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SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Digital sections and digital line system – Optical line systems for local and access networks

A broadband optical access system with increased service capability using dynamic bandwidth assignment

ITU-T Recommendation G.983.4

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ITU-T Recommendation G.983.4

**A broadband optical access system with increased service capability
using dynamic bandwidth assignment**

Summary

This Recommendation specifies requirements for adding Dynamic Bandwidth Assignment (DBA) functionality to the Broadband Optical Access Systems defined in ITU-T Rec. G.983.1. The use of DBA functionality enables dynamic sharing of upstream bandwidth. This dynamic sharing uses upstream bandwidth more efficiently and enables additional services flexibility. This Recommendation captures specifications for DBA operation and for DBA-related communication between the OLT and the ONUs/ONTs.

FOREWORD

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

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

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

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

NOTE

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

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

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ITU-T Recommendation G.983.4

**A broadband optical access system with increased service capability
using dynamic bandwidth assignment**

1 Introduction

1.1 Scope

This Recommendation describes enhanced capabilities for flexible optical access networks based on ITU-T Rec. G.983.1. Specifically, this Recommendation describes the functions that extend ITU-T Rec. G.983.1 to enable Dynamic Bandwidth Assignment (DBA).

The requirements and specifications preserve backward compatibility and interoperability with the current G.983.1 systems, including management systems.

This Recommendation includes:

– Performances objectives (for example bandwidth assignment delay, maximum waiting time).

– Application functionality (for example dynamic bandwidth assignment for bursty traffic and for ONU/ONT aggregated traffic composed of different traffic classes).

– Fairness criteria and protocols (for example dynamic bandwidth assignment based on ONU/ONT status reporting, dynamic bandwidth assignment based on OLT monitoring, dynamic bandwidth assignment based on a combination of reporting and monitoring).

– Backwards compatibility and interoperability that allows legacy OLTs and ONUs/ONTs to operate in systems where DBA is employed.

It is anticipated that the introduction of DBA functionality into B-PON systems will increase efficiency and therefore lower the cost of providing broadband services.

1.2 Background

1.2.1 Bandwidth assignment in non-DBA G.983.1 systems

The current method for bandwidth assignment via grant control on ITU-T G.983.1 systems is described below.

ITU-T Rec. G.983.1 specifies a flexible access platform to provide broadband services through passive optical networks. It defines physical and link layer requirements. Traffic is conveyed in the passive optical network in the following frame formats.

The upstream traffic from the ONUs/ONTs to the OLT is transferred in a frame of 53 timeslots (cellslots). Each timeslot consists of three bytes of PON layer overhead and an ATM cell or a PLOAM cell. The upstream bandwidth is shared among the associated ONUs/ONTs. The OLT controls each upstream transmission from the ONUs/ONTs on a timeslot-by-timeslot basis. This is accomplished by sending data grants in downstream PLOAM cells.

PLOAM data grant cells are sent in the downstream direction to all ONUs/ONTs. The data grants are addressed to specific ONUs/ONTs and contain parameters that include the number of upstream data grants and the timeslots for the grants that are assigned to the individual ONU/ONT. Currently the grants are assigned in a static manner.

1.2.2 Enhancing the bandwidth assignment on G.983.1 PON systems

In ITU-T Rec. G.983.1, the OLT grant generation and distribution are updated when a new connection is provisioned on a PON or an existing connection is removed from a PON. However, there are also other occasions when bandwidth is reassigned. Once the bandwidth is provisioned, the OLT will continuously send the assigned grants to the associated ONUs/ONTs; subsequently, the OLT will receive corresponding user cells in the upstream. This current granting mechanism is most efficient for real time traffic. For example, real time traffic (represented by circuit emulation services) is a typical application that is provided over an ATM DBR Class 1 service connection. This service will generate a well-behaved traffic pattern and can be readily accommodated using the static bandwidth assignment method.

However, ITU-T Rec. G.983.1 is intended to enable a wide range of broadband services, including those that do not have a constant bit rate. For example, the Internet connects to many bursty traffic sources, which are best accommodated by ATM SBR Class 2 or GFR, which have less rigid requirements on cell transfer delay and cell delay variation. Mapping these non-real-time services into a fixed bandwidth channel prevents the ONUs/ONTs on a PON from dynamically sharing the upstream PON bandwidth. For these non-real-time traffic types, the ability to assign bandwidth dynamically is expected to provide higher efficiency than the current static granting mechanisms.

