ATIS-1000627.2014**(R2019)**

Broadband ISDN – ATM Layer Functionality and Specification

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American National Standard for Telecommunications

Broadband ISDN – ATM Layer Functionality and Specification

Alliance for Telecommunications Industry Solutions

Approved June 2014

American National Standards Institute, Inc.

Abstract

This standard is one a series of standard on Broadband Integrated Services Digital Network (B-ISDN). These standards describe the B-ISDN capabilities, architectural model, and network interfaces including protocol functionalities and specifications, and signaling characteristics. In particular, this standard describes the protocol of the ATM Layer.

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At the time of consensus on this document, PTSC, which was responsible for its development, had the following leadership:

> M. Dolly, PTSC Chair (AT&T)
> V. Shaikh, PTSC Vice-Chair (ACS)
> M. Dolly, PTSC SAC Chair (AT&T)

The **SAC** Subcommittee was responsible for the development of this document.

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1 Scope

This standard is one of a series of ANSI standards on Broadband Integrated Services Digital Network (B-ISDN). These standards describe the B-ISDN capabilities, architectural model, and network interfaces including protocol functionalities and specifications, and signaling characteristics. In particular, this standard describes the protocol of the ATM Layer. This document specifies:

- the service provided by the ATM Layer;
- the service required from the Physical Layer (PHY);
- the interrelation with Layer Management;
- the encoding of the protocol data units;
- the protocol procedures.

In specifying the service, it defines:

- the primitives and the resulting actions and events;
- the parameters and format associated with each primitive;
- interrelationship between the primitives;
- valid sequence of primitives.

The primitives and their associated parameters describe in an abstract manner the logical exchange of information between the ATM Layer and its service users (e.g., the ATM Adaptation Layer and the ATM Layer Management). They do not specify nor con- strain the implementation of entities or inter- faces.

2 Normative Reference

The following standard contains provisions which, through reference in this text, constitute provisions of this American National Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this American National Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

ANSI T1.624-1993, Broadband ISDN User- Network Interfaces: Rates and Formats Specifications

3 Definitions

3.1 assigned cell: Cell that provides a service to an upper layer entity or ATM Layer Management entity (ATMM-entity).

3.2 asynchronous time division multiplexing: A multiplexing technique in which a transmission capability is organized in a priori unassigned time slots. The time slots are assigned to cells upon request of each application's instantaneous real need.

3.3 Asynchronous Transfer Mode (ATM): A transfer mode in which the information is organized into cells. It is asynchronous in the sense that the recurrence of cells containing information from an individual user is not necessarily periodic.

3.4 ATM connection: A virtual channel connection (VCC) or a virtual path connection (VPC).

3.5 ATM Layer connection: An association established by the ATM Layer to support communication between two or more ATM service users (i.e., two or more next higher layer entities or two or more ATMM-entities). The communication over an ATM Layer connection may be either bidirectional or unidirectional. When bidirectional, two VCCs are used. When unidirectional, only one VCC is used.

NOTE – In the case where there is ATM Layer connection associated ATM Layer Management (e.g., F5 Flow), the ATM Layer connection is bidirectional even if the user communication is unidirectional.

3.6 ATM Layer link: A section of an ATM Layer connection between two adjacent active ATM Layer entities (ATM-entities).

3.7 ATM link: A virtual path link (VPL) or a virtual channel link (VCL).

3.8 ATM Traffic Descriptor: A generic list of traffic parameters that can be used to capture the intrinsic traffic characteristics of a requested ATM connection.

3.9 broadband: A service or system requiring transmission channels capable of supporting rates greater than the Integrated Services Digital Network (ISDN) primary rate.

3.10 broadband access: An ISDN access capable of supporting one or more broadband services.

3.11 cell: ATM Layer protocol data unit (PDU).

3.12 cell delay variation:[1] A quantification of variability in cell delay for a connection.

3.13 cell header: ATM Layer protocol control information.

3.14 cell loss ratio:[1] In a network, cell loss ratio is $(1 - x/y)$, where: y is the number of cells that arrive in an interval at the ingress of the network; and x is the number of these y cells that leave at the egress of the net- work.

In a network element, cell loss ratio is $(1 - x/y)$, where: y is the number of cells that arrive in an interval at the ingress of the net- work element; and x is the number of these y cells that leave at the egress of the network element.

3.15 connection admission control:[1] The procedure used to decide if a request for an ATM connection can be accepted based on the attributes of both the requested connection and the existing connections.

3.16 Connection Endpoint (CE): A terminator at one end of a layer connection within a Service Access Point (SAP).

3.17 Connection Endpoint Identifier (CEI): Identifier of a CE that can be used to identify the connection at a SAP.

3.18 corresponding entities: Peer entities with a lower layer connection among them.

3.19 demultiplexing: A function performed by a layer entity that identifies and separates SDUs from a single connection to more than one connection.

3.20 End System (ES): A system where an ATM connection is terminated or initiated.

3.21 fairness: As related to Generic Flow Control (GFC), fairness is defined as meeting all the agreed Quality of Service (QOS) requirements, by controlling the order of service for all active connections.

3.22 intermediate system (IS): A system that provides forwarding functions or relaying functions or both for a specific ATM connection.

3.23 layer entity: An active element within a layer.

3.24 layer function: A part of the activity of the layer entities.

3.25 layer service: A capability of a layer and the layers beneath it that is provided to the upper layer entities at the boundary between that layer and the next higher layer.

3.26 layer user data: Data transferred between corresponding entities, on behalf of

> 1) Corresponding network performance parameters are specified in ANSI T1.AI/93-029. the upper layer or layer management entities, for which they are providing services.

3.27 metasignaling: ATM Layer Management (LM) process that manages different types of signaling virtual channels (VCs), including the assignment, removal, and checking of VCs.

3.28 metasignaling VCs: The standardized VCs that convey metasignaling information across a User-Network Interface (UNI).

3.29 multiplexing: A function within a layer that interleaves the information from multiple connections into one connection.

3.30 multipoint access: User access in which more than one terminal equipment (TE) is supported by a single network termination.

3.31 multipoint connection: A connection with more than two endpoints.

3.32 Network Node Interface (NNI): The interface between two network nodes.

3.33 Operation and Maintenance (OAM) cell: A cell that contains ATM LM information. It does not form part of the upper layer information transfer.

3.34 peak cell rate: See 7.4.1.

3.35 peer entities: Entities within the same layer.

3.36 Physical Layer (PHY) connection: An association established by the PHY between two or more ATM-entities. A PHY connection consists of the concatenation of PHY links in order to provide an end-to-end transfer capability to PHY SAPs.

3.37 point-to-point connection: A connection with only two endpoints.

3.38 primitive: An abstract, implementation independent, interaction between a layer service user and a layer service provider.

3.39 protocol: A set of rules and formats (semantic and syntactic) that determines the communication behavior of layer entities in the performance of the layer functions.

3.30 protocol control information: Information exchanged between corresponding entities, using a lower layer connection, to coordinate their joint operation.

3.31 Protocol Data Unit (PDU): A unit of data specified in a layer protocol and consisting of protocol control information and layer user data.

3.32 relaying: A function of a layer by means of which a layer entity receives data from a corresponding entity and transmits it to another corresponding entity.

3.33 segment: A single ATM link or group of interconnected ATM links of an ATM connection.

3.34 semipermanent connection: A connection established via a service order or via network management.

3.35 Service Access Point (SAP): The point at which an entity of a layer provides services to its LM entity or to an entity of the next higher layer.

3.36 Service Data Unit (SDU): A unit of interface information whose identity is pre- served from one end of a layer connection to the other.

3.37 Source Traffic Descriptor: A set of traffic parameters belonging to the ATM Traffic Descriptor used during the connection setup to capture the intrinsic traffic characteristics of the connection requested by the source.

3.38 sublayer: A logical sub-division of a layer.

3.39 switched connection: A connection established via signaling.

3.40 traffic parameter: A parameter for specifying a particular traffic aspect of a connection.

3.41 transfer capacity:[1] The maximum sustainable rate of information transfer.

3.42 transit delay:[1] The time difference between the instant at which the first bit of a PDU crosses one designated boundary, and the instant at which the last bit of the same PDU crosses a second designated boundary.

3.43 unassigned cells: A cell identified by a standardized virtual path identifier (VPI) and virtual channel identifier (VCI) value, which has been generated and does not carry information from an application using the ATM Layer service.

3.44 Virtual Channel (VC): A communication channel that provides for the sequential unidirectional transport of ATM cells.

3.45 Virtual Channel Connection (VCC): A concatenation of VCLs that extends between the points where the ATM service users access the ATM Layer. The points at which the ATM cell payload is passed to, or received from, the user of the ATM Layer (i.e., a higher layer or ATMM-entity) for processing, signify the endpoints of a VCC. VCCs are unidirectional.

3.46 Virtual Channel Link (VCL): A means of unidirectional transport of ATM cells between the point where a VCI value is assigned and the point where that value is translated or removed.

3.47 virtual channel switch: A network element that connects VCLs. It terminates VPCs and translates VCI values. It is directed by Control Plane functions and relays the cells of a VC.

3.48 Virtual Path (VP): A unidirectional logical association or bundle of VCs.

3.49 Virtual Path Connection (VPC): A concatenation of VPLs between virtual path Terminators (VPTs). VPCs are unidirectional.

3.50 Virtual Path Link (VPL): A means of unidirectional transport of ATM cells between the point where a VPI value is assigned and the point where that value is translated or removed.

3.51 virtual path switch: A network element that connects VPLs. It translates VPI (not VCI) values and is directed by Control Plane functions. It relays the cells of the VP.

3.52   Virtual Path Terminator (VPT): A system that unbundles the VCs of a VP for independent processing of each VC.

4 Abbreviations & Acronyms

AAL   ATM Adaptation Layer

ANSI   American National Standards Institute

ATM   Asynchronous Transfer Mode

ATM-CE ATM connection endpoint

ATM-LI ATM link identifier

ATMM   ATM Layer Management

B-ISDN Broadband (aspects of) Integrated Services Digital Network

CBR   Constant Bit Rate

CE   Connection Endpoint

CEI   Connection Endpoint Identifier

CIF   Cell information field

CLP   Cell Loss Priority

CLS   Connectionless Service

CO   Connection oriented

CPE   Customer Premises Equipment

EFCN   Explicit Forward Congestion Notification

ES   End system

GFC   Generic Flow Control

HEC   Header Error Control

IS   Intermediate system

ISDN   Integrated Services Digital Network

ITU-T   International Telecommunication Union – Telecommunications

LI   Link identifier

LM   Layer management

NNI   Network-Node Interface

NPC   Network parameter control

OAM   Operation and Maintenance

PDU   Protocol Data Unit

PHY   Physical Layer

PM   Plane Management

PMD   Physical Medium Dependent (Sub- layer)

PRM   Protocol Reference Model

PTI   Payload Type Identifier

QOS   Quality of Service

RM   Resource management

SAP   Service Access Point

SAR   Segmentation and Reassembly (Sublayer)

SDL   Specification   and   Description Language

SDU   Service Data Unit

TC   Transmission Convergence (Sublayer)

TE   Terminal Equipment

UNI   User-Network Interface

UPC   Usage Parameter Control

VBR   Variable Bit Rate

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

VPT   Virtual Path Terminator

5   B-ISDN Protocol Reference Model (PRM)

The B-ISDN PRM is shown in figure 1. This model contains three structural elements: User Plane, Control Plane, and Management Plane.

The abstract model of the ATM Layer (including the primitives and their associated parameters and procedures of the ATM service, the PHY service and the relationship between the ATM Layer and Layer Management) is provided as a description of the relationship of the ATM Layer to the rest of the B-ISDN Protocol Reference Model. This clause is for informative purposes. Primitives and their associated parameters do not specify nor constrain the implementation of entities or interfaces.

