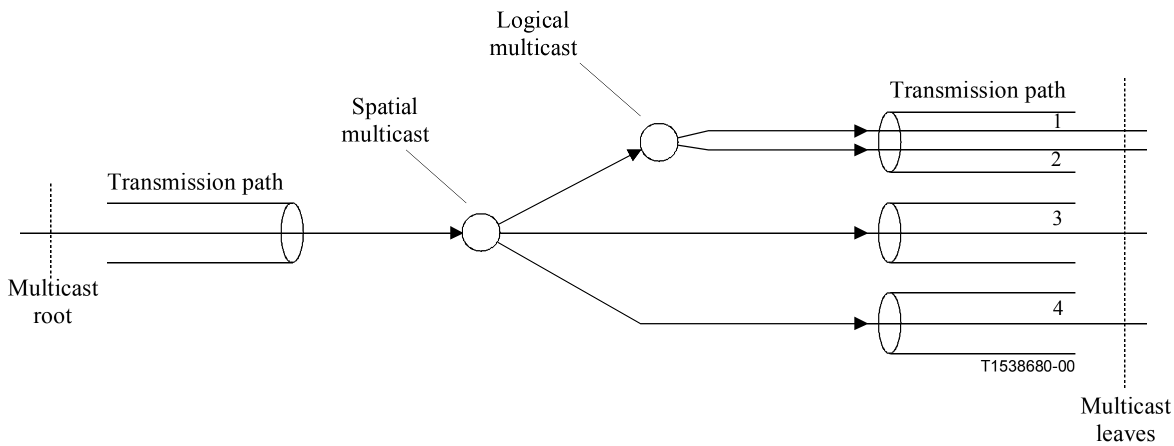

Figure 8/I.731 – Example for spatial and logical multicast for point-to-multipoint connections

7.1.2.2.2 Spatial multicast

If the destination of the cell copies are different transmissions paths, the operation is called ATM spatial multicast. Within the switching network, cells are physically multiplied by sending them to several outputs. Since the ATM connection identifier (Virtual Path Identifier (VPI) or VPI/Virtual Channel Identifier (VCI) depending on the layer) used by the root may already be in use by another connection on the server layer, header translation may be required.

7.1.2.2.3 Logical multicast

If several leaves share the same Transmission Path (TP), e.g. several cell copies have to be sent over the same Virtual Container level 4 (VC-4), the operation is called ATM logical multicast. In this case, a cell is sent repeatedly to the same port with different VPI/VCI values. It is possible, for example, to put one Virtual Channel Connection (VCC) into several Virtual Path Connections (VPCs) with different VCI values.

7.1.3 Multipoint-to-point connections

There are two mechanisms by which multipoint-to-point connections can be constructed: by channel merging in the same layer or by keeping the channels separate and bringing them together at a higher layer. The channel merging technique is the concept that has been long established in ATM.

However it will only work in a small selection of cases where the communications carry a source identifier within a higher layer or where the communications have no need to identify the source.

7.1.3.1 Merging is different from multiplexing

ATM VP multiplexing consists of mixing ATM cells of many VPCs into the same transport path but being able to distinguish them from each other thanks to their VPI values. The ATM VC multiplexing consists of mixing ATM cells of many VCCs into the same VPC, but being able to distinguish them from each other thanks to their VCI values.

The main fundamental characteristic of the ATM VP (respectively VC) merging is that all cells after being merged have the single VPI value of the root (respectively [VPI, VCI] values of the root).

It has the drawback to prevent identification of the source of the traffic at the ATM VP (respectively VC) level.

This rule makes the merging different from the multiplexing, where the information is clearly identified.

7.1.3.2 The use of merging

7.1.3.2.1 Identification of the information at higher layer(s)

When using merging, the information is mixed up at a given layer, without any chance to demultiplex it at this layer. However, it is possible to demultiplex the information at higher layers.

If necessary, the demultiplexing of the information merged at the ATM VP (respectively VC) level can be done at the VC layer (respectively AAL):

– when considering merging at the VP level, the demultiplexing can be done by using the VCI values. It allows for distinguishing the different flows coming from different VP connections and which have been previously merged into one single ATM VP connection. The condition for that is that the VCI values of the different VPCs leaves have to be arranged to be different. If not, it will not be possible to distinguish two merged cells coming from two different VPCs and with the same VCI. This condition shall be checked when setting up the VCCs (e.g. by configuration);

– when considering merging at the VC level, some AALs provide for a multiplex identifier so that the far end can demultiplex the different streams. In AAL 3/4, the MID field allows for distinguishing different flows coming from different VC connections and merged into one single ATM VC connection. However, one condition for this is to be able to rebuilt the AAL 3/4 Protocol Data Unit (PDU) correctly when terminating the multipoint-to-point ATM connection. This aspect is treated in 6.5.3. The AAL 2 also provides an identifier for multiplexing/demultiplexing different flows.

7.1.3.3 Merging scheme

A second aspect of VC channel merging is the way the information (the ATM cells) coming from several leaves is mixed up onto the root connection.

This aspect is called the "merging scheme". It has to be taken into account when:

– the upper layer makes use of a PDU which is too big to be projected into one single cell; and

– the upper layer needs to rebuild the messages for processing them (e.g. ITU-T X.25 [40] packets).

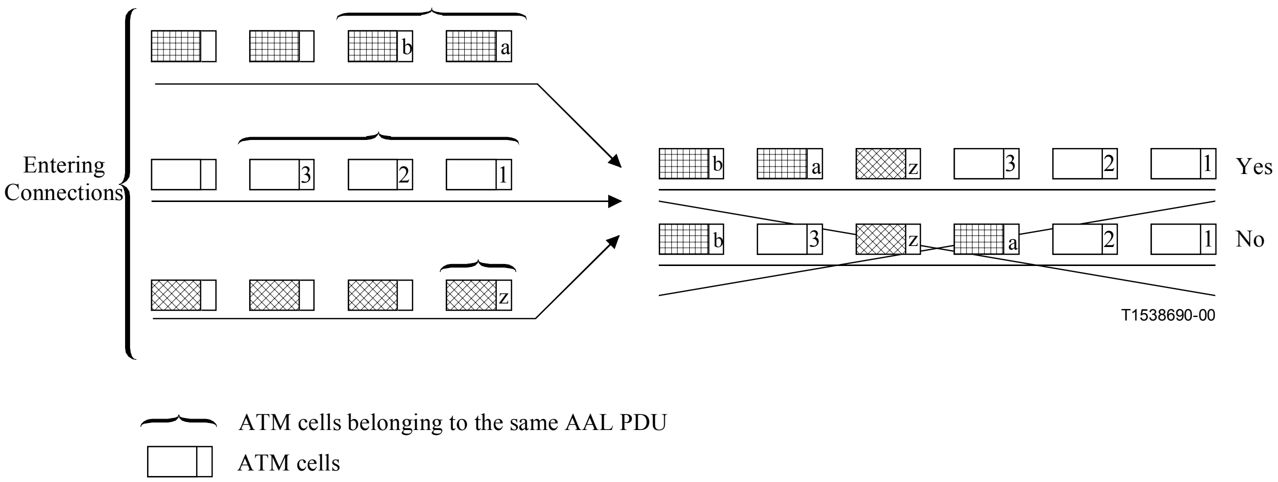

Figure 9/I.731 – Example of a merging scheme where cell ordering needs to be respected