1.2.3 Effectiveness of dynamic bandwidth assignment

A Dynamic Bandwidth Assignment (DBA) mechanism improves the efficiency of the PON upstream bandwidth by dynamically adjusting the bandwidth among the ONUs/ONTs in response to ONU/ONT bursty traffic requirements. The practical benefits of DBA are twofold. First, the network operators can add more subscribers to the PON due to more efficient bandwidth use. Second, the subscribers can enjoy enhanced services, such as those requiring bandwidth peaks that would extend beyond the traditional fixed allocation. A comparison between the current static mechanism and DBA is shown in Figure 1. Three ONUs/ONTs are represented and labelled No. 1, No. 2 and No. 3. ONU/ONT No. 1 requires constant bit rate traffic such as DBR Class 1, which is carried efficiently using the static bandwidth assignment method. ONU/ONT No. 2 and ONU/ONT No. 3, however, both have bursts of traffic; traffic from ONU/ONT No. 3 also has delay requirements. With static bandwidth allocation (shown in Figure 1 a)), traffic from ONU/ONT No. 2 would be lost and traffic from ONU/ONT No. 3 would be delayed. The efficiency of DBA is shown in Figure 1 b)), where ONU/ONT No. 3 is dynamically assigned enough bandwidth to carry its traffic burst, followed by ONU/ONT No. 2 being dynamically assigned sufficient bandwidth for its traffic.

Constant bit rate traffic

Original traffic

ONU/ONT #1

ONU/ONT #2

Bursty traffic

Bursty and delay sensitive traffic

ONU/ONT #3

Lost traffic in #2   Delayed traffic in #3

ONU/ONT #1

ONU/ONT #2

ONU/ONT #3

a) Transfer by Static bandwidth assignment

ONU/ONT #1

ONU/ONT #3

ONU/ONT #2

T1546240-02

b) Transfer by DBA
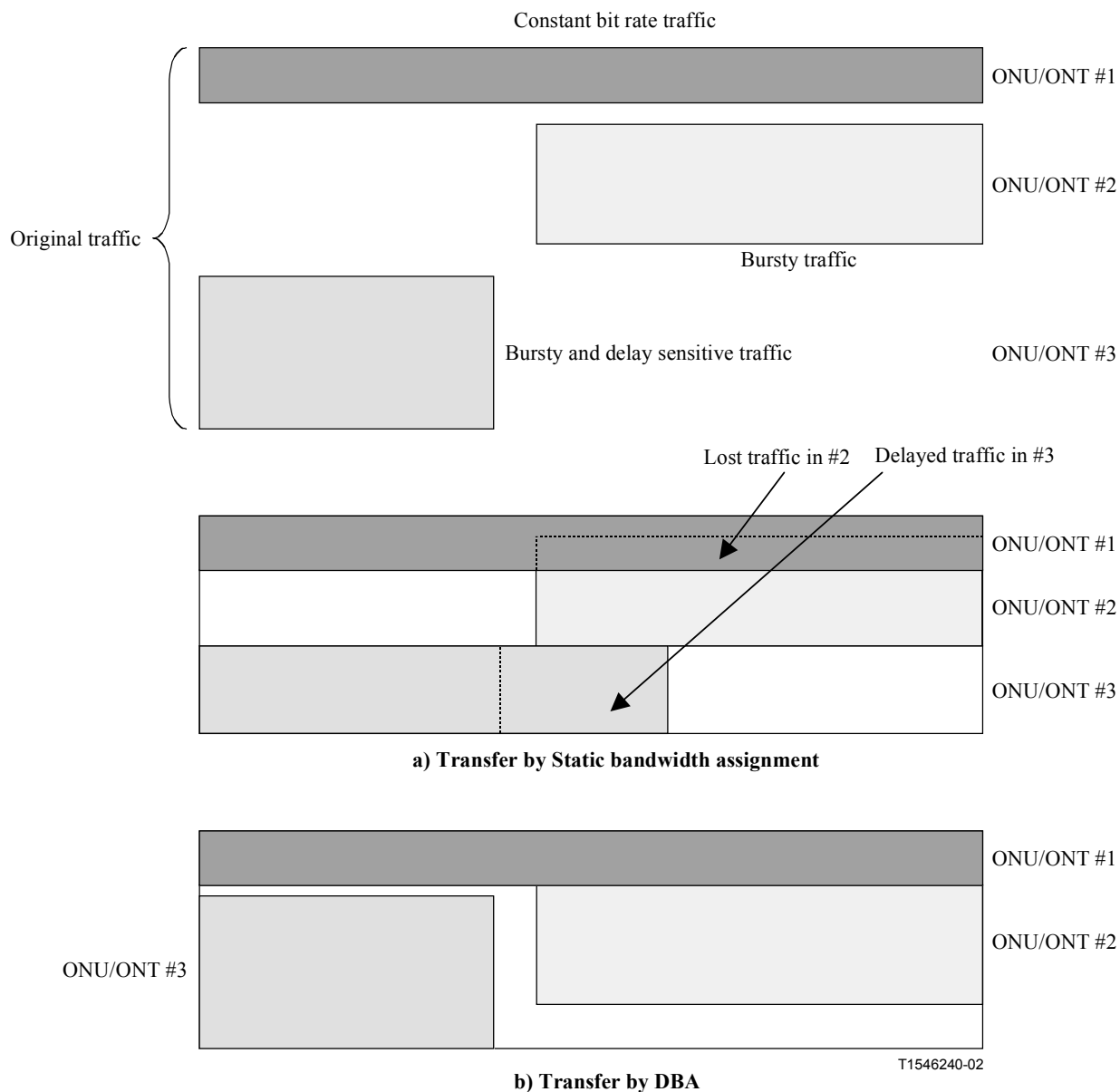
Figure 1/G.983.4 – Comparison between the current mechanism and DBA

1.2.4   General DBA approaches

Two different DBA mechanisms are summarized below.