The User Plane, with its layered structure, transfers the user application information. The Control Plane, also with a layered structure, handles the call and connection control functions, including the signaling. The signaling function is used to establish and release calls and connections (including negotiation of net- work resources). Renegotiation of call and connection characteristics is also considered as a Control Plane function.

The Management Plane provides management application functions and a mechanism for information exchange between Control Plane processes and User Plane processes. Functions related to the management aspects such as coordination of local operations across layers in establishing network connections, monitoring established connections, and responding to status queries to support net- work supervision reside in the Management Plane. The Management Plane has two sections: Layer Management and Plane Management (i.e., System Management). The Layer Management (LM) performs the management functions specific to a layer, such as metasignaling (at the ATM Layer) and the layer specific operation and maintenance (OAM) functions, and interacts with the layer entities and the Plane Management (PM). The PM performs the management functions related to the sys- tem as a whole, the coordination between all planes and the various LM entities. The PM is not layered.

The PHY and ATM Layer are common to both User Plane and Control Plane. The PHY pro- vides for the transport of PHY Service Data Units (PHY-SDUs) between two ATM-entities. The functions of this layer are grouped into two sublayers: the Physical Medium Dependent (PMD) Sublayer and the Transmission Convergence (TC) Sublayer. The PMD Sublayer deals with bit transmission over the physical medium and the TC Sublayer performs the functions required to transform a flow of PHY-SDUs into a flow of data units (e.g., bits) that can be transmitted and received over a physical medium. The ATM Layer provides for the transparent and sequential transfer of fixed-size data units between a source and the associated destination(s) with an agreed Quality of Service (QOS). These two layers, Physical and ATM, are common to all services.

The ATM Adaptation Layer (AAL) performs the necessary functions to adapt the services provided by the ATM Layer to the services required by the different service users. Therefore, the AAL functions are service specific. The functions of the AAL include service-related functions and the segmentation and reassembly of the data units so they can be mapped into the fixed length payloads of the ATM cells.

The LM entities communicate with the local layer entities through primitives. Peer LM entities communicate within a pre-established User or Control Plane connection or through a separate connection. They may also communicate through the PM.

Note that figure 1 is a pictorial representation of a generic model and not of physical equipment. Thus, end systems (ESs) and intermediate systems (ISs) (e.g., a PHY cross-connect, an ATM relaying node, or an ES using the ATM bearer service) may contain only a subset of the elements represented in the model. In this figure, the solid lines between layers and between planes represent defined interfaces between the layers, or between the planes, or between the layers and planes. The dotted lines represent functional subdivisions of layers or planes. The diagonal dash lines highlight the ATM Layer that is the subject of this standard.

6   Basic Principles of ATM

ATM is the transfer mode solution for implementing a B-ISDN.

ATM is used in this standard as addressing a specific packet oriented transfer mode using an asynchronous time division multiplexing technique: the multiplexed information flow is organized in fixed size blocks, called cells. A cell consists of an information field (cell pay- load) and a header; the primary role of the header is to identify cells belonging to the same connection on an asynchronous time division multiplex.

The information field is transported transparently by the ATM Layer; no processing (e.g., error control) is performed on the information field at the ATM Layer. The header size (5 octets) and the information field size (48 octets) are the same at all reference points, including User-Network Interface (UNI) and Network Node Interface (NNI), where the ATM technique is applied.

Transfer capacity can be assigned on demand depending on the available resources.

Cell sequence integrity on an ATM connection is preserved. Sequency integrity implies that cells that originated at a connection endpoint

shall be delivered at the destination endpoint in the same order in which they were originated. For an ATM connection, cells transmitted from an ATM link endpoint shall arrive at any subsequent ATM link endpoint in the same order in which they were transmitted.

The services provided by the ATM Layer are connection-oriented. Connection identifiers are assigned to each link of a connection when required, and released when no longer needed. Signaling and user information are carried on separate ATM Layer connections.

7 ATM Layer Model

The functions of the ATM Layer are available to all services. Figure 1 shows the relation- ship between the ATM Layer and the layers in the B-ISDN PRM.

The ATM Layer uses ATM connections to pro- vide its service. These connections may be established and released by various methods such as metasignaling, network provided signaling, provisioning, etc. Metasignaling is an ATM LM process and as such resides in the Management Plane. Network provided signaling is a function of the Service Layer in the Control Plane (as shown in figure 1). Entities in the Management Plane coordinate the local interactions between the Control Plane and the User Plane, and across the layers in the process of establishing and releasing a call or a connection. All the information associated with an ATM connection (e.g., connection identifiers, etc.) are conveyed to the ATM- entities by the ATMM-entities.

In general, cells of ATM connections are relayed by a series of intermediate ATM-entities located in ISs. These intermediate ATM- entities map ATM cells from one PHY connection to another PHY connection without passing the payload up to the upper layer. They may also multiplex ATM cells from several PHY connections into one PHY connection (demultiplexing is also performed) and may provide copies of ATM cells from one PHY connection to multiple PHY connections. Figure 2 (a) shows an example of cell relaying at ISs. Figure 2 (b) shows how multiple ATM connections may be multiplexed by the ATM- entities into one single PHY connection at ESs.
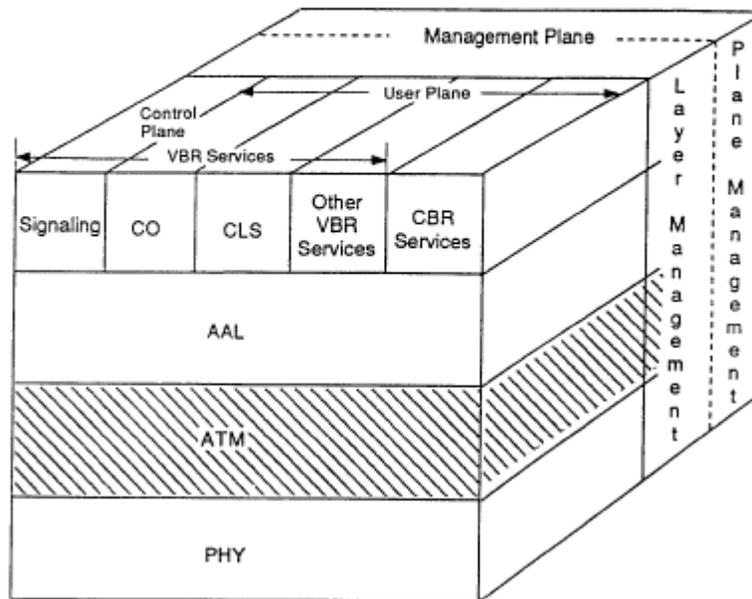
Figure 1 - B-ISDN protocol reference model

a) *Intermediate system*

b) *End system*
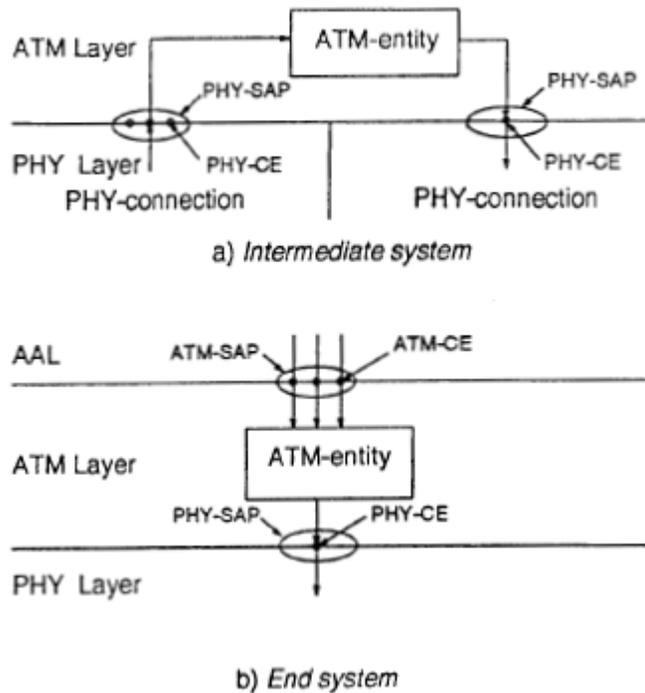
Figure 2 - Example of Cell Relaying and Multiplexing

Certain aspects of traffic management are addressed in this clause. Other areas of traffic management may be subject to future standardization.

7.1 *Types of Connection*

The ATM Layer supports two connection types at the ATM Layer service access points (SAPs):

- point-to-point connection;
- multipoint connection.

By the appropriate combination of the connection parameters at connection setup, the ATM Layer provides its user multiple types of communication services such as unidirectional or bidirectional multipoint communication, and unidirectional or bidirectional point-to-point communication.

7.2 *Virtual Channel*

A virtual channel (VC) is the communication channel associated with a VC connection (VCC) that provides for the sequential trans- port of ATM cells among ESs. A VCC is an

association established at the ATM Layer between two or more ATM service users (i.e., corresponding upper layer entities or ATMM- entities).

A VC:

- preserves cell sequence integrity;

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- provides a user with a QOS specified by such parameters as cell loss ratio and cell delay variation;
- may require negotiation and may be monitored for compliance with the traffic descriptor;
- can be associated with both switched and semipermanent VCCs;
- may be established and released by service order or signaling.

7.2.1 QOS of a VCC

A VCC provides a QOS class selected from the QOS classes supported by the network. Requested QOS classes are indicated to net- works during connection establishment. The

QOS class associated with a VCC does not change for the duration of the connection. QOS is defined in terms of parameters such as

- cell loss ratio;
- cell delay variation;
- mean cell transfer delay.

7.2.2 VC Traffic Parameters Negotiation & Usage Monitoring

Traffic parameters shall be negotiated between a user and a network for each VC at establishment or during the connection. Cells sent from the user to the network are monitored for compliance with the negotiated traffic parameters.

Peak Cell Rate is the only VCC traffic parameter presently defined in this standard. Other traffic parameters such as Average Cell Rate, Burstiness, Peak Cell Duration, and Source Type may be subject to future standardization and are covered in other ANSI standards.

7.2.3 Methods for Establishment or Release of a VCC

At the UNI, a VC link (VCL) of a VCC may be established and released using one or more of the following four methods:

- without signaling procedures: e.g., by service order or network management procedures on a demand basis;
- metasignaling procedures: e.g., by using a metasignaling VC to establish or release VCCs for signaling;
- user-network signaling procedures: e.g., using a user-network signaling VC to establish or release a VCC used for end-to-end communication;
- user-user signaling procedures: e.g., using a user-to-user signaling VC to establish or release a VCC used for end-to-end communication.

At the NNI, a VCL of a VCC may be established and released between ATM network elements using one or more of the following methods:

- internetwork signaling;
- intranetwork signaling;
- without signaling procedures, e.g., by service order or network management pro- cedures on a demand basis.

7.3 Virtual Path

A virtual path (VP):

- preserves cell sequence integrity;
- provides a user with a QOS specified in such parameters as cell loss ratio and cell delay variation;
- may require negotiation and may be monitored for compliance with the traffic descriptor;
- can be associated with both switched and semipermanent VP connections (VPCs);
- may be established and released by service order or signaling.

7.3.1 QOS of a VPC

A VPC provides a QOS class selected from the QOS classes supported by the network. Requested QOS classes are indicated to the networks at connection establishment. The QOS class associated with a VPC does not change for the duration of the VPC. A VP that carries multiple VCs with various QOS classes shall meet the most demanding QOS of the VCs carried. QOS is defined in terms of parameters such as:

- cell loss ratio;
- cell delay variation;
- mean cell transfer delay.

7.3.2 VP Traffic Parameters Negotiation & Usage Monitoring

Traffic parameters shall be negotiated between a user and a network for each VP at VPC establishment or during the connection. Cells sent from the user to the network are monitored for compliance with the negotiated traffic parameters.

Peak Cell Rate is the only VPC traffic parameter presently defined in this standard. Other traffic parameters such as Average Cell Rate, Burstiness, Peak Cell Duration, and Source Type may be subject to future standardization and are covered in other ANSI standards.