The condition for being able to **rebuild the messages**, is that they **shall not be embedded or overlapped**. For that purpose, an indication of the structure of the messages has to be known at the ATM level for allowing a correct merging scheme. For example:

– when using the AAL 5, the Payload Type Identifier (PTI) field indicates the end of each message;

– for some applications, the RM cells are used to delineate each message (as in ABT, for example).

In the two previous cases, the equipment can access the structure of the message at the ATM layer and merge the ATM cells on a "message basis", by avoiding mixing up cells belonging to different messages (see Figure 9).

If the messages are embedded or overlapped then a more complicated solution is required which either seeks to control the sources so that only a single message is in transit at any one time or the message PDUs are reconstructed at a higher layer. The solution of controlling the sources is seen as impractical as it increases the delay, requires a complicated timing and token scheme, and is prone to hacking. The solution which consists of rebuilding the messages of the upper layer for allowing a good ATM merging scheme cannot be considered as a "purely" ATM solution, since the equipment would terminate the ATM connection and process the upper layer PDU. These approaches also increase costs and delays.

Due to these limitations an alternative technique, defined in the following clause, was developed.

7.1.3.4 Bypassing merging

The alternative solution of merging at an equipment level consists of replacing a [N] multipoint-to-point unidirectional connection by N point-to-point unidirectional connections (see Figure 10). This solution is a network level solution.

In that case, each leaf is characterized by its ATM VPI or (VCI, VPI), and each leaf is connected to the root by a single unidirectional point-to-point connection.

This solution prevents from developing specific features in the equipment and allows for emulating merging very easily. The emulation of the merging takes place at the root with multiplexing in the middle of the network for the reverse direction. This division of labour is particularly important since it avoids having a "merge point" in the middle of the network. The interworking with higher layer protocols to reconstitute the "messages" from different users is handled at the root. The root is then able to forward or process the discrete "messages" from each distinct user. Hence all the root has to do is support having multiple "sockets" or occurrences on the same protocol stack, perhaps in the same way that a windows PC can run multiple copies of a word-processor. This is particularly important compared to a real merge point in the middle of the network where it shall be of high efficiency and able to take into account the message structure of the higher layer protocols.

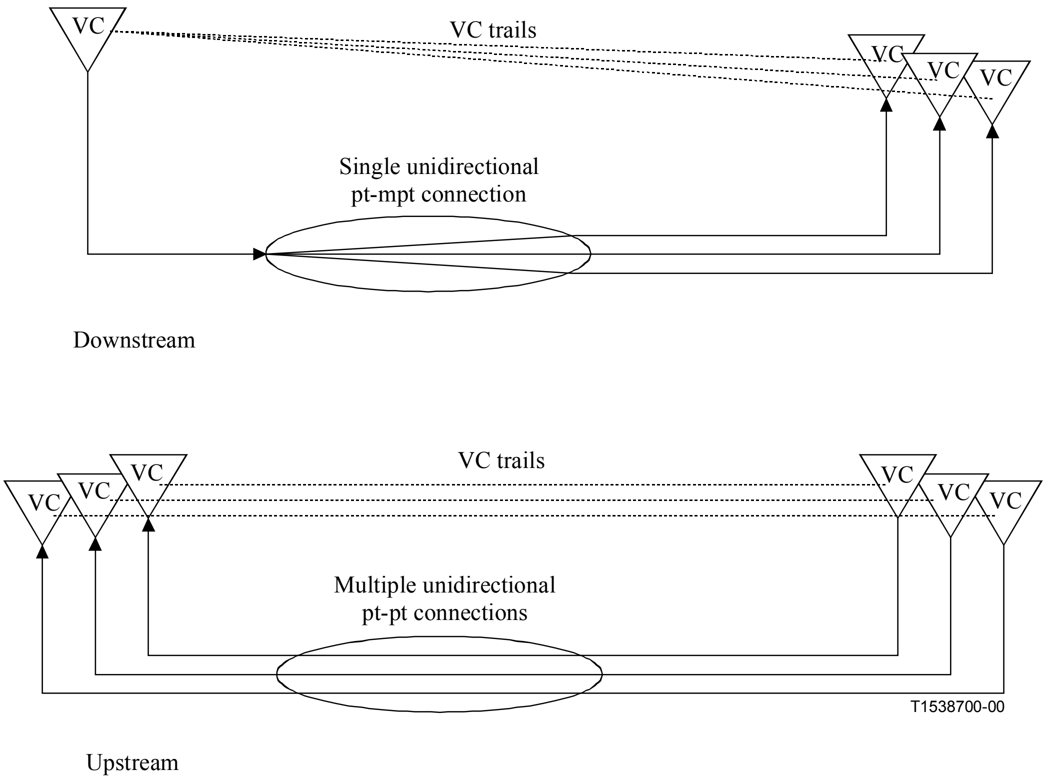

Figure 10/I.731 – Combining simple connection types to form a bidirectional point-to-multipoint capability

7.1.4 Multipoint-to-multipoint connections

Multipoint-to-multipoint connections interconnect multiple connection endpoints such that cells originating at any endpoint are copied and sent to each remaining endpoint involved in the connection, i.e. if the multipoint-to-multipoint connection involves N endpoints, every endpoint involved in a multipoint-to-multipoint connection serves as a root in a tree for all of the remaining N-1 endpoints and at the same time as a leaf for the N-1 trees originating at the other N-1 endpoints (Figures 6 and 7). Multipoint-to-multipoint connections can be symmetrical or asymmetrical.

7.1.5 OAM aspects of multipoint connections

The current OAM standards and recommendations do not allow for coping with merging connections. Therefore, I.732 Annex D [28] does not allow for coping with OAM aspects for ATM merged connections. For example, the receipt of multiple Receive Defect Indication (RDI) in response to a single downstream AIS has to be solved. That means that the development of services based on ATM merged connections today with an associated maintenance at the ATM level should make use of the merging-bypass solution.