Method one is referred to as "idle cell adjustment". In this approach, the OLT monitors the bandwidth used by each of the ONUs/ONTs. If the utilization exceeds a predefined threshold, then additional bandwidth will be assigned if it is available. In this approach, no bandwidth resources are needed for the ONU/ONT to report status; the OLT infers individual ONU/ONT bandwidth needs from the current utilization. However, a possible drawback of this approach would be slow reaction to ONUs/ONTs requesting upstream bandwidth.

Method two is called "buffer status reporting". ONUs/ONTs using this approach report the status of their buffers by using mini-slots. The OLT reassigns the bandwidth according to the ONU/ONT reports.

1.2.5 Features and Migration scenarios for DBA

Other features of DBA include the ability to accommodate several Transmission Containers (T-CONTs) in one ONU/ONT. T-CONTs in an ONU/ONT can operate independently of one another. The DBA mechanism associates grant characteristics to a T-CONT type classification. This classification enables the PON to better handle traffic flows that have similar characteristics. This classification is not intended, in any way or form, to change the related ITU-T Recommendations concerning ATM services.

The introduction of DBA into a system can be broken down into several steps. In the first step, an OLT with DBA capability is installed into a system that previously had no DBA capability. With no DBA capability, the system ONUs/ONTs do not explicitly report their buffer status and are called Non-Status-Reporting ONUs/ONTs (NSR-ONUs/ONTs). The OLT can use the idle cell adjustment approach for DBA. Next, ONUs/ONTs with buffer status reporting capability – called Status Reporting ONUs/ONTs (SR-ONUs/ONTs) – can be installed and the OLT can use the buffer status reports to allocate bandwidth to the ONUs/ONTs. DBA must also operate in a mixed case of NSR-ONUs/ONTs and SR-ONUs/ONTs. Moreover, if we define multiple T-CONTs in one ONU/ONT, DBA can provide more complicated services.

1.2.6 Requirements for this Recommendation

This Recommendation is needed to ensure interoperability between OLTs and ONUs/ONTs where one or more OLTs and/or ONUs/ONTs on a PON use DBA functionality. The specifications, including the PON frame formats and existing PLOAM cell format and message types, are consistent with ITU-T Rec. G.983.1 whenever possible. Full compatibility is required between DBA-capable and non-DBA-capable elements. Specifically the following combinations must be supported:

– NSR-ONUs/ONTs must interoperate with non-DBA-OLTs (a non-DBA system).

– NSR-ONUs/ONTs must interoperate with DBA-OLTs (idle cell monitoring).

– SR-ONUs/ONTs must interoperate with non-DBA OLTs (by disabling ONU/ONT status reporting).

– SR-ONUs/ONTs must interoperate with DBA-OLTs (status reporting DBA or idle cell monitoring).

In addition, both non-DBA-OLTs and DBA-OLTs must be able to support a mixture of NSR-ONUs/ONTs and SR-ONUs/ONTs on the same PON. The detailed operations in these combinations are described in 8.3.5.10.5.

The following items are included in this Recommendation:

The method for reporting ONU/ONT status is defined for SR-ONUs/ONTs.

The definition of T-CONT types, including support for variable rate services.

Performance benchmarks are addressed for:

– ONU/ONT bandwidth request detection.

– ONU/ONT bandwidth request reporting.

– OLT grant recalculation and distribution.

The number of types and definitions of T-CONTs are described.