7.3.3 Methods for Establishment or Release of a VPC

A VPC may be established and released between VP terminators (VPTs) by any of the following methods:

- without signaling procedures: e.g., service order or network management procedures on a demand basis;
- user-network signaling procedures: e.g., using a user-network signaling VC to establish or release a VPC used for end-to-end communication;
- network controlled VPC establishment or release: may be performed by network signaling procedures.

7.4 Peak Cell Rate

The following definition applies to ATM connections supporting both Constant Bit Rate (CBR) and Variable Bit Rate (VBR) services.

The Peak Cell Rate in the Source Traffic Descriptor specifies an upper bound on the traffic that can be submitted on an ATM connection. Enforcement of this, bound by the UPC/NPC, allows the network operator to allocate sufficient resources to ensure that the performance objectives (e.g., for Cell Loss Ratio) can be achieved.

7.4.1 Peak Cell Rate Definition for a VPC/VCC

- Location: At the Physical Layer SAP for an Equivalent Terminal representing the VPC/VCC (this is only a reference configuration; see figure 3).
- Basic event: Request to send an ATM- PDU in the Equivalent Terminal.
- Definition: The Peak Cell Rate of the ATM connection is the inverse of the mini- mum interarrival time T between two basic events defined above. T is the Peak Emission Interval of the ATM connection.

The Source Traffic Descriptor of the ATM connection currently reduces to the Peak Cell Rate defined above.

It is noted that conformance control of the Peak Cell Rate by UPC/NPC requires that the CDV tolerance τ allocated to the upstream portion of the ATM connection be specified. Whether additional parameters may be useful is subject to future standardization.

On a terminal with a single AAL and without ATM Layer OAM flows, location and basic event are equivalent to the following ones.

- Location: At the ATM Layer SAP.
- Basic event: Request to send an ATM- SDU.

In order to properly allocate resources to a VPC/VCC, a Peak Cell Rate as defined above has to be defined for each component of the ATM connection, i.e., the CLP=0 substream (not including the OAM), the aggregate(CLP=0+1) substream and the OAM sub- stream. The CDV tolerance accounts for delay variation that will be present in respective cell substreams of the ATM connection. Their values and interpretation are defined by algorithms described in annex E.

7.4.2 Peak Cell Rate Granularity Specification

Network functions such as UPC/NPC cannot be requested to handle every specific Peak Cell Rate value but only a restricted, discrete and finite set of values. The ordered list of these values is referred to as the ATM Peak Cell Rate Granularity.

As the Peak Cell Rate definition, the Peak Cell Rate Granularity specification should also be based on the Peak Emission Interval.

The ATM Peak Cell Rate Granularity and its coding are subject to future standardization.

7.5 VPs & VCs: Relationship & Identification

At a given interface, in a given direction, the different VPs multiplexed at the ATM Layer into the same PHY connection are distinguished by VP identifiers (VPIs). The different VCs within the same VP are distinguished by VC identifiers (VCIs) as indicated in figure 4. Two different VCs belonging to two different VPs at a given interface may have the same VCI value. Therefore, a VC is completely identified at an interface by a combination of both VPI and VCI values.

VPIs may be changed where VP links (VPLs) are terminated (e.g., cross-connects, concentrators, switches). VCIs may only be changed where VCLs are terminated. Within a VP, VCIs are not translated except at VPTs.
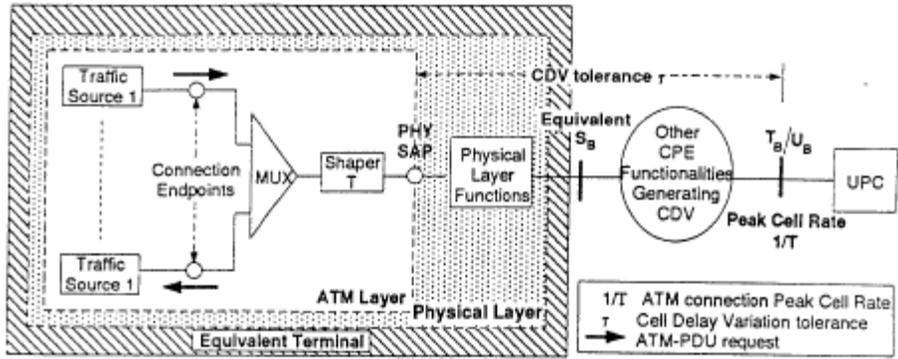
Figure 3 - Reference configuration and equivalent terminal for the definition of the Peak Cell Rate of an A5M connection

A VPI or VCI value has no end-to-end significance, except for connections with only one link, or in the case of some standardized VCI values (i.e., for F4 Flows), since otherwise, their value may change on a link-by-link basis.

The VPI and VCI values at a UNI, could be assigned by one of the following:

- the network;
- the user;
- negotiation between the network and the user;
- standardization.

In general, the specific value assigned to a VPI or a VCI at a UNI is independent of the service provided over that VC except for the preassigned values defined in 7.5.3.

7.5.1 VC Identifier Assignment

When a VPI and a VCI are assigned for a VCL at an interface (e.g., UNI or NNI), the same values are assigned for both directions. VPI and VCI values, used in one direction to sup- port an ATM Layer connection, may only be used in the opposite direction to support the same ATM Layer connection. Otherwise, the value is unavailable for any other use.

7.5.2 VP Identifier Assignment

When a VPI is assigned for a VPL at an interface (e.g., UNI or NNI), the same value is assigned for both directions. A VPI value used in one direction to support a bundle of ATM Layer connections may only be used in the opposite direction to support ATM Layer connections that are unidirectional or in the same bundle of ATM Layer connections. Otherwise, the value is unavailable for any other use.

7.5.3 Preassigned VP &VC Identifiers

VPI and VCI values are currently reserved for

- unassigned cell;
- metasignaling VCs;
- general broadcast signaling VCs;
- point-to-point signaling VCs;
- segment OAM F4 Flow;
- end-to-end OAM F4 Flow. Refer to tables 1 and 2.

7.5.4 Number of Active Connections at the UNI

At the UNI, 24 bits are available in the VPI/VCI, field of the ATM cell header for cell routing information.

The actual number of routing bits in the VPI and VCI subfields used for routing is negotiat- ed between the user and the network, e.g., on a subscription basis. This number is deter- mined on the basis of the lower requirement of the user or the network. The rules to deter- mine the position of the routing bits used with- in the VPI/VCI field are given in 12.2.1 (b).

NOTE – The number of VCI routing bits used in a user-to-user VP is negotiated between the users of the VP.

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7.5.5 Number of Active Connections at the NNI

At the NNI, 28 bits are available in the VPIVCI field for connection identification. The actual number of routing bits in the VPI and VCI sub- fields used for routing across the interface is established at installation. This number is determined on the basis of the requirement of each entity.

8 Service Characteristics

The service provided by the ATM Layer is the capability of that layer and the PHY, which is provided to the upper layer entities at the ATM- SAP. The service definition is based on a set of service primitives that describe in an abstract manner the logical exchange of information and control through the ATM-SAP.

> NOTE – The primitives do not specify nor con- strain the implementation of entities or interfaces.

8.1 Services Provided to the Upper Layer

ATM Layer provides for the transparent transfer of fixed-sized ATM Layer service data units (ATM-SDUs) between communicating upper layer entities (e.g., AAL-entities). This transfer occurs on a pre-established ATM connection with negotiated parameters such as QOS parameters and traffic parameters. Within an ATM connection, the information from each source is delivered in the order in which it is sent. No retransmission of lost or corrupted information is performed by this layer. The ATM Layer also provides its users with the following capabilities:

- loss priority indication of the data carried in each cell;
- explicit congestion notification to indicate that the cell has traversed a network node in congestion;
- ATM_user_to_ATM_user Indication.

Table 1 - Preassigned header field values at the UNI (excluding the HEC)

Use	Value			
	octet 1	octet 2	octet 3	octet 4
Unassigned cell indication	AAAA0000	00000000	00000000	0000BBB0
Metasignaling (see note 4)	AAAAXXXX	XXXX0000	00000000	00010A0C
General Broadcast signaling (see note 4)	AAAAXXXX	XXXX0000	00000000	0100AAC
Point-to-point signaling (see note 4)	AAAAXXXX	XXXX0000	00000000	01010AAC
Invalid pattern	BBBB0000	00000000	00000000	0000BBB1
Segment OAM Flow cell (see note 5)	AAAAYYYY	YYYY0000	00000000	00110A0A
End-to-end OAM F4 Flow cell (see note 5)	AAAAYYYY	YYYY0000	00000000	01000A0A

NOTES

1 A – indicates that the bit is available for use by the appropriate ATM Layer function.

2 B – indicates that the bit is a *don't care* bit.

3 C – indicates the originating entity shall set the CLP bit to 0. The value may be changed by the network.

4 These VCI values are reserved for user-to-network signaling with the local exchange, for VPI value, XXXXXXXX, equal to 0, and reserved for user-to-user signaling with other signaling entities (e.g., other users or remote network), for VPI values, XXXXXXXX, other than 0.

5 YYYYYYYY – any VPI value.

Table 2 - Preassigned header field values at the NNI (excluding the HEC)

Use	Value			
	octet 1	octet 2	octet 3	octet 4
Unassigned cell indication	00000000	00000000	00000000	0000BBB0
Point-to-point signaling	YYYYYYYY	YYYY0000	00000000	01010AAC
Invalid pattern	00000000	00000000	00000000	0000BBB1
Segment OAM F4 Flow cell (see note 4)	YYYYYYYY	YYYY0000	00000000	00110A0A
End-to-end OAM F4 Flow cell (see note 4)	YYYYYYYY	YYYY0000	00000000	01000A0A

NOTES

1   A – indicates that the bit is available for use by the appropriate ATM Layer function.

2   B – indicates that the bit is a *don't care* bit.

3   C – indicates the originating entity shall set the CLP bit to 0. The value may be changed by the network.

4   YYYYYYYY – any VPI value.

The information exchanged between the ATM Layer and the upper layer (e.g., the AAL) across the ATM-SAP includes the following primitives:

- ATM-DATA.request (ATM-SDU, Sub- mitted Loss Priority, Congestion Indication, ATM_user_to_ATM_user Indication);
- ATM-DATA.indication (ATM-SDU, Received Loss Priority, Congestion Indication, ATM_user_to_ATM_user Indication).

8.1.1 Description of Primitives (ATM/Upper Layer)

- ATM-DATA.request: This primitive is issued by an upper layer entity (e.g., AAL- entity) to request the transfer of an ATM- SDU to its corresponding entity (or entities) over an ATM Layer connection. The Submitted Loss Priority parameter and the ATM_user_to_ATM_user Indication parameter are used to assign the proper CLP and PTI fields to the ATM-PDU generated at the ATM Layer. The generated ATM-PDU is transferred over all the PHY-CEs assigned to that ATM Layer connection;
- ATM-DATA.indication: This primitive is issued to an upper layer entity (e.g., AAL-entity) to indicate the arrival of an ATM-SDU over an ATM Layer connection, with Received Loss Priority, Congestion Indication and received ATM_user_to_ATM_user Indication. In the absence of error, the ATM- SDU is the same as the ATM-SDU sent by the corresponding upper layer entity in the ATM-DATA.request primitive.

8.1.2 Description of parameters (ATM/Up- per Layer)

- ATM-SDU: This parameter contains 48 octets of ATM Layer user data (e.g., the AAL SAR-PDU) to be transferred by the ATM Layer between corresponding upper layer entities;
- Submitted Loss Priority: This parameter indicates the relative importance of the requested transport for the information carried in the ATM-SDU. It can take only two values, one for high priority and the other for low priority;

- Received Loss Priority: This parameter indicates the relative importance of the trans- port given to the information carried in the ATM-SDU. It can take only two values, one for high priority and the other for low priority;
- Congestion Indication: This parameter indicates that the received ATM-SDU has passed through a network node in congestion;
- ATM_user_to_ATM_user Indication: This parameter is transported transparently by the ATM Layer.