7.2 Methods of establishing connections

7.2.1 Permanent Virtual Connections (PVC)

Text describing the connectivity capabilities for PVCs will be provided in a later version of this Recommendation.

7.2.1.1 PVCs

PVCs are the traditional Permanent Virtual connections.

7.2.1.2 Soft PVCs

This is a network level function. It is realized by signalling and management functions and is not a different connection type. Text describing the connectivity capabilities for soft PVCs in this Recommendation is for further study.

7.2.2 Switched virtual connections

Text describing the connectivity capabilities of SVC connections are for further study.

Whether unidirectional SVC connections are allowed is for further study.

7.3 Transfer Capabilities

ITU-T has introduced a number of Transfer Capabilities applicable to individual connections. In ITU-T I.371 [22] a number of ATM Transfer Capabilities (ATC) are defined (refer to Table 1 and clause 6 of ITU-T I.371). The mapping between the traffic classes, as defined in [1] of Appendix II – Bibliography, and the ITU-T ATCs are given in Table 1 below. This table is for information only.

ITU-T specifies ATM transfer layer performance parameters objectives associated with QoS classes, whereas [1] of Appendix II defines ATM service categories which link up ATM transfer capabilities and QoS classes; so, before giving the NE performance objectives, it is useful to have a reminder of these different approaches, in order to know which performance objectives are applicable to which (ATC, QoS) combination or to which service category.

Table 1 gives the correspondence between ATCs and QoS classes as defined by ITU-T, and the service categories as defined by [1] of Appendix II . Shaded boxes give the (ATC, QoS class) combinations that are defined within ITU-T (see ITU-T I.356 [19]). There are no ITU-T equivalents of VBR2-rt, VBR3-rt and UBR2 service categories as defined in [1] of Appendix II.

Table 1/I.731 – Mapping between ITU-T Transfer Capabilities and Traffic Classes

	Class 1 (stringent class)	**Class 2 (tolerant class)**	**Class 3 (bi-level class)**	**U Unbounded class**
DBR	CBR1			UBR1
SBR1	VBR1-rt	VBR1-nrt		
SBR2			VBR2-nrt	
SBR3			VBR3-nrt	
ABT/DT				
ABT/IT				
ABR			ABR	
NOTE – GFR traffic class is for further study.				

8 OAM functions

It is not recommended to provide all OAM functions for all active connections simultaneously, e.g. PM may only be required for a percentage of active connections.

However, AIS and RDI functionality shall be provided for all active connections.

Continuity Check (CC) is suggested for all active connections (note that there are two options for CC functionality in ITU-T I.610 [27]).

LB OAM cell capability shall be possible for an active connection.

It is only necessary to provide N instances of PM capability that can be assigned to active connections. The value of N is dependent on the equipment and its usage, and is negotiable between the supplier and purchaser.

It should be noted that some fields of the OAM functions could be optional (e.g. the "Time Stamp" field in the performance management cells).

The OAM mechanisms have been designed for point-to-point and cross-connected connections. There is no clear restriction for the time being on the use of these mechanisms for switched connections. The use of OAM for switched connections and for point-to-multipoint connections are currently under study.

8.1 OAM naming conventions for ATM

ITU-T I.732 [28] keeps the transfer and layer management functions separate.

The OAM functions make it possible to have an inband mechanism for:

– defect and failure detection;
– fault localization;
– defect information;
– performance monitoring;
– system protection.

The OAM specification for ATM in ITU-T I.610 [27] classifies OAM functions into 5 levels, called "Flows", which are numbered F1 to F5.

The OAM functions related to Flows 1-3 are defined in the appropriate physical layer specification, e.g. ITU-T G.783 [6] for SDH and ITU-T G.705 for PDH structured interfaces and ITU-T I.432.2 [24] for cell-based interfaces. Note that the ATM terminology of F-n flows may not be used by those physical layers.

The OAM flow related to the ATM-layer (the expression "layer" is used in the sense of ITU-T I.321 [16]) is provided by means of specific cells named "F4/F5 cells" whose structure is defined in ITU-T I.610 [27]. The writing convention is that all flows are assumed to be End-to-End (e-to-e) unless specifically identified as Segment flows.

8.2 OAM procedures

This clause will provide an overview showing how the I.732 Annex D atomic functions can be connected together to form the OAM applications.

The following clauses have been identified, other clauses for OAM applications will be added where necessary.

8.2.1 AIS application

For further study.

8.2.2 RDI application

For further study.

8.2.3 CC application

For further study.

8.2.4 LB application

For further study.

8.2.5 Performance Management application

For further study.

9 Protection switching and restoration

An ATM network element can provide protection at physical layer and/or at ATM layer.

Physical layer protection switching capabilities may be provided, e.g. for SDH-based interfaces by STM-N Multiplex Section Linear Protection functionality (described in ITU-T G.707 [3] and ITU-T G.783 [6]) or STM-N Multiplex Section shared protection ring functionality (described in ITU-T G.841).

ATM layer protection switching capabilities may be provided at VP or VC layer, according to ITU-T I.630. Five different ATM VP and VC protection schemes have been defined:

– 1+1/1:1 trail protection;
– 1+1/1:1 SNC/S protection;
– 1+1 SNC/N protection (unidirectional only);
– 1+1/1:1 trail/T group protection;
– 1+1/1:1 SNC/T group protection.

The following clauses provide an overview of the NE functionality required to implement the ATM protection switching, using as a reference the functional model of ITU-T I.732.

9.1 Trail VP and VC individual protection (1+1/1:1 trail)

For further study.

9.2 Segment VP and VC individual protection (1+1/1:1 SNC/S)

For further study.

9.3 Subnetwork VP and VC individual protection (1+1 SNC/N)

ITU-T I.630 defines only the unidirectional 1+1 SNC/N protection, using the non-intrusive monitoring (NIM) point on the end-to-end OAM flow.

Because SNC/N is only 1+1 and unidirectional, APS protocol is not present.

In the source point, the connection function (i.e. the VP_C or the VC_C atomic function) implements the bridge function.

Figure 11 shows the model of 1+1 SNC/N unidirectional protection in the source point for a VP subnetwork connection. A similar model applies also to the VC layer.