1.2.7 Layered architecture

As previewed in ITU-T Rec. G.983.1, DBA is a Transmission Convergence layer function, not an ATM layer function. Figure 2 shows an example of the layered architecture.
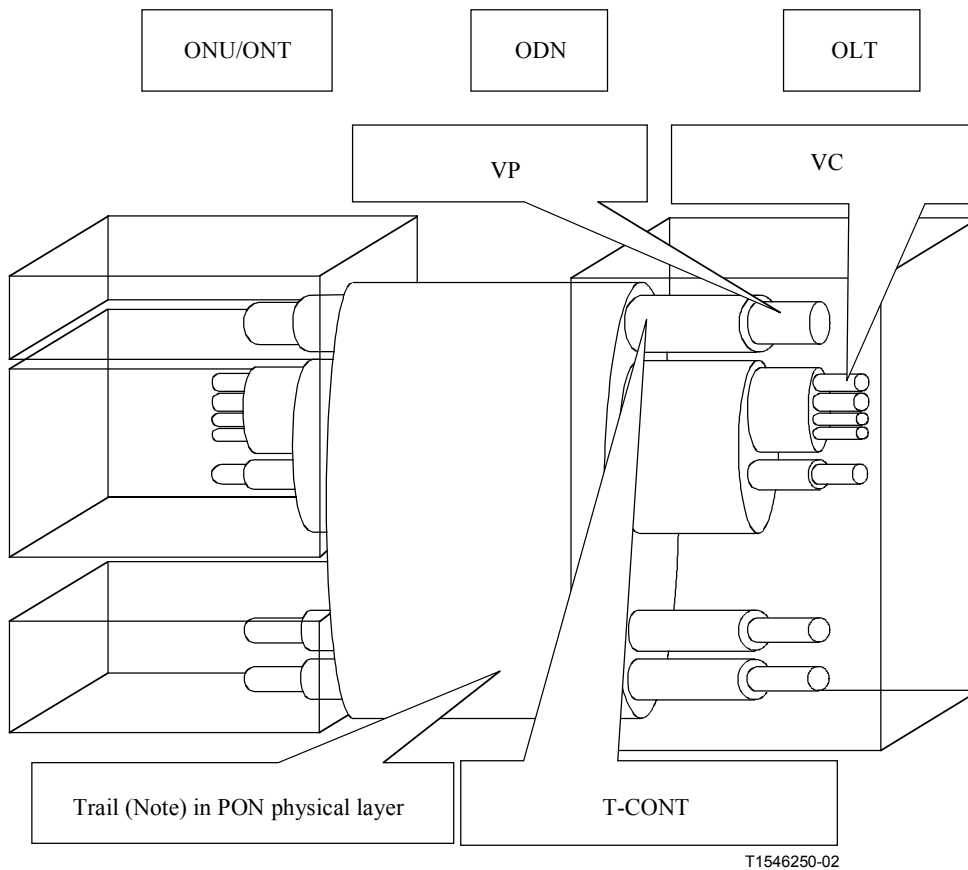
NOTE – Physical layer Trail includes the point to multi-points relationship between OLT and ONUs/ONTs

Figure 2/G.983.4 – The layer architecture in PON

1.3 Architectural Drawing

A single queue and multiple queues feeding a single T-CONT Buffer are shown in Figures 3 and 4.
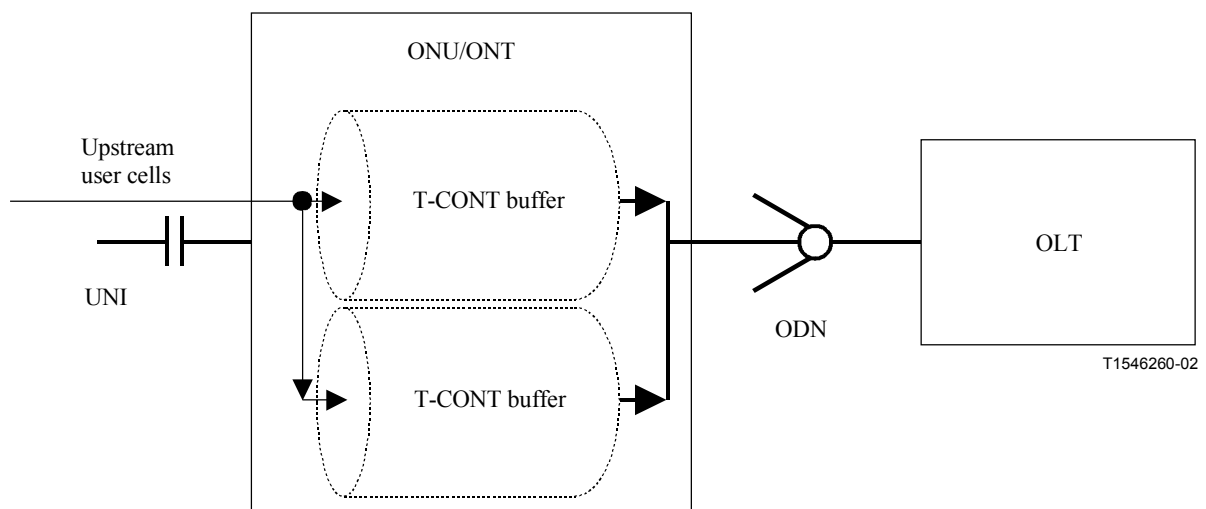
Figure 3/G.983.4 – Configurations of T-CONT buffers in one ONU/ONT