8.2 Service Expected from the PHY

The ATM Layer expects the PHY to provide for the transport of ATM cells between corresponding ATM-entities. The information exchanged between the ATM Layer and the PHY across the PHY-SAP includes the following primitives:

- PHY-DATA.request (PHY-SDU);
- PHY-DATA.indication (PHY-SDU).

8.2.1 Description of Primitives (ATM/PHY)

- PHY-DATA.request: This primitive is issued by the ATM Layer to request the transfer of an ATM cell from a local ATM- entity to the corresponding ATM-entity over an existing PHY connection. Each cell is exchanged between the ATM Layer and the PHY across the PHY-SAP. The entire cell (except for the HEC field) is transported unmodified by the PHY via the existing PHY connection;
- PHY-DATA.indication: This primitive is issued by the PHY to the ATM Layer to indicate the arrival of a PHY-SDU from a corresponding PHY-entity over an existing PHY connection. In the absence of error, this PHY-SDU (except for the HEC field) is the same as the PHY-SDU sent by the corresponding ATM-entity in a PHY-DATA.request primitive.

8.2.2 Description of Parameters (ATM/PHY)

- PHY-SDU: This parameter contains one ATM cell to be transferred between corresponding ATM-entities.

9 Layer Management Interactions

ATM Layer Management is part of the Management Plane, and only performs management functions specific to the ATM Layer such as metasignaling, ATM Layer OAM, and ATM resource management (RM).

There are two types of interactions between the ATM-entity and the ATMM-entity. One interaction is for the exchange of local information between these two entities. The other interaction is for peer-to-peer communication between ATMM-entities.

To support the first type of interaction, an ATM node has local associations between the ATM-entity and the ATMM-entity.

To support the second type of interaction, ATM LM information is transported between two ATMM-entities, and conveyed via the following two bidirectional communication methods: Type A and Type B.

Type A communication method uses a user data cell indication for the PTI field. The PTI field coding is shown in table 3. ATM LM information is placed in the cell payload. An ATM Layer connection is established for the purpose of providing the ATM LM communication. This

connection cannot be used for any other purpose. The link identifier (VPI and VCI) of this ATM Layer connection can be assigned by standardization, provisioning, or signaling.

For example, metasignaling and VPC OAM Flows (F4) use this method. Their VPI values are the same as those used for Control or User Plane communications, and their VCI values are standardized. The standardized VCI values are shown in tables 1 and 2.

The F4 Flow is bidirectional. OAM cells for the F4 Flow have the same VPI value as the user cells of the VPC and are identified by one or more preassigned VCI values. The same pre- assigned VCI value shall be used for both directions of the F4 Flow. The OAM cells for both directions of the F4 Flow must follow the same physical route so that any connecting points supporting that connection can correlate the fault and performance information from both directions.

There are two cases of OAM F4 Flows (i.e., Segment OAM and End-to-end OAM). Segment OAM F4 Flow is used for ATM LM communications among the ATMM-entities at the endpoints of a VPC segment. End-to-end OAM F4 Flow is used for ATM LM communications among the ATMM-entities at the ESs of a VPC. All ISs of the given VPC can copy the information received on these OAM flows, and also send information on these OAMflows. The information received on either the Segment OAM F4 Flow or End-to-end OAM F4 Flow can be removed only at the endpoints of the OAM Flow, i.e., segment endpoint or connection endpoint, respectively.

Type B communication method uses an OAM indication for the PTI field. The PTI field coding is shown in table 3. ATM LM information is placed in the cell payload. In both directions, the link identifier (VPI and VCI) of the associated ATM Layer connection is used. For example, VCC OAM Flows (F5) use thismethod.

The F5 flow is bidirectional. OAM cells for the F5 flow have the same VPI/VCI values as the user cells of the VCC and are identified by the Payload Type Identifier (PTI). The same PTI value shall be used for both directions of the F5 Flow. The OAM cells for both directions of the F5 Flow must follow the same physical route so that any connecting points supporting that connection can correlate the fault and performance information from both directions.

There are two cases of OAM F5 Flows (i.e., Segment OAM and End-to-end OAM). Segment OAM F5 Flow is used for ATM LM communications among the ATMM-entities at the endpoints of a VCC segment. End-to-end OAM F5 Flow is used for ATM LM communications among the ATMM-entities at the ESs of a VCC. All ISs of the given VCC can copy the information received on these OAM Flows, and also send information on these OAM Flows. The information received on either the Segment OAM F5 Flow or the End-to-end

Table 3 - PTI field and coding

PTI Coding	Interpretation
000	User data cell, congestion not experienced, ATM_user_to_ATM_user Indication equal to 0
001	User data cell, congestion not experienced, ATM_user_to_ATM_user Indication equal to 1
010	User data cell, congestion experienced, ATM_user_to_ATM_user Indication equal to 0
011	User data cell, congestion experienced, ATM_user_to_ATM_user Indication equal to 1
100	Segment OAM F5 Flow cell
101	End-to-end OAM F5 Flow cell
110	Reserved for fast resource management (see note)
111	Reserved for future functions

NOTE – Fast resource management refers to future functions that operate on the same time scale of the round-trip propagation delay of the ATM Layer connection.

OAM F5 Flow can be removed only at the endpoints of the OAM Flow, i.e., segment endpoint or connection endpoint, respectively.

9.1 Information Exchanged between ATM- Entity & ATMM-Entity

The information exchanged between the ATM- entity and the ATMM-entity includes the following primitives:

For peer-to-peer communication between ATMM-entities:

- ATMM-DATA.request (ATM-SDU, Sub-mitted Loss Priority, PHY-CEIs);
- ATMM-DATA.indication (ATM-SDU, PHY-CEI, Congestion-indication, Received Loss Priority).
- For the exchange of local information between the ATM-entity and the ATMM-entity:
- ATMM-MONITOR.indication (CIF, PHY- CEI, Congestion-indication, Priority);
- ATMM-ASSIGN.request (ATM-CEI, PHY- CEI(s), ATM-LI(s), LM-Type(s), ATM-Connection Parameters);
- ATMM-ASSIGN.confirm (ATM-LI(s), LM- Type(s), PHY-CEI(s));
- ATMM-REMOVE.request (ATM-LI(s),LM-Type(s), PHY-CEI(s));
- ATMM-REMOVE.confirm (ATM-LI(s),LM-Type(s), PHY-CEI(s));
- ATMM-ERROR.indication (Error Type, Error Cause, PHY-CEI);
- ATMM-STATUS-CHANGE.request(PHY-CEI, Copy-indication, Status);

> NOTE – The primitives do not specify nor con- strain the implementation of entities or interfaces.

9.1.1 Description of Primitives

- ATMM-DATA.request: This primitive is issued by an ATMM-entity to request the transfer of a management ATM-SDU via Type A or Type B method;
- ATMM-DATA.indication: This primitive is issued to an ATMM-entity to indicate the arrival of an ATM-SDU via Type A or Type B method;
- ATMM-MONITOR.indication: This primitive is issued to an ATMM-entity to indicate the sending or receiving of an ATM-PDU in an ATM connection to facilitate OAM functions;
- ATMM-ASSIGN.request. This primitive is issued by an ATMM-entity to request an association between the identified ATM-CE, PHY-CE(s), ATM-LI(s), and LM-Type(s) with the specified connection parameters. This request is part of the establishment of an ATM connection;

  NOTES:

  - At intermediate nodes, the ATM-CEI parameter is not present for user data. The association for relaying user data is performed between incoming and outgoing ATM-LIs and the specified PHY-CEs.
  - Two ATMM-ASSIGN.request primitives will be used to establish a bidirectional ATM Layer connection, one for each direction.

- ATMM-ASSIGN.confirm: This primitive is issued to an ATMM-entity to confirm the establishment of the association required for the ATM connection;
- ATMM-REMOVE.request. This primitive is issued by an ATMM-entity requesting the release of an association established for the identified ATM connection;
- ATMM-REMOVE.confirm: This primitive is issued to an ATMM-entity to confirm the release of the specified association for the identified ATM connection;
- ATMM-ERROR.indication: This primitive is issued to an ATMM-entity to indicate an error event, and invoke the necessary man- agement actions and procedures;

- ATMM-STATUS-CHANGE.request: This primitive is issued by the ATMM-entity to request a change in the status of the ATM link.

9.1.2 Description of Parameters

- ATM-LI: This parameter is used to identify an ATM link within a PHY-CE. It is direct- ly associated with a VPI or a VPI-VCI;
  > NOTE – In nodes performing relaying functions, pairs of ATM-LIs are associated. Incoming ATM-LIs are associated with outgoing ATM-LIs for the same ATM connection.
- Priority: This parameter identifies the Cell Loss Priority of the ATM-PDU;
- Submitted Loss Priority: This parameter indicates the relative importance of the requested transport for the information car- ried in the ATM-SDU. It can take only two values, one for high priority and the other for low priority;
- Received Loss Priority: This parameter indicates the relative importance of the transport given to the information carried in the ATM-SDU. It can take only two values, one for high priority and the other for low priority;
- ATM-CEI: This parameter identifies the ATM-CE within the ATM-SAP;
- PHY-CEI: This parameter identifies the PHY-CE within the PHY-SAP. Certain characteristics are uniquely associated with this identifier, such as UNI or NNI cell format;
  > NOTE – In some cases, such as multipoint connections, multiple PHY-CEIs could be associated with the same ATM connection. Also, in nodes per- forming relaying functions, at least two PHY-CEIs are associated with the same ATM connection.
- ATM-SDU: This parameter contains 48 octets of ATM LM data to be transparently transferred between corresponding ATMM- entities;
- CIF (Cell Information Field): This parameter contains the information field (48 octets) of the ATM-PDU;
- Error Type: This parameter indicates the kind of error event that occurred, e.g., a discarded cell. The ATMM-entity uses this parameter in conjunction with the Error Cause parameter to determine which of its procedures should be invoked to handle the error condition;
  – Error Cause: This parameter conveys the cause of the error event, e.g., a cell dis- card is caused by a non-assigned ATM-LI, or buffer overflow. The ATMM-entity uses this parameter in conjunction with the Error Type parameter to determine which of its procedures should be invoked to handle the error condition;
  – ATM-Connection Parameters: This set consists of the parameters that characterize an ATM connection. It may include directionality of the communication, (i.e., whether an ATM-CEI is sending ATM-SDUs, or receiving ATM-SDUs) and negotiated QOS;
- Status: This parameter conveys the status of the ATM link specified in the same primitive. Status indications may for example include Halt, Transfer, Accept, and Discard;
- Copy-indication: This parameter is used to activate or deactivate the copying function for the ATM link specified in the same primitive;
- Congestion-indication: This parameter indicates that the received ATM-SDU has passed through a network node in congestion;
  – LM-Type: This parameter distinguishes among the following types of LM associations: User data (e.g., F4 Flow), Segment F5 OAM Flow, and End-to-end F5 OAM Flow.
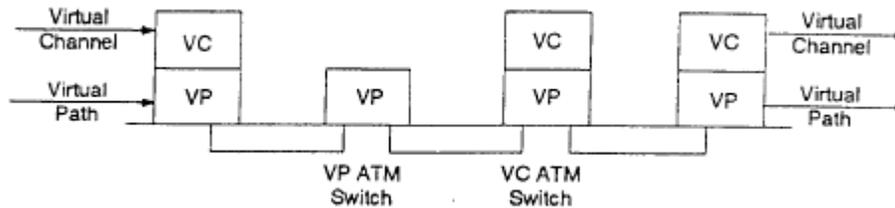
Figure 4 - ATM Layer Relaying Schemes

10 Functions of the ATM Layer

The ATM Layer performs the following functions:

- cell relaying;
- cell multiplexing/demultiplexing;
- delay handling;
- cell loss priority processing;
- usage parameter control;
- explicit forward congestion notification;
- cell payload type discrimination;
- generic flow control;
- connection assignment;
- connection removal;
- cell construction;
- unassigned cell generation;
- unassigned cell extraction;
- cell copying;
- cell header validation;
- cell forwarding;
- cell reception.