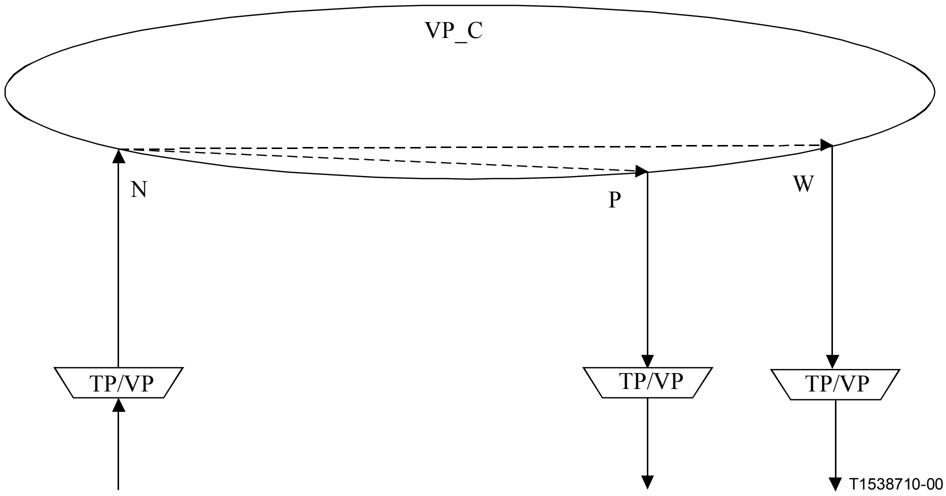

Figure 11/I.731 – 1+1 VP SNC/N unidirectional individual protection model in the source point

In the sink point, the protection switching process in the connection function (i.e. the VP_C or the VC_C atomic function) controls the selector between the working and the protection connections, according to ITU-T I.630.

The signal fail and the signal degrade conditions are detected in the monitoring function (i.e. the VPM_TT_Sk or the VCM_TT_Sk atomic function) and are signalled to the protection switching by the AI_TSF and AI_TSD signals. External commands for manual control are forwarded by the AEMF through the MI_ExtCmd. The wait-to-restore and the hold-off timer are configured by the AEMF through the MI_WTRtime and MI_HOtime.

Figure 12 shows the model of 1+1 SNC/N unidirectional protection in the sink point for a VP subnetwork connection. A similar model applies also to the VC layer.

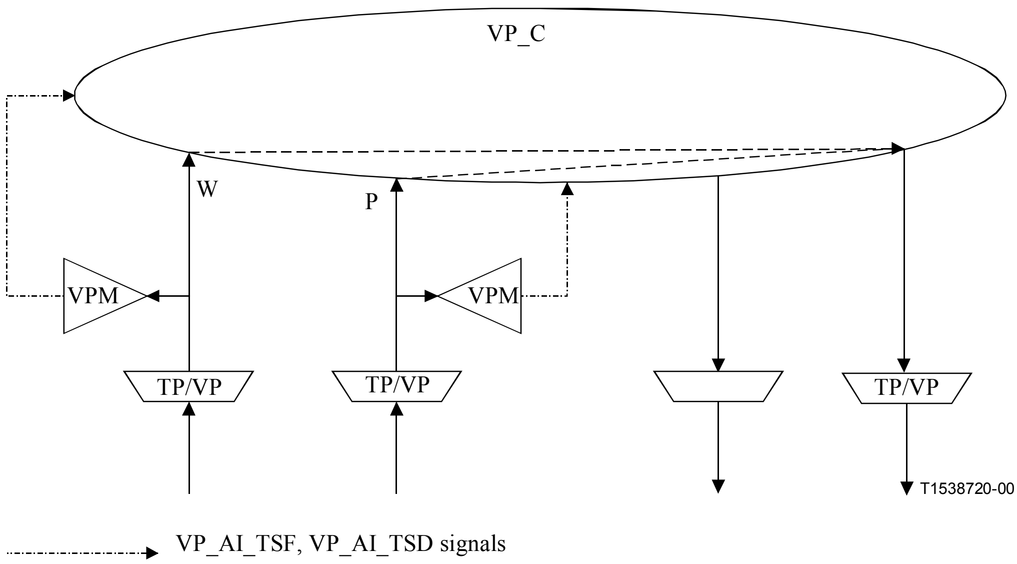

Figure 12/I.731 – 1+1 VP SNC/N unidirectional individual protection model in the sink point

9.4 Trail VP and VC group protection (1+1/1:1 trail/T)

For further study.

9.5 Subnetwork VP and VC group protection (1+1/1:1 SNC/T)

ITU-T I.630 defines 1+1 SNC/T and 1:1 SNC/T unidirectional and bidirectional protection.

In case of 1:1 or bidirectional 1+1 SNC/T protection scheme, the APS protocol should be implemented by the connection function (i.e. the VP_C or the VC_C atomic function). Because insertion/extraction of cells is mainly a sink/source function, the APS cells are inserted by the VP/VPP_A_So and extracted by the VP/VPP_A_Sk. The AEMF shall properly enable the APS insertion/extraction process in the VP/VPP_A functions.

In the source point, the connection function (i.e. the VP_C or the VC_C atomic function) implements the bridge function in case of unidirectional 1+1 SNC/T protection.

In case of 1:1 or bidirectional 1+1 SNC/T protection, the protection switching process of the connection function controls the selector between the working and protection connections, according to ITU-T I.630.

The selector applies to all the connections of the group. This means that all the connections in the normal (N) group are cross-connected either to all the corresponding connections in the working (W) group or to all the corresponding connections in the protection (P) group. External commands for manual control are forwarded by the AEMF through the MI_ExtCmd.

NOTE – The extra-traffic function, for the 1:1 SNC/T protection scheme is for further study.

Figure 13 shows the model of SNC/T protection in the source point for a VP subnetwork connection. A similar model applies also to the VC layer.