In Figure 3, an ONU/ONT supports one or more T-CONT buffers that are the object of data grants by an OLT regardless of any internal mechanism as shown in Figure 4.
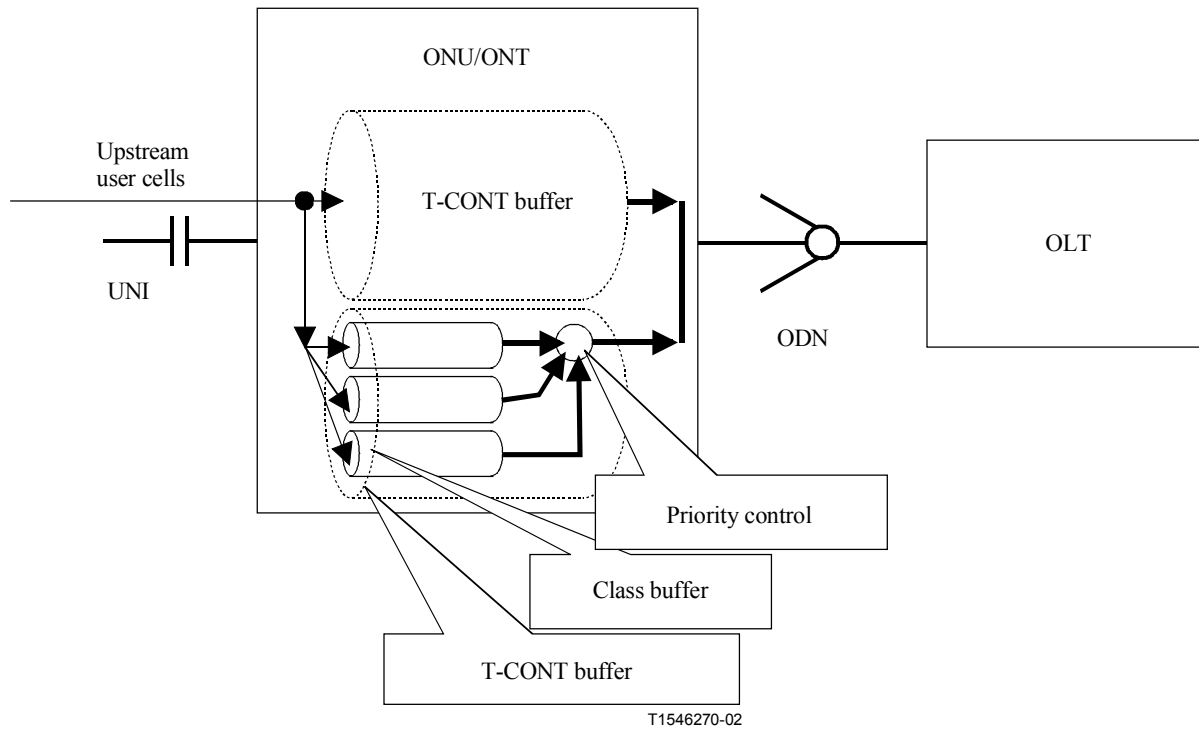
Figure 4/G.983.4 – An example of internal mechanisms in a T-CONT buffer

In Figure 4, some T-CONT buffers are serviced by an internal scheduler or some other mechanism in an upper layer (for example, the ATM layer). This figure shows one T-CONT buffer with no internal scheduler and one T-CONT buffer that consists of one or more traffic class buffers. In some applications, a priority control mechanism is used.

1.4 T-CONT priority hierarchy

The priority hierarchy for data grants to T-CONTs is shown in Figure 5.
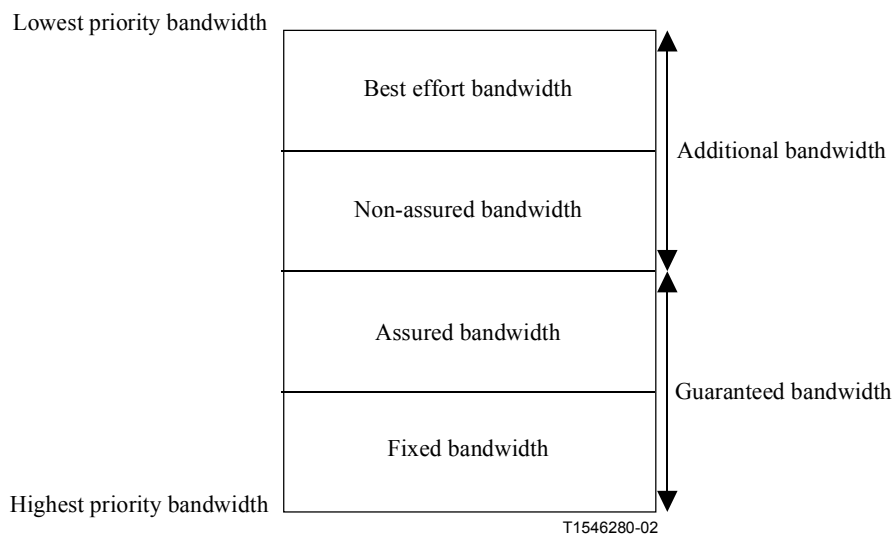
Figure 5/G.983.4 – Priority of bandwidth for grant allocation

1.5 Objectives

When providing DBA functionality the following objectives should be observed.

Compatibility should be maintained with ITU-T Rec. G.983.1 and ITU-T Rec. G.983.2:

– A single PON will support both SR-ONUs/ONTs and NSR-ONUs/ONTs.

The cost to implement DBA should remain as low as possible:

– Cost includes the overall system.

– Strategies that add cost to all ONUs/ONTs (for example requiring excessively large memory buffers at the ONU/ONT) are less desirable.

Equipment from different vendors should interoperate.

ATM traffic contracts should be met for each ATM connection in all T-CONTs:

Grants from the OLT to the T-CONTs on a PON should be equitably distributed.