Not all functions are present at all ATM-entities.

10.1 Cell Relaying

This function forwards cells from one corresponding ATM-entity to one or more corresponding ATM-entity(ies). It is performed only at the ISs of a connection. Cells can be relayed from one VP link to one or more VP link(s) or from one VC link to one or more VC link(s). This function is associated with the VPI/VCI field of the ATM cell header. A dia- gram of the basic point-to-point VP and VC relaying scheme is shown in figure 5.

For example, at VC switches, both the VPI and VCI are translated, in general, by the relaying function. At VP switches, the VPI only is translated by the relaying function.

10.2 Cell Multiplexing/demultiplexing

The cell multiplexing function aggregates cells from individual VCs or VPs into a composite flow of cells, and is associated with the sending ATM-entity.

The cell demultiplexing function differentiates, from a composite flow of cells arriving on the same PHY connection, the cells that belong to individual VCs or VPs, and is associated with the receiving ATM-entity.

These functions are associated with the VPI/VCI field of the ATM cell header.

10.3 Delay Handling

This function distinguishes among connections with different delay requirements (e.g., mean cell transfer delay, cell delay variation). All the cells of the same ATM connection are subject to the same delay handling.

10.4 Cell Loss Priority Processing

This function selectively discards cells during congestion according to network policies.

A field in the ATM cell header is used for explicit cell loss priority indication. This field may be used by the subscriber or the network to indicate lower loss priority cells.

10.5 Usage Parameter Control

This function monitors a connection to identify those cells that are not in compliance with a traffic descriptor. It is performed at the user network interface and may also be performed at network-to-network interfaces. At the user network interface, this function is called UPC. When it exists at a network-to-network inter- face, this function is called NPC. The descriptor is provided to the ATM Layer by the ATMM-entity using the ATMM-ASSIGN.request primitive.

When non-complying cells are detected, the ATM-entity may take one of the following actions:

- Mark non-complying cells (cell tagging) and submit them to the network;
- Discard non-complying cells.

When used as an option, tagging operates on cells with CLP field value equal to 0 by setting the CLP field value equal to 1. The non-com- plying cells, which are marked, are merged with the flow of cells with the CLP field value equal to 1 before this flow is controlled.

For an ATM connection, for which cell tagging does not operate, non-complying cells with the CLP field value equal to 0 are dis- carded.

10.6 Explicit Forward Congestion Notification

This function sets an explicit forward congestion notification (EFCN) indicator in the cell header so the appropriate action may be taken at an ES. It is set by ISs in a congested state. When an IS is not in a congested state, it will not modify the EFCN indicator.

The mechanism by which a network element determines whether it is congested is an implementation issue and is not subject to standardization.

10.7 Cell Payload Type Discrimination

This function discriminates between cells containing upper layer information or ATM LM information.

This function is associated with the PTI and VPI/VCI fields of the ATM cell header.

10.8 Generic Flow Control at UNI (GFC)

This function assists in controlling the flow of traffic of ATM connections with various QOS at each UNI. It is used to schedule the information transfer among multiple sources. It determines when a generated cell can be sent to the PHY for transmission. This function coordinates media access among multiple broadband terminals at the customer premises and across the user network interface. It uses the GFC field in the cell header to con- vey information needed to perform this coordination. The exact encoding of the GFC field and the algorithm used are subject to future standardization. Independent of which algorithm is chosen in the future, this procedure should not prohibit the physical realization of any broadband terminal configurations. The Generic Flow Control procedures are applicable at the T_B and S_B reference points and the SSB interface. These interfaces are described in T1.624.

There are two sets of procedures for use with- in the GFC field, Uncontrolled-transmission procedures and Controlled-transmission procedures. The Uncontrolled-transmission procedures can be used across the interfaces at the S_B and T_B reference points. The Controlled-transmission procedures can be used across the SSB interface and the interface at the S_B reference point. In cases where a TE is directly connected to the interface at the T_B reference point, the TE can execute the Controlled-transmission procedures. However, the public network can implement the Uncontrolled-transmission set of procedures.

The Controlled-transmission set of procedures for both multiaccess and point-to-point configurations are subject to future standardization.

For equipment implementing the Uncontrolled- transmission set of procedures, the GFC function is not used. For equipment implementing the Controlled-transmission set of procedures, the actions taken upon receipt of the GFC field and the setting of the GFC field upon transmission are subject to future standardization.

In order to minimize the interactions between these two sets of procedures, it is necessary to identify the procedures operating on a specific interface at any particular time. Themechanism to distinguish between procedures is as follows: any piece of equipment that receives ten or more non-zero GFC fields within 30,000 cell times shall consider the other ATM-entity to be executing the Controlled-transmission set of procedures. Any TE that implements the Uncontrolled- transmission set of procedures, which detects that the corresponding ATM-entity is executing the Controlled-transmission set of procedures, shall notify LM. No other actions are taken on the received GFC field by a TE implementing the Uncontrolled-transmission set of procedures.

The procedures related to Controlled-trans- mission shall assure compatibility with the dis- crimination mechanism between Controlled- transmission procedures and Uncontrolled- transmission procedures.

10.9 Connection Assignment

This function assigns associations between ATM-CEIs, PHY-CEIs, ATM-LIs, and LM-

Types with specified connection parameters. This function is performed at the request from the ATMM-entity through an ATMM-ASSIGN.request primitive.

10.10 Connection Removal

This function removes the associations established between ATM-CEIs, PHY-CEIs, ATM- LIs, LM-Types and the connection parameters. This function is performed at the request from the ATMM-entity through an ATMM-REMOVE.request primitive.

10.11 Cell Construction

This function generates the protocol control information required to transmit an ATM-SDU to a corresponding ATM-entity or a corresponding ATMM-entity. This function is activated by the receipt of an ATM-DATA.request primitive or an ATMM-DATA.request primitive.

10.12 Unassigned Cell Generation

This function inserts unassigned cells into the flow of assigned cells to be passed to the PHY for transmission, transforming a stream of assigned cells into a stream of assigned and unassigned cells. It is associated with the sending procedure of an ATM-entity.

10.13 Unassigned Cell Extraction

This function extracts unassigned cells from the flow of cells received from the PHY, trans- forming a stream of assigned and unassigned cells into a stream of assigned cells. It is associated with the receiving process of an ATM-entity.

10.14 Cell Copying

This function copies the payload of the received cells and sends it to the ATMM-entity via the ATMM-MONITOR.indication primitive. It is associated with the receiving process of ATM-entities to support certain OAM functionalities. This function is performed on a connection basis. It is invoked by the ATMM-entity.

10.15 Cell Reception

This function determines if the cell payload contains upper layer or ATM LM information, and generates the ATM-DATA.indication primitive or ATMM-DATA.indication primitive. It is associated with the receiving process of an ATM-entity.

10.16 Cell Header Validation

This function verifies if the VPI and VCI, of the received cell form the unassigned value. If it is not the unassigned value, this function also verifies whether the ATM-LI of the received cell is active. This function checks if the first four octets of the cell header do not form an invalid pattern. (See tables 1 and 2.) When a non-active ATM-LI has been received, it generates an ATMM-ERROR.indication primitive to the ATM LM.

10.17 Cell Forwarding

This function forwards cells received at a PHY-CE to another PHY-CE without performing ATM-LI translation. It is performed by customer premises equipment (CPE) in a bus or ring configuration.

11 Functions of the Layer Management

The ATMM-entities perform management functions specific to the ATM Layer such as metasignaling and testing. Other functions may be performed to facilitate traffic control and RM. Also, the ATMM-entities in conjunction with the PM provide coordination of the local interactions between the User Plane and the Control Plane across the layers, mainly for the connection establishment or release. ATM connection information such as delay priority, and the associated ATM connection identifiers, are conveyed to the related ATM-entity by the ATMM-entity during connection setup.
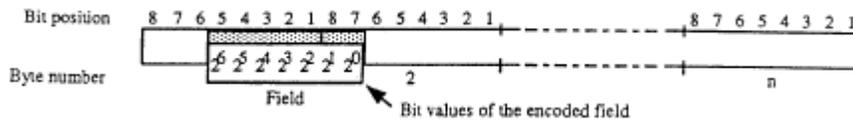

Figure 5 - Field Encoding Convention

ISDN OAM procedures sometimes require the exchange of operations information between various nodes. For some VPCs or VCCs, connection-specific operations information such as failure indications, performance monitoring data and test requests (e.g., loop-back commands) needs to be exchanged between VPC and VCC ISs or ESs.

In summary, the ATM LM functions identified in this clause are:

- metasignaling;
- fault management;
- performance management;
- configuration management;
- resource management.

12 Cell Structure & Encoding

12.1 Encoding Principles

As shown in figure 6, the cell shall be encoded according to the following principles:

- the header shall be sent first followed by the information field;
- when a field is contained within a single octet, the lowest bit number of the field shall represent the lowest order value;
- when a field spans more than one octet, the order of bit values within each octet shall decrease progressively as the octet number increases. The lowest bit number associated with the field shall represent the lowest order value.

The following conventions shall be used:

- bits within an octet shall be sent in decreasing order, starting with 8;
- octets shall be sent in increasing order, starting with octet 1;
- the first bit sent of each field shall be the Most Significant Bit of that field.

12.2 Cell Structure

The ATM cell consists of a 5-octet header and a 48-octet payload as shown in figure 7. The header contains the ATM Layer protocol control information. Two different coding schemes have been adopted: the UNI format, and the NNI for- mat. These formats are described in 12.2.1 and 12.2.2, respectively. At the SSB interface and at the interfaces at the S_B, T_B, and U_B reference points, the UNI format is used.

12.2.1 Cell Header Fields of the UNI format

The structure of the UNI cell header format is shown in figure 8. It contains the following fields:

    a) Generic Flow Control(GFC): A 4-bit field used by the generic flow control mechanism. For equipment implementing Uncontrolled- transmission procedures (see 10.8), the GFC function is not used and the GFC field is set to all zeros. For equipment implementing Controlled-transmission procedures, the GFC function is used. However, the actions taken and the encoding of this field are under study;

    b) VPI/VCI field: A 24-bit field containing 2 subfields:

        a. an 8-bit VPI;

        b. a 16-bit VCI.

The number of bits of the VPI and VCI sub- fields used for routing are established by negotiation between the user and the network as described in 7.5.4. The bits within the VPI and VCI subfields used for routing are allocated using the following rules:

- the allocated bits of the VPI subfield shall be contiguous;
- the allocated bits of the VPI subfield shall be the least significant bits of the VPI subfield, beginning at bit 5 of octet 2;
- the allocated bits of the VCI subfield shall be contiguous;
- the allocated bits of the VCI subfield shall be the least significant bits of the VCI subfield, beginning at bit 5 of octet 4.