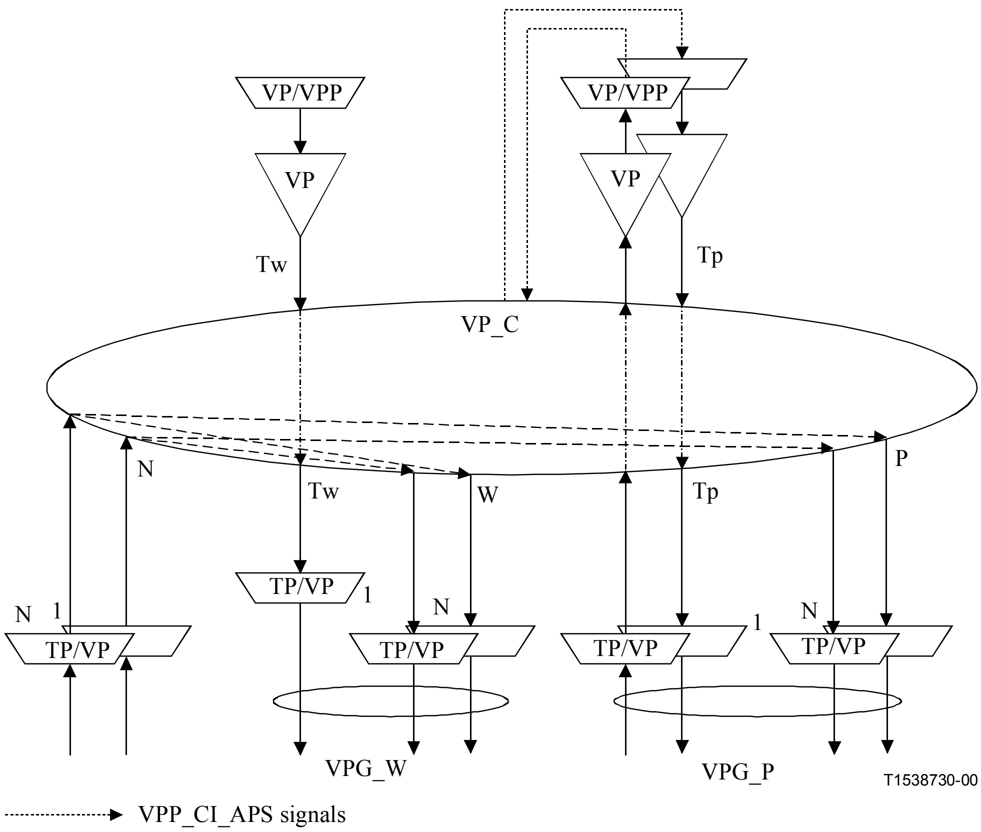

Figure 13/I.731 – 1+1/1:1 VP SNC/T group protection model in the source point

In the sink point, the protection switching process of the connection function controls the selector between the working and protection connections, according to ITU-T I.630.

The selector applies to all the connections of the group. This means that either all the connections in the working (W) group or all the connections in the protection (P) group are cross-connected to the corresponding connections in the normal (N) group.

NOTE – The extra-traffic function, for the 1:1 SNC/T protection scheme is for further study.

The signal fail conditions are detected in the trail termination function (i.e. the VP_TT_Sk or the VC_TT_Sk atomic function) of the test trails and they are signalled to the adaptation function through the AI_TSF. The adaptation function (i.e. the VP/VPP_A_Sk or the VC/VCP_A_Sk atomic function) will inform the connection function (i.e. the VP_C or the VC_C atomic function) through the CI_SSF signal. External commands for manual control are forwarded by the AEMF through the MI_ExtCmd. The wait-to-restore and the hold-off timer are configured by the AEMF through the MI_WTRtime and MI_HOtime.

NOTE – The detection of the signal degrade conditions for the SNC/T protection scheme is for further study in ITU-T I.630.

Figure 14 shows the model of SNC/T protection in the sink point for a VP subnetwork connection. A similar model applies also to the VC layer.

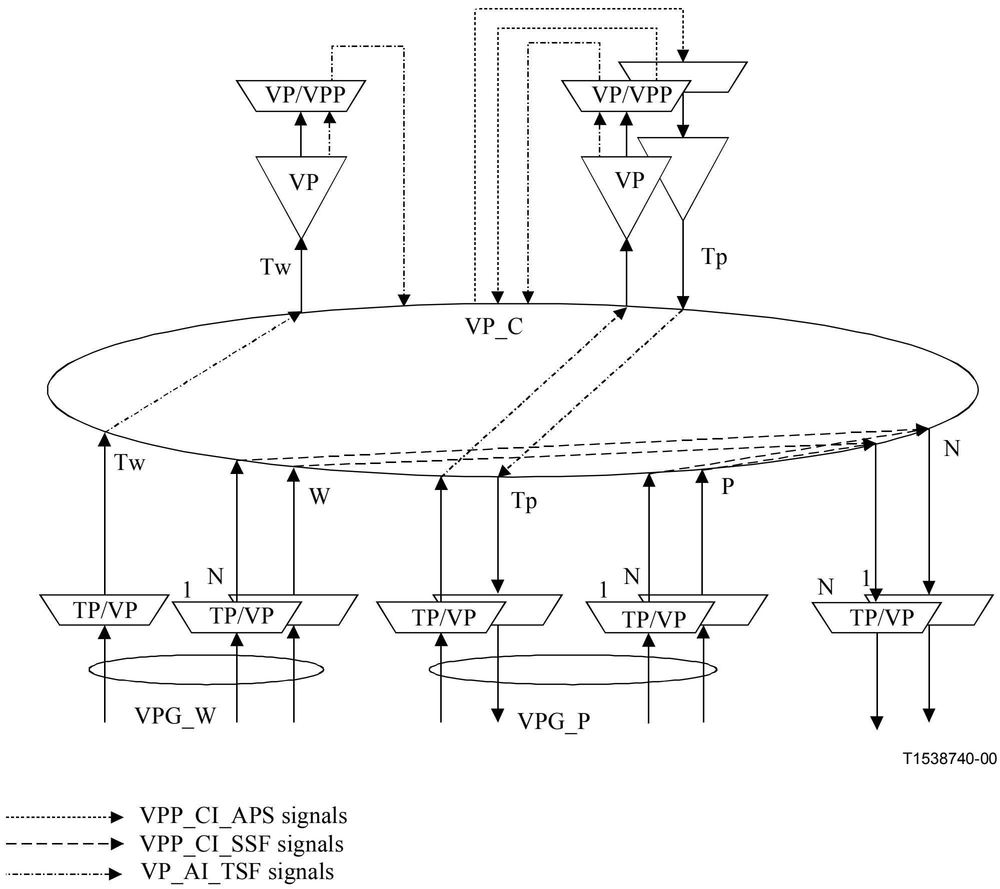

Figure 14/I.731 – 1+1/1:1 VP SNC/T group protection model in the source point

10 Traffic measurement functions

The necessity to set different performance objectives for different pieces of equipment is for further study.

It is for further study whether different classes of equipment may be required to only measure a subset of the parameters.

Traffic measurements is a main function required to get the necessary information (in short term and in the longer term) on how traffic varies with time in the network. The results can be taken into account for network dimensioning (i.e. efficient usage of network resources, evaluation of capabilities for additional end customer connections, definition of routing tables), tariff structure definitions and traffic contract supervision.

The dimensioning of an ATM network shall guarantee an optimized usage of the provided network resources with a high quality of service for the end customers, and also a high availability of the network resources.