2 References

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

[1]   ITU-T Recommendation G.652 (2000), *Characteristics of a single-mode optical fibre cable.*

[2]   ITU-T Recommendation G.671 (2001), *Transmission characteristics of optical components and subsystems.*

[3]   ITU-T Recommendation G.783 (2000), *Characteristics of synchronous digital hierarchy (SDH) equipment functional blocks.*

[4]   ITU-T Recommendation G.902 (1995), *Framework Recommendation on functional access networks (AN) – Architecture and functions, access types, management and service node aspects.*

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

[6]   ITU-T Recommendation G.958 (1994), *Digital line systems based on the synchronous digital hierarchy for use on optical fibre cables.*

[7]   ITU-T Recommendation G.982 (1996), *Optical access networks to support services up to the ISDN primary rate or equivalent bit rates.*

[8]   ITU-T Recommendation G.983.1 (1998), *Broadband optical access systems based on Passive Optical Networks (PON).*

[9]   ITU-T Recommendation G.983.2 (2000), *ONT management and control interface specification for ATM-PON.*

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

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

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

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

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

[15]   ITU-T Recommendation I.371.1 (2000), *Guaranteed frame rate ATM transfer capability.*

[16]   ITU-T Recommendation I.432.1 (1999), *B-ISDN user-network interface – Physical layer specification: General characteristics.*

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

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

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

3   Abbreviations

This Recommendation uses the following abbreviations:

AF	Adaptation Function
AN	Access Network
APS	Automatic Protection Switching
ATC	ATM Transfer Capability
ATM	Asynchronous Transfer Mode
BER	Bit Error Ratio
BIP	Bit Interleaved Parity
B-ISDN	Broadband Integrated Services Digital Network
B-PON	Broadband Passive Optical Network
CID	Consecutive Identical Digit
CPE	Cell Phase Error
CRC	Cyclic Redundancy Check
DBA	Dynamic Bandwidth Assignment
DSL	Digital Subscriber Line
E/O	Electrical/Optical
FTTB/C	Fibre to the Building/Curb
FTTCab	Fibre to the Cabinet
FTTH	Fibre to the Home
HEC	Header Error Control
IEC	International Electrotechnical Commission
ISDN	Integrated Services Digital Network
LAN	Local Area Network
LCD	Loss of Cell Delineation
LCF	Laser Control Field
LSB	Least Significant Bit
LT	Line Terminal

MAC	Media Access Control
MSB	Most Significant Bit
NSR	Non Status Reporting
NT	Network Termination
OAM	Operations Administration and Maintenance
OAN	Optical Access Network
ODF	Optical Distribution Frame
ODN	Optical Distribution Network
OLT	Optical Line Termination
ONT	Optical Network Termination
ONU	Optical Network Unit
OpS	Operations System
PLOAM	Physical Layer OAM
PON	Passive Optical Network
PRBS	Pseudo Random Bit Sequence
PST	PON Section Trace
PSTN	Public Switched Telephone Network
QoS	Quality of Service
RAU	Request Access Unit
RMS	Root Mean Square
SDH	Synchronous Digital Hierarchy
SN	Serial Number
SNI	Service Node Interface
SR	Status Reporting
TC	Transmission Convergence
T-CONT	Transmission Container
TDMA	Time Division Multiple Access
UI	Unit Interval
UNI	User Network Interface
UPC	Usage Parameter Control
VC	Virtual Channel
VCC	Virtual Channel Connection
VCI	Virtual Channel Identifier
VoD	Video-on-Demand
VP	Virtual Path
VPC	Virtual Path Connection

VPG   Virtual Path Group

VPI   Virtual Path Identifier

WRR   Weighted Round Robin

4   Definitions

This Recommendation defines the following terms:

4.1   additional bandwidth: Additional Bandwidth is the summation of Non-assured Bandwidth and Best Effort Bandwidth.

4.2   assured bandwidth: Assured Bandwidth is bandwidth that is always available to the ONU/ONT if the T-CONT buffer is expected to have cells to transmit. If the T-CONT buffer does not have cells to transmit, this bandwidth may be used by other T-CONTs. Assured Bandwidth is therefore able to participate in DBA.

4.3   best effort bandwidth: Best Effort Bandwidth is bandwidth that a T-CONT may be able to use if no higher-priority traffic consumes the bandwidth; there is no assurance or guarantee that the bandwidth will be available. Best Effort Bandwidth is able to participate in DBA.

4.4   broadband passive optical network (B-PON): B-PONs are one-to-many broadband optical transmission systems. B-PONs can transparently transport any type of data, for example voice, video, IP data, etc. The B-PON is able to carry data regardless of the type of data link frame (i.e. not only native ATM but also HDLC Ethernet frame, etc.).

4.5   churning: Churning is a function that can be applied to the downstream user data from an OLT to its ONUs/ONTs. Churning provides the necessary function of data scrambling and offers a low level of protection for data confidentiality. It is installed at the TC layer of the ATM-PON system and can be activated for point-to-point downstream connections.

4.6   data grant: A data grant is sent from an OLT to a T-CONT in an ONU/ONT and indicates permission for the T-CONT to transmit an upstream cell.