Any bit of the VPI subfield that is not allocated is set to 0. For a given VP, any bit of the VCI subfield that is not allocated is set to 0.

    a) Payload Type Identification (PTI) field: A 3-bit field used for payload type identification. The field coding is described in table 1;

    b) Cell Loss Priority (CLP) field: A 1-bit field used by the cell loss priority processing function. If the CLP is set (CLP value is 1), the cell is subject to discard, depending on network conditions and network policies. If the CLP is not set (CLP value is 0), the cell has higher priority, as specified in 10.5;

    c) Header Error Control (HEC) field: The HEC is an 8-bit field. The coding and function of the HEC field are described in T1.624.
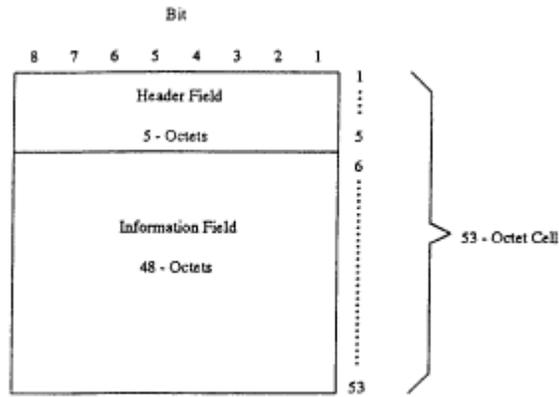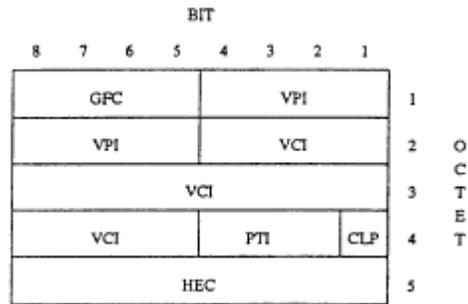
Bit

Figure 6 - ATM Cell Structure

BIT

Figure 7 - ATM Cell Header Fields for the UNI Format
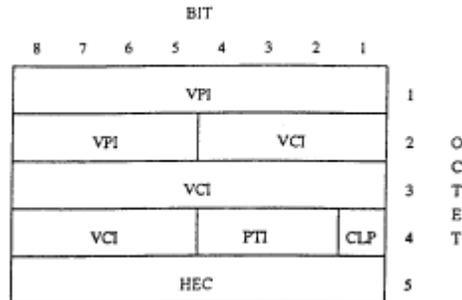
BIT

Figure 8 - Cell Header Fields for the NNI Format

12.2.2 Cell Header Fields of the NNI Format

The structure of the NNI cell header format is shown in figure 9. It contains the following fields:

a) VPI/VCI field. A 28-bit field containing 2 subfields:
    a. a 12-bit VPI;
    b. a 16-bit VCI.

The number of bits of the VPI and VCI subfields used for routing are established by the procedures described in 7.5.5. The bits within the VPI and VCI subfields used for routing are allocated using the rules described in 12.2.1 (b).

    a) Payload Type Identification (PTI) field. The value and function of this field is described in 12.2.1 (c);

    b) Cell Loss Priority (CLP) field. The value and function of this field is described in 12.2.1 (d);

    c) Header Error Control (HEC) field. The coding and function of this field are described in T1.624.

12.3 Preassigned Header Field Values

Preassigned header field values are given in table 1 for the UNI and in table 2 for the NNI, excluding the HEC field. The VCI value of 0 is not available for user virtual channel identification. ATM cells containing invalid patterns are discarded by the ATM Layer.

Annex A: Traffic Management Framework

(informative)

The following mechanisms form a framework for managing traffic in ATM networks and may be used in appropriate combinations in order to manage traffic and thereby control congestion events. Provisioning may be used to provide network resources. Traffic may be classified by service characteristics and treated separately.

A.1 Admission Control

A source requests a connection with given connection parameters (e.g., QOS and a traffic descriptor). The network accepts or rejects the request.

A.2 Usage Parameter Control

The exchange termination monitors each connection to identify those cells that are not in compliance with the traffic descriptor. This descriptor is derived from the descriptor agreed upon at connection establishment (source traffic descriptor); and may need to account for cell jitter that may be introduced by access multiplexing. When non-complying cells are detected, the exchange termination may take actions such as:

- marking non-complying CLP-equal-to- zero cells (cell tagging);
- discarding non-complying cells;
- informing the source of the detection of non-complying cells.

A.3 Congestion Dependent Network Element Cell Processing

Congested network elements may, for example, take the following actions:

- Selective cell discard: Congested net- work elements may selectively discard explicitly identified non-complying cells and those cells with CLP equal to 1.
- Explicit forward congestion notification: ATM network elements, when in a congested state, may set an EFCN indicator in the cell header PTI field of a user data cell so that action may be taken at the ES. When a net- work element is not in a congested state, it will not modify the EFCN indicator.

The following items are under study:

- mechanisms by which protocols above the ATM Layer may exploit the EFCN func- tionality;
- the interactions of the EFCN functionality with other traffic management mechanisms;
- procedures for setting the EFCN indicator.

A.4 Backward Notification of Congestion

A congested network element may send congestion notification in the backward direction. Mechanisms for providing a backward congestion notification are under study.

A.5 Exception/Failure Handling

- May require the ability to release connections;
- Other handling may also be useful.

Annex B: Layer Service Concepts

(informative)

B.1 Layer Service Concept

A layer service or (N)-service is the capability of the (N)-layer and the layers beneath it, which is provided to (N+1)-entities at the boundary between the (N)-layer and the (N+1)- layer. A service definition is based on a set of service primitives that describe in an abstract manner the logical exchange of information and control through the SAP at which the service is provided.

NOTE – Primitive description does not imply any specific implementation.

There are four generic types of primitives identified as: request primitive, confirm primitive, indication primitive, and response primitive. A request primitive is issued by the user of the service to the provider of the service to invoke some procedure. A confirm primitive is issued by the provider of the service to the user of the service, to complete some procedure previously invoked by a request primitive at that SAP. An indication primitive is issued by the provider of the service to the user of the service either to invoke some procedure or to notify that a procedure has been invoked by the service user at the peer SAP. A response primitive is issued by the user of the service to the provider of the service to complete some procedure previously invoked by an indication at that SAP.

B.2 Naming Convention for the Primitives

The naming convention used in this document for the primitives follows the general syntax X- Y.z, which uniquely identifies a primitive.

- X specifies the abbreviated name of the layer providing the service and is written in capital letters (e.g., PHY, ATM, etc.)
- Y specifies the service name (usually a verb is used), and is written in capital letters (e.g., DATA, CONNECT, DISCONNECT, etc.)
- z specifies the primitive type and is written in lower case letters (e.g., request, indication, etc.)

The associated parameters of each primitive specify in an abstract sense the information that is made available through the primitive.

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Annex C: ATM Protocol Processes

(informative)

The descriptions of the ATM protocol processes are illustrative and do not specify nor constrain the implementation of entities or interfaces.

C.1 Elements of Processes

The following variable and parameter are not part of the protocol control information, but are used in describing the ATM Layer operations:

- Timer_TC: This variable is used by the ATM-cell-send process. Timer_TC represents the remaining time before the next PHY-DATA.request primitive is sent across a PHY-CE;
    NOTE – Timer_TC is used to model the temporal relationship between the cell emission times at the Physical Layer and the ATM Layer.
- RC: This parameter represents the time to transmit an ATM cell at the ATM data rate to the PHY. It represents the value of the Timer_TC after each reset, and is closely related to the underlying transmission system.

C.2 Connection-Assignment (Reassignment) Process

This process, performed by the ATM-entity, creates an association between the ATM-entity and the specified CEs, and initializes (or reinitializes) the parameters associated with the newly established (or re-established) connection by the request from the ATMM-entity via an ATMM-ASSIGN.request primitive. The connection parameters include delay priority, and directionality of the connection.

Upon receiving an ATMM-ASSIGN.request primitive, the following operations take place:

a) The association between the ATM-CEI, LM-Type(s), ATM-LI(s), and PHY-CEI(s) is established (or re-established) at the ESs. In nodes performing relaying function, the association between the incoming PHY- CEI(s) and the outgoing PHY-CEI(s) is also established (or re-established);
    NOTES:
    i. In nodes performing forwarding function, the association between the incoming PHY-CEI(s) and the outgoing PHY-CEI(s) is established at the provisioning phase, but not at the connection establishment phase.
    ii. At ISs the ATM-CEI for the user data flow is not present, hence no association between the ATM- CEI and PHY-CEI(s) is established for the user data flow. However, an ATM-CE may be present for Segment F5 OAM Flow.
b) The connection parameters are initialized (or reinitialized). At the ES, the directionality parameter of the connection indicates whether the ES of the connection is receiving or sending;
    NOTE – Bidirectional ATM LM communications could be established for a unidirectional user data flow.
c) An ATMM-ASSIGN.confirm primitive is sent back to the ATMM-entity.

The SDL graphical representation for this process is given in figure D.l.

C.3 Connection-Remove Process

This process, performed by the ATM-entity, releases associations of an established ATM connection. (See C.2).

This process is invoked by the ATMM-entity via an ATMM-REMOVE.request primitive. Upon receiving an ATMM-REMOVE.request primitive, the following operations take place:

a) The records are cleared;
b) The associated resources are release
c) The ATMM-REMOVE.confirm primitive is issued to the ATMM-entity.

The SDL graphical representation for this process is given in figure D.2.

C.4 ATM-Cell-Construction Process

This process constructs ATM cells to be trans- mitted over PHY-CE(s). The ATM-SDU is passed to an ATM-entity by an upper layer entity or an ATMM-entity using the primitives ATM- DATA.request or ATMM-DATA.request, respectively. Different delay priority levels may be associated with each ATM connection during a connection setup, and be used by a scheduler to determine the service order when contention occurs at a node. However, the cell sequence integrity, as described in clause 6, is preserved within a VCC or VPC. The delay pri- ority level assigned to each ATM connection is a local parameter that depends on the services supported at the node. Cells associated with the same ATM connection have the same delay priority. The specific scheduling algorithm used is a local implementation issue.

Upon receiving an ATM-DATA.request or an ATMM-DATA.request primitive the following operations take place:

a) Set PTI according to
   a. the received ATM_user_to_ATM_user Indication, if an ATM-DATA.request prim- itive was received;
   b. the LM-Type associated with the ATM-CE, if an ATMM-DATA.request primitive was received.
b) Set CLP field according to the Submitted Loss Priority parameter conveyed in the primitive;
c) If the cell is transmitted over multiple PHY-CEs, multiple copies of the cell are generated;
d) The VPI/VCI field of each copy is set to the assigned VPI and VCI value;
e) Each copy is passed through the Dispatch procedure.

The SDL graphical representation for the ATM- cell-construction process is given in figure D.3.

C.5 ATM-Cell-Send Process

This process transfers the ATM cells queued in Send-queue to the PHY via a PHY-DATA.request primitive. It also generates

Unassigned cells when Send-queue is empty. The Timer_TC is used to generate the ATM cell flow across the boundary between the PHY and the ATM Layer.

Upon expiration of the Timer_TC the following operations take place:

a) The Timer_TC is set to RC, i.e., the transmitting time of an ATM cell at the data rate of the ATM Layer;
b) If Send-queue is not empty, one cell is extracted and passed to the PHY via a PHY-DATA.request primitive;
c) If Send-queue is empty, an Unassigned cell is generated and passed to the PHY via a PHY-DATA.request primitive;
d) The process waits for the expiration of the Timer_TC, and returns to D.5(a).

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The SDL graphical representation for theATM-cell-send process is given in figure D.4.

C.6 Link-Status-Update Process

This process updates the parameters associated with a specific ATM link. It is activated by the ATM LM via an ATMM-STATUS-CHANGE.request primitive. The update may be the result of ATM LM functions such as fault management, performance monitoring, or RM.

For example, upon receiving an ATMM-STA- TUS-CHANGE.request primitive from the LM, the following operations take place:

a) The Copy-indication associated with the ATM link is updated according to the Copy- indication received in the ATMM-STATUS- CHANGE.request primitive;

b) Other operations may be performed as a result of the update. In the following example it is assumed that a Halt and a Transfer status exist:

c) If the link status is changed toTransfer and GFC processing is applicable, all ATM cells in a Halt-queue together with the PHY-CEI(s) of the PHY-CE(s) to which the ATM cells are destined, are sent to the GFC process;

      a. If the link status is changed toTransfer but GFC processing is not applicable (e.g., at NNIs), all cells from a Halt-queue may then be passed to Send- queue used by the ATM-cell-send process to be transmitted to the PHY;

      b. If the ATM link status is changed to Halt, no further processing is per- formed until another ATMM-STATUS- CHANGE.request primitive changes the ATM link status to Transfer.