NOTE – There is an OAM cells counter only defined in ITU-T I.751 [29]. This counter does not appear in ITU-T I.732 [28]. The formerly proposed OAM only counters are for further study.

10.1 Traffic information collection

The definitions used for the traffic parameters in this clause can be found in ITU-T I.751.

10.1.1 TP usage measurement

The operations interface shall provide the OS with the ability to retrieve current counts (15-minute/24-hour) of the following information from the TP/VP_A:

– ingress cells (whole stream);
– ingress cells Cell Loss Priority (CLP = 0);
– egress cells (whole stream);
– egress cells CLP = 0.

NOTE –These measurements are for all cells excluding idle cells, corresponding to usage measurement in Table 4-1/I.732. These measurements are not the same as per VP measurements and should not be confused with them. These counts allow the OS to assess the network utilization in real-time and allow for capacity planning.

10.1.2 ATM cell level procedure performance information collection

Cell level procedure monitoring involves collecting and thresholding information counts that measure an ATM NE's ability to successfully process and deliver incoming ATM cells. Cell level procedure monitoring is particularly concerned with procedure abnormalities detected at the adaptation between the TP and the VP layers, and at the adaptation between the VP and the VC layers.

The operations interface shall provide to the OS the ability to retrieve current counts (15-minute/24-hour) of the following information from each ATM TP/VP_A:

Invalid HEC cell discard events: This parameter provides a count of the number of incoming ATM cells discarded due to the header being examined and found to be in error (see HEC process in ITU-T I.432.1 [24]).

Invalid HEC events: This parameter provides a count of the number of cells where the header is examined and found to be in error, independent of whether the error was correctable or not (see HEC process in ITU-T I.432.1).

Discarded cells due to unprovisioned VP or VC: There is a common counter for the cells that have a valid HEC but are discarded due to an invalid header, invalid VPI, and invalid VCI cell discard.

This counter may receive inputs from the TP/VP_A function and each VP/VC_A for each VP that has been established.

10.1.3 VP and VC traffic load information collection

The operations interface shall provide, mandatory to the OS, the ability to retrieve current counts (15-minute/24-hour) of the following information for selected VPTM_TT_Sk and VCTM_TT_Sk. This corresponds to usage measurement in Table 4-1/I.732 and 6.3.2.3/I.751:

– Ingress cells (whole stream);

– Egress cells (whole stream).

These counts allow the OS to assess the network utilization in real-time and allow for capacity planning.

10.1.4 VP and VC UPC/NPC information collection

UPC and NPC algorithms are intended to enforce the traffic contract of the incoming cells to ensure that each access connection supported by the ATM NE is complying with pre-negotiated traffic descriptors. Since cells discarded due to UPC/NPC functions and cells discarded due to transmission errors and malfunctions will have the same effect on the e-to-e performance of a VPC/VCC, it is important for trouble shooting and trouble sectionalization purposes to provide network managers with the tools needed to distinguish between these two events.

The following operations interface capabilities are required, so that management applications can retrieve ATM NE collected information that reflects the extent to which individual connections are violating their prenegotiated traffic descriptors.

The operations interface shall provide to the OS the ability to retrieve current counts (15-minute/24-hour) of the following information from selected VP and VC links for which UPC/NPC Disagreement Monitoring is being performed:

– Discarded Cells due to UPC/NPC Disagreements (whole stream)

  This parameter provides a count of the number of ATM cells discarded due to traffic descriptor violations, detected by the combined CLP = 0 and CLP = 1 UPC/NPC policing function.

– Discarded CLP = 0 Cells due to UPC/NPC Disagreements (whole stream)

  This parameter provides a count of the number of high priority (CLP = 0) ATM cells, discarded due to traffic descriptor violations detected by the CLP = 0 UPC/NPC policing function. This counter is only required if CLP = 0 traffic is separately policed.

– Tagged CLP = 0 cells (whole stream)

  This parameter provides a count of the cells which have been tagged.

– Successfully Passed Cells (whole stream)

  This parameter provides a count of the number of cells that have been passed (i.e. not discarded) by the combined CLP = 0 and CLP = 1 UPC/NPC policing function. Successfully passed cells are not counted in ITU-T I.732; these parameters can be derived from the other counters.

– Successfully Passed CLP = 0 Cells (whole stream)

  This parameter provides a count of the number of high priority cells that have been passed (i.e. not discarded) by the CLP = 0 UPC/NPC policing function. This counter is only required if CLP = 0 traffic is separately policed. Successfully passed cells are not counted in ITU-T I.732; these parameters can be derived from the other counters.

10.1.5 Call level information collection

With the support of Switched Virtual Connections (SVC) the dimensioning of an ATM network element depends also on the behaviour of the end customers. Much more important now are the number of seizures by a single end customer, the duration of the SVCs and the flexibility of the destinations for a call.

For the call processing performance, the number of call attempts, valid call attempts shall be counted. These parameters are measured in normal resource load conditions (i.e. a call will not be rejected due to a lack of transfer resources):

– a call attempt is counted when receiving a Setup/Initial Address Message (IAM) (signalling) message per access and call direction;

– a valid call attempt is counted per access and call direction when a Setup/IAM message has been sent with respect to the conditions described in Annex A/I.358 and the call has been established.

How to associate a connection to a customer with SVCs for maintenance, SLAD (as in ITU-T I.732) checking and billing is for further study.

As SVCs are very short in length it may be necessary to change how and what is measured. This is for further study.

11 Generic performance requirements

11.1 Quality of Service aspects

B-ISDNs are envisaged to support a range of bearers/Network Services which may require different QOS categories, depending on Network Operator/Service Providers choice.

The ATM Equipment should be capable, by means of appropriate traffic engineering and resource allocation of both bandwidth and buffer capacity, of providing sufficient performance in terms of the selected parameters such as Cell Loss Ratio (CLR), Cell Transfer Delay (CTD) and Cell Delay Variation (CDV), to meet the QOS requirements specified by the Service Provider.

The functions required as a basis for ATM resource management shall be in accordance with ITU-T I.371 [22]. These include:

1) Usage Parameter Control (UPC)/Network Parameter Control (NPC);

2) Connection Admission Control (CAC);

3) Congestion Control;

4) Network Resource Management.

The ATM Equipment should provide these functions to support the Network Performance QOS requirements of ITU-T I.356 [19] and I.211 [14]. ATM Networks are envisaged as capable of providing end-to-end cell loss and delay performance sufficient to support stringent services such as circuit emulation and high quality video transmission. Consequently, the ATM NEs should be capable of providing low cell loss ratio, low delay and low CDV to those connections requiring them, as specified by the Service Provider.