4.7   dynamic bandwidth assignment (DBA): is the process by which ONUs/ONTs (and their associated T-CONTs) dynamically request upstream bandwidth (either implicitly or explicitly) and the method, through idle cell monitoring at OLT or buffer status reporting from ONUs/ONTs to OLT, the OLT reassigns upstream bandwidth accordingly.

4.8   DBA-OLT: An OLT that is able to provide DBA functionality on one or more PONs.

4.9   diplex working: Bidirectional communication using a different wavelength for each direction of transmission over a single fibre.

4.10   duplex working: Bidirectional communication using the same wavelength for both directions of transmission over a single fibre.

4.11   fixed bandwidth: Fixed Bandwidth is entirely reserved and cyclically allocated in order to achieve a low cell transfer delay. If a T-CONT is provisioned with Fixed Bandwidth and has no cells to send, grants associated with the Fixed Bandwidth are still sent from the OLT and consequently idle cells will be sent upstream from the ONU/ONT to the OLT.

4.12   guaranteed bandwidth: Guaranteed Bandwidth is the summation of Assured Bandwidth and Fixed Bandwidth.

4.13   logical reach: The logical reach is defined as the maximum length that can be achieved for a particular transmission system independent of optical budget.

4.14   maximum bandwidth: Maximum Bandwidth is the upper limit of bandwidth to be assigned to a T-CONT and is the sum of Guaranteed Bandwidth and the upper limit of Additional Bandwidth.

**4.15	mean signal transfer delay**: The average upstream and downstream delay values between reference points "V" and "T" in Figure 7; a given value is determined by measuring round-trip delay, then dividing by 2.

**4.16	non-DBA-OLT**: An OLT that does not provide DBA services but conforms to the existing ITU-T Rec. G.983.1 and G.983.2.

**4.17	non-assured bandwidth**: Non-assured Bandwidth is a high priority variation of Additional Bandwidth that is assigned to T-CONTs with Assured Bandwidth. Non-assured bandwidth is able to participate in DBA.

**4.18	Non-Status Reporting ONU/ONT (NSR-ONU/ONT)**: ONUs/ONTs that do not communicate their bandwidth needs and requirements to a DBA-OLT. All ONUs/ONTs conforming to ITU-T Recs. G.983.1 and G.983.2 but that do not report buffer status are NSR-ONUs/ONTs.

**4.19	Optical Access Network (OAN)**: The set of access links sharing the same network-side interfaces and supported by optical access transmission systems. The OAN may include a number of ODNs connected to the same OLT.

**4.20	Optical Distribution Network (ODN)**: An ODN provides the optical transport between the OLT and its associated ONUs/ONTs. It uses passive optical components.

**4.21	Optical Line Termination (OLT)**: An OLT provides the network-side interface of the OAN, and is connected to one or more ODNs.

**4.22	Optical Network Termination (ONT)**: An ONT provides the customer-side interface for the OAN, and is connected to one ODN. An ONT is used for FTTH and includes the User Port function. From a DBA point of view, ONT and ONU are identical and are represented by the term "ONU/ONT" in this Recommendation.

**4.23	Optical Network Unit (ONU)**: An ONU provides (directly or remotely) the user-side interface of the OAN, and is connected to the ODN. From a DBA point of view, ONU and ONT are identical and are represented by the term "ONU/ONT" in this Recommendation.

**4.24	QoS class**: In the context of ATM services, QoS refers to a set of performance parameters that constitute the traffic contract between the subscriber equipment and the network. Examples of these performance parameters include, cell loss ratio, cell transfer delay, and cell delay variation tolerance. The parameters are used to define distinct QoS classes.

**4.25	ranging**: Ranging is a method of measuring the logical distance between each ONU/ONT and its associated OLT and determining the transmission timing such that upstream cells sent from different ONUs/ONTs on the same ODN do not collide.

**4.26	service port function**: The Service Port Function (SPF) adapts the requirements defined for a specific SNI to the common bearers handling function and selects the relevant information for treatment in the AN system management function.

**4.27	Status Reporting ONU/ONT (SR-ONU/ONT)**: An ONU/ONT that reports the status of its T-CONT buffers to a DBA-OLT.

**4.28	surplus bandwidth**: Surplus Bandwidth is PON bandwidth not committed to Fixed Bandwidth or Assured Bandwidth or bandwidth reserved for special usage like OAM. Surplus Bandwidth is able to participate in DBA.

**4.29	Transmission Containers (T-CONTs)**: T-CONTs are used for the management of upstream bandwidth allocation in the PON section of the Transmission Convergence layer. T-CONTs are primarily used to improve the upstream bandwidth use on the PON.

–	T-CONTs carry ATM VPCs and VCCs and report their buffer status to their associated OLTs.

–	T-CONTs dynamically receive grants from the OLT.

–	A single T-CONT can carry ATM traffic with various service classes and VCCs and/or VPCs.

–	A T-CONT can accommodate one or more physical queues and aggregates them into a single logical buffer.

–	A DBA-T-CONT status report summarizes the status of the logical buffer of that T-CONT.

–	A T-CONT is a transport entity in the TC layer that transfers higher-layer information transparently from input to output.

–	Information traversing a T-CONT is unchanged except where degradation occurs in the transfer process.