The SDL graphical representation for the Link- status-update process is given in figure D.5.

The Dispatch procedure in D.8, also illustrates how these hypothetical statuses may be used.

C.7 ATM-Cell-Receive Process

This process describes operations performed at the ATM Layer after receiving a cell from the PHY.

Upon receiving a cell in a PHY-DATA.indiction primitive, the following operations take place:

a) If the cell copying function is to be per- formed for the cell flow associated with the received ATM-LI and LM-Type, copy theATM-SDU and send it to the LM via theATMM-MONITOR.indication primitive;

b) The cell may be discarded, e.g., based on UPC/NPC monitoring. If the cell is dis- carded, an ATMM-ERROR.indication primitive is sent to the ATMM-entity;

c) If the cell is not discarded, the following operations take place:

  1) If the node performs the forwarding function:

    – invoke the Dispatch procedure to forward a copy of the cell;

    – if the cell received is not anUnassigned cell and the node is a receiving system for the cell flow associated with the received ATM-LI and LM-Type, invoke the Reception procedure to receive the cell.

  2) If the node performs the relayingfunction, the following actions take place:

– if the cell flow associated with the received ATM-LI and LM-Type is to be relayed, the Relay procedure is invoked and, if the node is also a receiving system for this cell flow, the Reception procedure is also invoked;

– if the cell flow associated with the received ATM-LI and LM-Type is not to be relayed and the received cell is not an Unassigned cell, and if the node is a receiving system for this cell flow, the Reception procedure is invoked; but, if the node is not a receiving system for this cell flow, the received cell is dis- carded and an ATMM-ERROR.indication primitive is sent to the ATMM-entity.

    3) If the node performs neither the relaying function nor the forwarding function:

– if the cell received is not an Unassigned cell and the node is a receiving system for the cell flow associated with the received ATM-LI and LM-Type, invoke the Reception procedure to receive the cell;

– if the cell received is not an Unassigned cell and the node is not a receiving system for the cell flow associated with the received ATM-LI and LM-Type, discard the received cell and send an ATMM-ERROR.indication primitive to the ATMM-entity.

The SDL graphical representation for the ATM- cell-receive process is given in figure D.6.

C.8 Dispatch Procedure

This procedure places the cell in the appropriate queue or passes the cell to the GFC process. The following description of the procedure assumes the existence of the hypothetical statuses in the Link-status update process (C.6). When this procedure is invoked, the following operations take place:

  a) If the ATM link status is Halt, the cell being processed is sent to a Halt-queue;
  b) If the ATM link status is Transfer, and if GFC field processing is applicable, the par- tially formed ATM cell together with the PHY- CEI(s) of the PHY-CE(s) to which the ATM cell is destined, is sent to the GFC process;
  c) If the ATM link status is Transfer, but GFC processing is not applicable (e.g., at NNI), the cell is sent to the Send-queue used by the ATM-cell-send process.

The SDL graphical representation for the Dispatch procedure is given in figure D.7.

C.9 Reception Procedure

This procedure determines whether the received cell is destined to the LM or to the upper layer, and generates the appropriate indication primitive. When this procedure is invoked, the following operations take place:

  a) Extract the ATM-SDU;
  b) If the ATM-LI and LM-Type indicate ATM LM communication, send the ATMM-DATA.indication primitive to the ATMM-entity;
  c) If the ATM-LI and LM-Type indicate User or Control Plane communication, send the ATM-DATA.indication primitive to the upper layer entity.

The SDL graphical representation for the Reception procedure is given in figure D.8.

C.10 Relay Procedure

This procedure transfers cells received from one PHY-CE to one or more PHY-CE(s). When this procedure is invoked, the following operations take place:

a) If the received cell should be sent to multiple PHY-CEs, one copy per PHY-CE isgenerated;

b) The received cell and each copy of the cell (if any) is processed as follows:

1) The ATM-LI is translated to the appropriate outgoing value (i.e., the incoming VPI or VPI/VCI is translated to the outgoing VPI or VPI/VCI, respectively);

2) The Dispatch procedure is invoked to send the cell.

The SDL graphical representation for theRelay procedure is given in figure D.9.

C.11 UPC/NPC Procedure

This procedure performs the usage parameter control at the user network interface. This procedure may also perform the usage parameter control at the network-to-network interface. Depending upon the specific implementation, the activation of the various actions may be different. A specific algorithm is notaddressed.

Annex D: SDL diagrams

(informative)

This annex is provided as an example illustrating the operation of an ATM-entity.
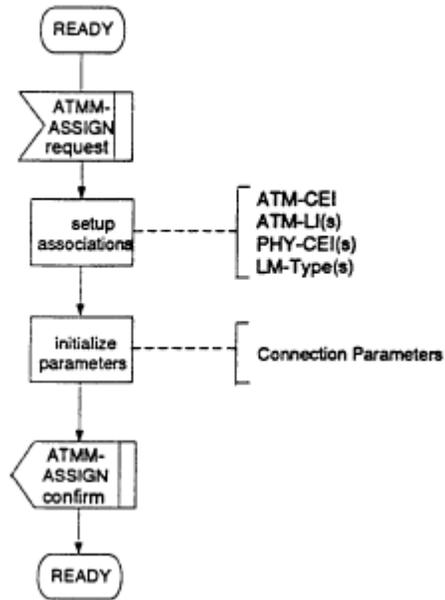
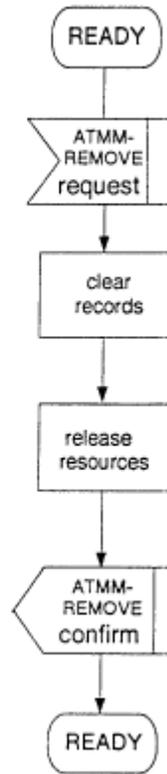**Figure D. 1 - SDI Diagram for the Connection - Assignment Process**
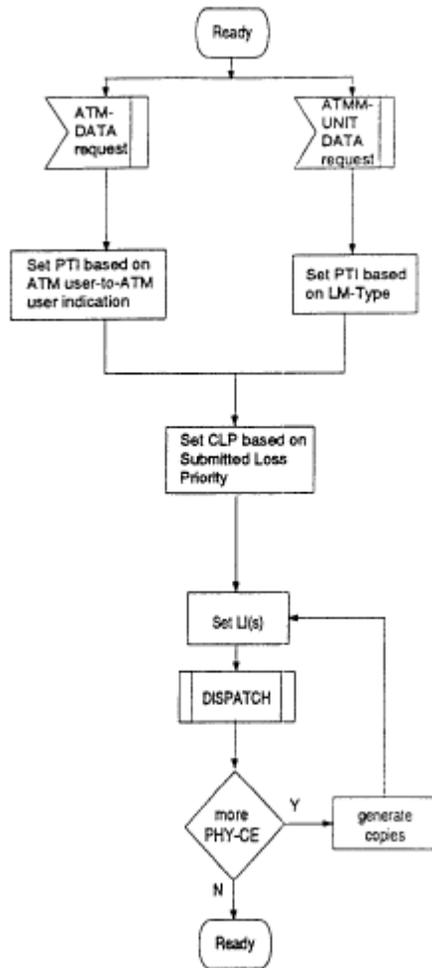
Figure D. 2 - SDL Diagram for the Connection-Remove Process

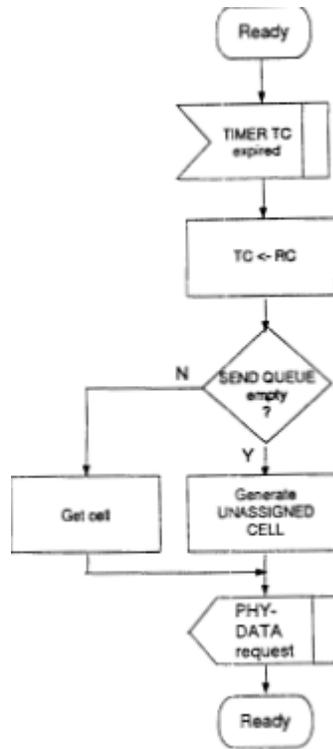**Figure D. 3 - SDL Diagram for the ATM-Cell-Construction Process**

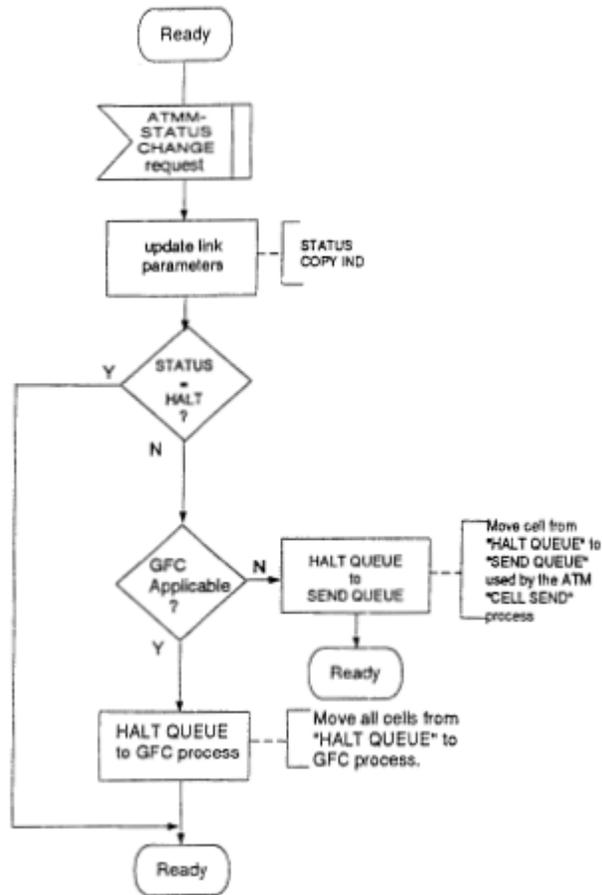**Figure D. 4 - SDL Diagram for the ATM-Cell-Send Process**

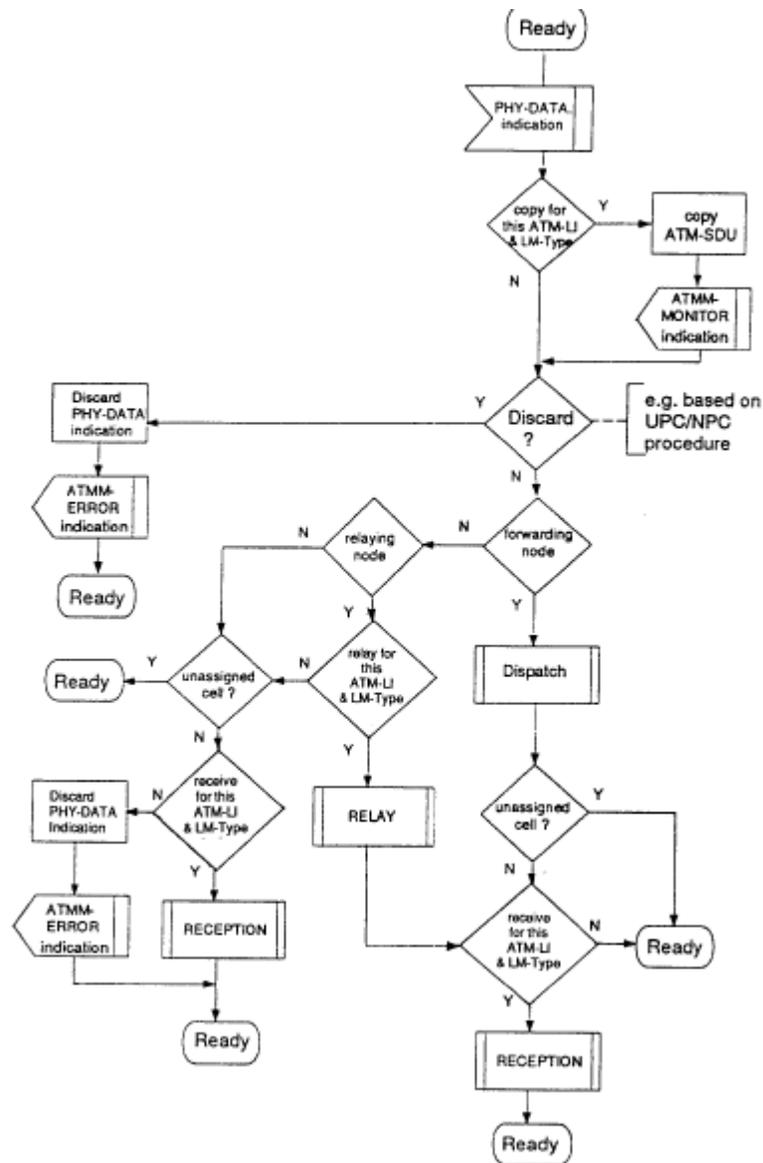**Figure D. 5 - SDL Diagram for the Link-Status-Update Process**