11.2 ATM Network Element performance objectives

The definitions, measurement methods and values of the ATM network performance parameters should be in accordance with ITU-T I.356.

The following clauses provide performance objectives for a network element to be used as provisional values. These objectives may have to be revised to be consistent with ITU-T I.356.

Test methods have to be defined for the verification of these objectives. Different methods may be required to suit different operational states for the equipment and the connections. A full description of the test methods is out of the scope of this Recommendation.

The objective values should be measured with a physical interface load of 80% and for 155.520 Mbit/s interface. Other values of link load and interface rates are for further study.

11.2.1 Cell loss objectives, cell transfer objectives and CDV objectives

See Appendix I.

11.2.2 Semi-permanent connection availability

The performance parameters for semi-permanent connection availability are defined in ITU-T I.357; this Recommendation is closely related to ITU-T I.356 [19], for it uses the definition of SESs in the ATM layer based on CLR and Severely Errored Cell Block Ratio (SECBR) cell transfer performance parameters.

The availability parameters are the Availability Ratio (AR) and the Mean Time Between Outages (MTBO). Two other related parameters may also be used: Unavailability Ratio (UR = 1-AR) and Outage Intensity (OI = 1/MTBO).

11.2.3 Call processing performance

This clause addresses call processing performance for switched VCCs in an ATM switch only; call processing performance for switched VCCs in an IAM (Initial Address Message) and for switched VPCs in any type of NE is for further study.

Call processing performance for switched VCCs are defined in ITU-T I.358 for a general B-ISDN network; in this clause, we give more details on how these definitions are to be adapted when addressing call processing performance in a single NE.

Table 2 summarizes the generic performance criteria for B-ISDN call processing functions as defined in ITU-T I.358; some of these parameters are not relevant when considering a single NE. The objectives for call processing performance parameters can be expressed in terms of mean and 95 percentile values and by giving worst-case objectives taking into account peak traffic factors such as "busy hour". The adaptation of ITU-T I.358 parameters for a single NE is for further study.

The most important parameters that are generally evaluated on ATM switches are the Connection Establishment Delay (CED) and the Call Setup Rate, although the latter is not mentioned in ITU-T I.358. The Call Setup Rate is the maximum number of call setups that can be processed by the switch without any failure and is expressed in terms of Busy Hour Call Attempts (BHCA). The BHCA parameter is tightly dependent on the type of the NE: network core element, network edge element, network access element, Interworking ATM multiplexer, etc. A strict definition of BHCA is required from the signalling community, but it is approximately the number of call attempts per second successfully handled under busy hour conditions. It is not the function of this Recommendation to make the definition.

Table 2/I.731 – Call processing performance parameters (Table 1/ITU-T I.358-09/97)

Call Processing Function	Speed	Accuracy	Dependability
Connection Set-up	Connection Set-up delay Connection post selection delay Connection answer signal delay	Connection Set-up Error Probability	Connection Set-up Failure Probability
Party set-up	Party set-up delay Party Post Selection Delay Party answer signal delay	Party Setup Error Probability	Party Set-up Failure Probability
Connection Disengagement	Connection Release Delay Connection Disconnect Delay	Connection Premature disconnect probability	Connection clearing failure probability (CRFP)
Party Disengagement	Party Release Delay Party Disconnect Delay	Party premature disconnect probability	Party clearing failure probability

12 Timing and synchronization requirements

12.1 User plane related timing

Although the nature of ATM does not require any timing of the cell stream as such, there are several aspects in an ATM NE that require timing information:

– timing of the TP layers including the adaptation function to the TP function (TP/VP_A_So/Sk);

– timing of the AAL function within VC/XXX_A (where XXX is a client layer of VC).

For network timing requirements, refer to ITU-T G.813.

The timing requirements for the UPC/NPC functions are for further study.

12.1.1 Timing accuracy

In general, the timing accuracy of the clock information shall satisfy at least the requirements of the NE component that is the most sensitive to timing inaccuracy, i.e. if in an NE there are PDH interfaces without synchronous PDH or SDH interfaces, then the Equipment Timing Source shall in the minimum fulfil the requirements regarding accuracy, jitter and wander of this interface. If in an NE there are SDH interfaces or synchronous PDH interfaces of the hierarchy P31s or P4s, the Equipment Timing Source (Station Equipment Clock) shall in minimum fulfil all the requirements regarding accuracy, jitter and wander of this interface.

From the NE functionality point of view, it is not required to have more stringent requirements specified (e.g. Synchronization Supply Unit (SSU) quality). The transport network currently set up in the European Community has the timing sources such as Primary Reference Clock (PRC) or SSU to provide the necessary timing accuracy within the operators' transport and switching networks.

12.1.2 Equipment timing source

The Equipment Timing Source (ETS) is responsible for selecting the extracted timing information derived from the incoming traffic carrying signals or external timing inputs. It distributes the timing information with the NE to the functions and processes requiring timing information for e.g. timing the output of the traffic signals. The Equipment Timing Source functions and their processes are described in ITU-T G.781 [5].

12.1.3 Timing of the TP layers

The TP layers are synchronized by the Equipment Timing Source. Timing information is also required for the cell rate adaptation into the Physical Path. Refer to ITU-T G.783 [6] for the timing requirements of the TP layers and to Annex D/I.732 for the requirements of the TP Adaptation function.

12.2 Management of plane related timing

A time-of-day reference shall be available in the NE for the purposes of, e.g.:

– time stamping events from the FM and Performance Management process;

– for measurement purposes of VP and VC Usage Measurement of connections.

The reference source for the time-of-day clock shall be derived from a frequency reference having the precision, reliability and redundancy characteristics of the clock used to synchronize the TP signal, e.g. from the Equipment Timing Source. The resolution shall be in steps of To Be Determined (TBD) milliseconds/seconds. The synchronization of time-stamps to absolute time (i.e. UTC) shall be to TBD seconds so that all stations can determine that a fault occurred at hh:mm:ss dd:mm:yy.

13 Availability and reliability

13.1 Availability objectives

For availability objectives, refer to 9.3/G.806 [10].

13.2 Data integrity

Measures to ensure data integrity shall be taken in order to protect against data information losses, inaccuracies and misproductions that can be due to many factors, including:

– hardware failures;

– software malfunctions;

– procedural and documentation errors;

– maintenance and administrative activities;

– switch-overs between redundant equipment.

Redundant mass storage devices and processors, and backup mechanisms could be used to help conform to the data loss requirements. However, the techniques employed to achieve the required level of reliability are an implementation issue and therefore outside the scope of this Recommendation.