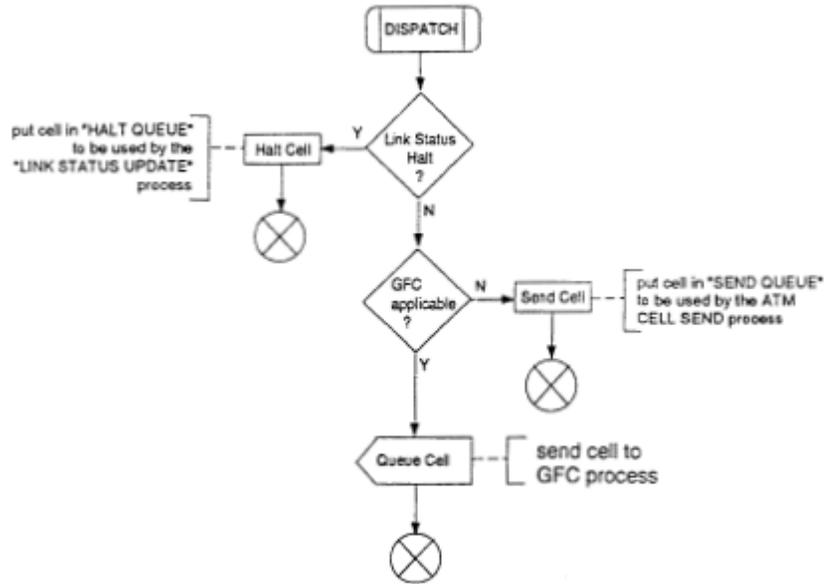**Figure D. 6 - SDL Diagram for the ATM Cell-Receive Process**

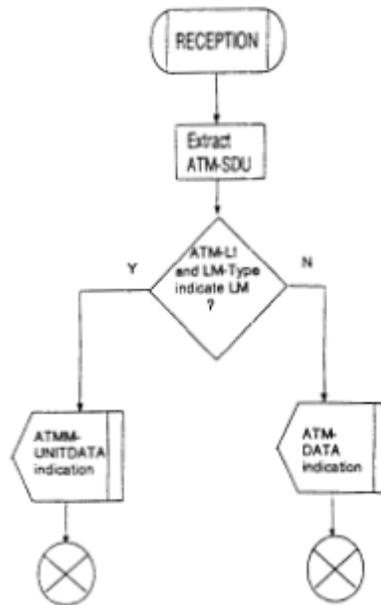**Figure D. 7 - SDL Diagram for the ATM Layer Dispatch Procedure**

Figure D. 8 - SDL Diagram for the ATM Layer Reception Procedure
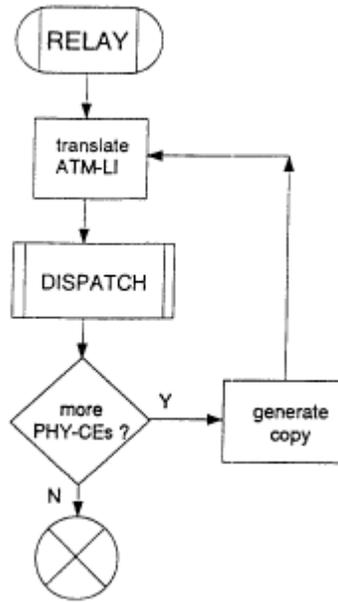
Figure D. 9 - SDL Diagram for the ATM Layer Relay Procedure

Annex E: Peak Cell Rate Monitor Algorithms Accounting for Cell Delay Variation Tolerance

(informative)

This annex provides two examples of algorithms that may be useful in monitoring the Peak Cell Rate 1/T of an ATM connection while taking into account a certain CDV tolerance τ. No recommendation is made that either of these algorithms be used for actual implementation.

A Virtual Monitor Algorithm (which might be located within the Equivalent Terminal) deter- mines whether or not ATM-PDU requests are compliant with the negotiated values of the Peak Cell Rate Descriptor.

Let T be the Peak Emission Interval and τ the Cell Delay Variation tolerance. τ corresponds to the amount of "distortion" introduced by, for example, either customer equipment multiplexing before the T_B reference point or the mapping of ATM-PDU requests onto cell time slots. τ may be set to the difference between the maximum and minimum Cell Transfer Delay throughout the CPE.

T and τ are the only parameters needed to define the Virtual Monitor Algorithm.

The Virtual Monitor Algorithm is described in figure E.1. Two equivalent versions of this algorithm are shown: the Virtual Scheduling Algorithm and the Continuous State Leaky Bucket Algorithm. In the first version, τ is expressed in units of time. In the second, the leaky bucket capacity measured in units of time is equal to $L_B = T + \tau$.
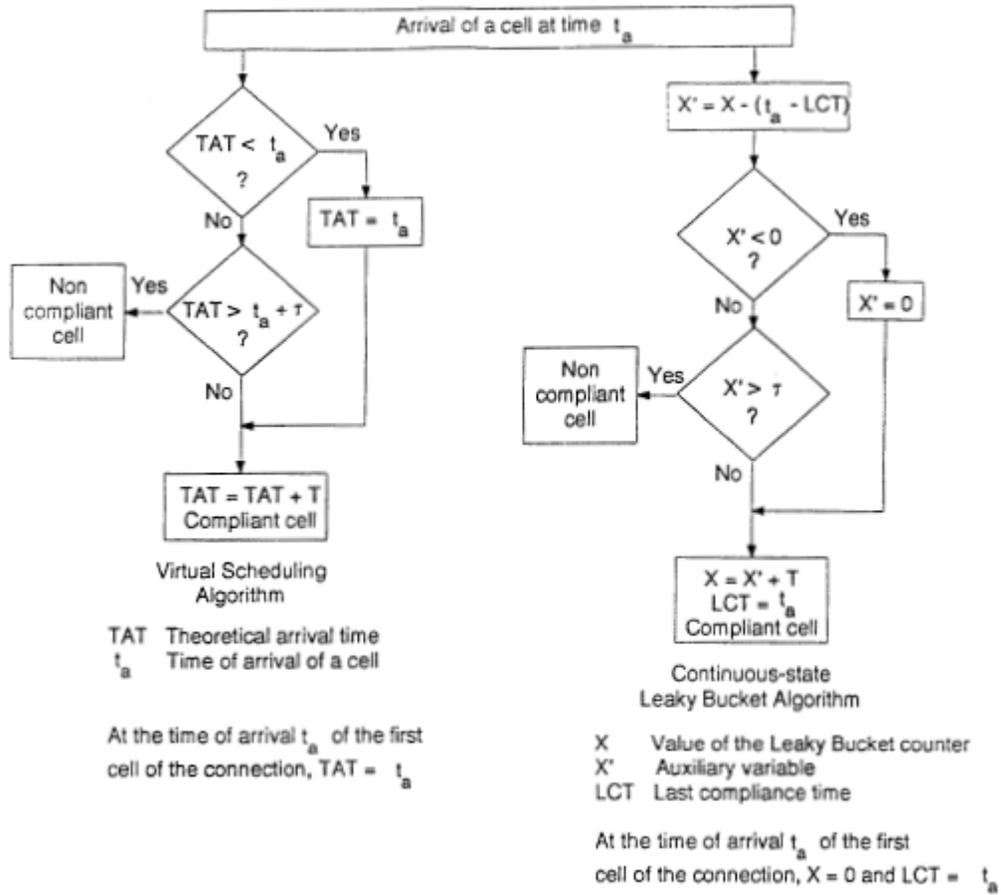
Figure E. 1 - Equivalent Versions of the Peak Cell Rate Monitor Algorithm

Annex F: Technical Differences with ITU-T Recommendations

(informative)

This annex identifies technical differences between this standard and the relevant portions of the following 1992 ITU-T Recommendations: I.150, I.311, I.361, I.371, I.432, I.610.

- The ITU-T Recommendations permit the ATM Layer to either deliver a continuous cell stream or a non-continuous cell stream to the PHY. This standard permits only the continuous cell stream option. This results in the following technical difference:

- The Physical Layer Idle Cells (see tables 1 and 3 of ITU-T Recommendation 1.361) are considered invalid cells in tables 1 and 2 of this document.

Reason for difference: For simplification of modeling only one of the options was chosen;

- The wording in section 2 of ITU-T Recommendation I.150 on cell sequence integrity is not as restrictive as the wording of clause 6 of this standard. In particular, the wording in Recommendation I.150 allows a multipoint ATM connection in an ATM inter- mediate system to alter the sequence of cells arriving to it on an ATM link as long as it preserves the sequence of cells from each ATM connection endpoint of the ATM connection. Such alteration of cell sequence is not allowed by this ANSI standard.

Reason for difference: To ensure the proper operation of the OAM performance monitoring function;

- The local ATMM primitives defined in 9.1 of this standard do not exist in the ITU-T Recommendations.

Reason for difference: These primitives pro- vide additional informative details on ATM functions;

- In clause 10 there are ATM functions identified that are not identified in ITU-T Recommendations. These functions are: delay handling, cell copying, cell forwarding.

Reason for difference: These functions pro- vide additional informative details;

In ITU-T Recommendation I.361, the UNI cell format is used across the S_B and T_B reference points. This differs from 12.2 of this standard in that the UNI format is used

at the U_B, S_B and T_B reference points.

Reason for difference: ITU-T does not recognize the U_B reference point;

- The Received Loss Priority indicator appears in 8.1.2 of this standard and not in the ITU-T Recommendations.

Reason for difference: There may be users of the ATM services that can utilize this indication (e.g., layered video coding).

Annex G: Bibliography

(informative)

At the time of publication, the editions indicated were valid. All standards are subject to revision, and users of this document are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

T1E1.2/91-038, Broadband ISDN Customer Installation Interfaces, Physical Media Dependent Specifications

T1S1/93-331,B-ISDN Metasignaling Baseline Document [2)]

T1A1/93-029, B-ISDN ATM Layer Cell Transfer – Performance Parameters. (T1Q1.3/91-02OR2)

ISO 7498-1984(E), Information Processing Systems – Open System Interconnection – Basic Reference Model [1]

ITU-T Recommendation X.200, Reference Model of Open System Interconnection for ITU-T Applications [2]

ITU-T Recommendation I.150: B-ISDN Asynchronous Transfer Mode Functional Characteristics [2]

ITU-T Recommendation I.311: B-ISDN General Network Aspects [2]

ITU-T Recommendation I.361: B-ISDN ATM Layer Specification [2]

ITU-T Recommendation I.432: B-ISDN User-network interface – Physical Layer Specification [2]

ITU-T Recommendation I.610: B-ISDN Operation and Maintenance Principles and Functions [2]

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[1] This document is available from the International Organization for Standardization. < http://www.iso.ch/iso/en/prods-services/ISOstore/store.html >

[2] This document is available from the International Telecommunications Union. < http://www.itu.int/ITU-T/ >