Various types of information shall be stored in non-volatile memory to be protected against complete NE failures and, for example, loss of electrical power:

– run-time software;

– configuration data;

– log files from, for example, Fault Management (FM), Performance Management;

– usage measurement data;

– others.

On system start-up, the NE shall perform a diagnostic self test of hardware (e.g. mass storage) and software to ensure the integrity of the system. The self test shall not cause any degradation in traffic data.

13.3 Upgrade

In general, upgrade corresponds to a change in hardware or software versions, respectively. Hardware or software expansion of the equipment should not degrade the performance and/or availability of any given connection through equipment not affected by the hardware or software change.

13.3.1 Hardware upgrade

Upgrade of hardware may be required for system expansion, replacement of older hardware release, etc. Any hardware change shall not disturb traffic or other information not involved in the upgrade process. It is typically a user's requirement that replacement of single plug-in units shall be done in-service.

13.3.2 Software upgrade

Upgrade of run-time software may be required for system expansion, introduction of new functionalities or correction of malfunctioning of present software. It is typically a user's requirement that software upgrade shall be done in-service. New software may be downloaded through the in-band or out-band DCN (Data Communication Network), and switch-over between the active software parts and the new software parts (i.e. activation) may be done on command. A switch-over should not affect traffic or impair data integrity.

Some users may require to have the possibility to revert to the software version active prior to the switch-over.

13.4 Start-up requirements

On initial system start, the NE shall be working according to an initial default configuration of the installed hardware and an initial MIB in the software system. If the newly installed equipment has previously been provisioned by an operator, the NE shall be initialized according to the provisioned configuration.

It shall be possible to initiate a restart of a complete running NE. After a restart, the state of the NE shall be the same as after initial system start.

After a power failure, the NE shall automatically start up to its normal operating state, which is working according to the configuration data in the MIB, without any interaction over external interfaces.

After power restoration, the operating state of the NE should be reached as soon as possible, in order to keep the connection unavailability of affected traffic as low as possible. A parameter for Mean Time To Restore should be investigated and is under study.

APPENDIX I

ATM layer cell transfer performance

ITU-T I.732 [28] defines several types of ATM Network Equipment: cross-connects, switches, multiplexers and on-demand multiplexers. This subclause will focus on NE performance parameters for cell transfer in the ATM layer; thus, we will address cross-connects and switches only; some modifications shall be made in order to adapt NE equipment performance parameters definitions and their measurement conditions to the Interworking ATM Multiplexers.

ATM layer cell transfer performance of a NE can be evaluated using the following ATM cell transfer parameters defined both in ITU-T I.356 [19] and in [1] of Appendix II:

CER: Cell Error Ratio. However, this is difficult to measure and therefore not realistic for in-service measurements;

CLR: Cell Loss Ratio (CLR_0, CLR_{0+1}, CLR_1);

CMR: Cell Misinsertion Rate;

SECBR: Severely Errored Cell Block Ratio;

MCTD: Mean Cell Transfer Delay;

2-point CDV: CDV between two MPs (generated by the NE).

The reference events for performance parameters measurement are defined in ITU-T I.356.

Measurement methods of these parameters are described in ITU-T I.356, and in [1] of Appendix II. The ability to measure these parameters and hence their usefulness depends on whether the measurements are being made "in-service" or "out-of-service" (see ITU-T O.191). The application of these parameters to in-service and out-of-service testing is for further study.

NOTE – ITU-T I.356 is closely related to ITU-T I.357 because performance parameters shall be measured during availability periods only, which are defined in ITU-T I.357.

ATM NE performance objectives are QoS class dependent and are summarized in Table I.1. As these figures are for a single NE these are more stringent than those in ITU-T I.356 which are for a hypothetical reference connection stretching across 27 500 km.

Table I.1/I.731 – QoS classes and the corresponding performance objectives

	CTD	2-pt. CDV	CLR_{0+1}	CLR_0	CER	CMR	SECBR
Class 1 (stringent class) DBR SBR1 ABT	(see Note 1)	(see Note 2)	5×10^{-10}	none	5×10^{-10}	1/day	10^{-8}
Class 2 (tolerant class) DBR SBR1 ABT	Undefined	Undefined	10^{-8}	none	5×10^{-10}	1/day	10^{-8}

Table I.1/I.731 – QoS classes and the corresponding performance objectives *(concluded)*

	CTD	2-pt. CDV	CLR_{0+1}	CLR_0	CER	CMR	SECBR
Class 3 (bi-level class) SBR2 SBR3 ABR	Undefined	Undefined	Undefined	10^{-7}	5×10^{-10}	1/day	10^{-8}
U class	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined

NOTE 1 – The delay experienced by a cell transported by a VPC/VCC with a load equal to 0 should not exceed 50 µs per multiplexing stage; the number of multiplexing stages ranges from 1, for the most common NE, to 5 for big cross-connects. In addition, If we assume an 80% load of the link under consideration and a M/D/1/k queue model (this case is similar to a ΣD/D/1/k model when considering only one traffic source), then we shall take into account an extra mean delay, due to the queue, equal to 2xΔ, where Δ is the cell transmission time at the interface link speed (the time interval that is necessary to transmit all the bits of one cell on the physical link under consideration).

The maximum CTD (10^{-9} quantile) to be replaced should not exceed the:

$$CTDmax(10^{-9} \text{ quantile}) = T_{mean} + 6\times\sigma$$

For an 80% load, $T_{mean} = 2.4\times\Delta$

and $\sigma = 5.8\times\Delta$

Then $CTDmax(10^{-9} \text{ quantile}) = 37.2\times\Delta$

For an 80% load, $T_{mean} = 2.4\times\Delta$

NOTE 2 – The value of the maximum CDV generated by the ATM NE can be that given in ITU-T I.371:

$$\frac{\tau_{PCR}}{\Delta} = \max\left[\frac{T_{PCR}}{\Delta}, \alpha\left(1 - \frac{\Delta}{T_{PCR}}\right)\right]$$

where:

T_{PCR} is the peak emission interval of the connection (expressed in seconds)

Δ is the cell transmission time at the output interface link speed and

α is a dimensionless coefficient for the link load; the suggested value is α = 80%

This means that if two NEs (which are compliant with ITU-T I.371 [22]), are cascaded, and if a shaped DBR traffic is introduced at the input of the first NE which generates a maximum CDV, then the traffic is still compliant with ITU-T I.371 at the input of the second NE.

The value of the input link speed is not relevant for the calculation of the CDV generated by the NE, except that it limits the bit rate of the connection.

APPENDIX II

Bibliography

[1] ATM Forum: Traffic Management Specification; Version 4.0; *af-tm-0056.000*; April 1996.

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