–	A data grant is associated with one and only one T-CONT. T-CONTs physically occur in the ONU/ONT hardware and software.

See subclause 8.3.5.10.2 T-CONT types for detailed T-CONT definition and examples. This subclause also details the T-CONT sub-types.

**4.30	Time Division Multiple Access (TDMA)**: Transmission technique that allocates specific timeslot(s) to each traffic source that shares a transmission medium.

**4.31	user port function**: The User Port Function (UPF) adapts the specific UNI requirements to the core and management functions. The AN may support a number of different accesses and user network interfaces which require specific functions according to the relevant interface specification and the access bearer capability requirements, i.e. bearers for information transfer and protocols.

**4.32	verification**: It is possible for a malicious user to masquerade as another ONU/ONT and use the network if the user knows that the ONU/ONT is power-off. Verification is a function to check whether the connected ONU/ONT is masquerading.

# 5	Architecture of the optical access network

## 5.1	Network architecture

The optical section of a local access network system could be either point-to-point, point-to-multipoint, active, or passive. Figure 6 shows the architectures considered, which range from Fibre to the Home (FTTH), through Fibre to the Building/Curb (FTTB/C) to Fibre to the Cabinet (FTTCab). The Optical Access Network (OAN) is common to all architectures shown in Figure 6, hence commonality in this system has the potential to generate large worldwide volumes.

ONU   Optical Network Unit
ONT   Optical Network Termination   T1528110-98
OLT   Optical Line Termination
NT   Network Termination
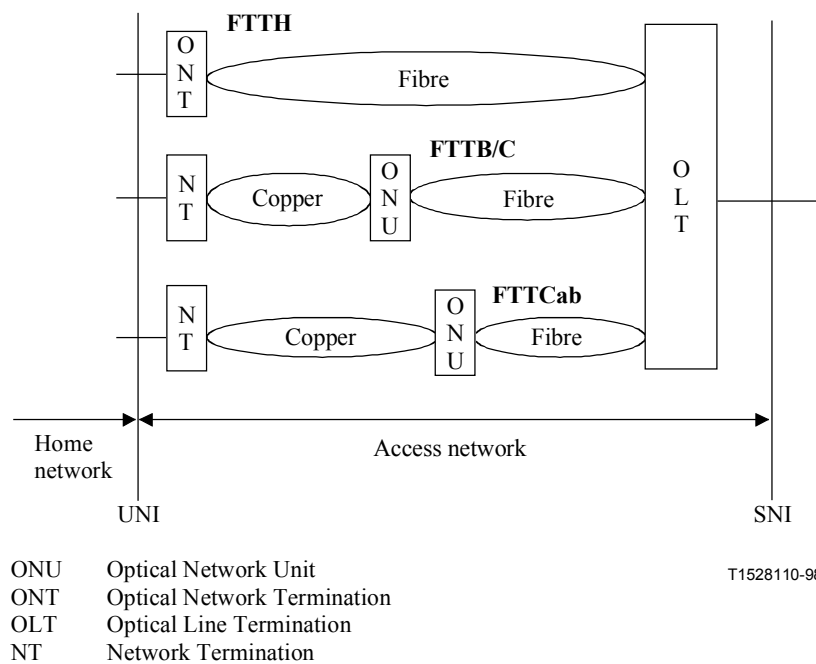
Figure 6/G.983.4 – Network architecture

The FTTB/C and FTTCab network options are predominantly different only as a result of implementation, as a result they can be treated the same in this Recommendation. Protocols supported by ONTs on the fibre are the same as those supported by ONUs. In this Recommendation, ONU and ONT are represented as "ONU/ONT".

5.1.1   FTTCab/C/B scenario

Within this scenario the following service categories have been considered:

–   Asymmetric broadband services (e.g. digital broadcast services, VoD, Internet, distance learning, telemedicine, etc.).

–   Symmetric broadband services (e.g. telecommunication services for small business customers, teleconsulting, etc.).

–   PSTN and ISDN. The access network must be able to provide, in a flexible way, the narrowband telephone services.

5.1.2   FTTH scenario

Fibre-to-the-Home service drivers are similar to those of the previous scenarios and include:

–   Consideration of indoor ONUs/ONTs resulting from more favourable environmental conditions.

–   No change of an existing ONU/ONT is required when upgrading access network capabilities to accommodate future evolution of broadband and multimedia services.

–   Easier maintenance resulting from a passive fibre plant between the OLT and ONUs/ONTs, because fibre systems are regarded as more reliable than hybrid fibre-metallic systems.

–   FTTH is a driver for the development of advanced optoelectronics technologies. The higher volumes associated with FTTH should help reduce the costs of optoelectronic components.

When these factors can be fully used they may counterbalance a slightly higher per line cost when compared to metallic alternatives. In this situation the FTTH scenario may be regarded as economically feasible even in the short term.

5.1.3 DBA installations Scenario for FTTx

DBA can be installed for FTTx to increase availability of bandwidth by dynamically allocating all or part of the upstream bandwidth among the ONUs/ONTs. In short, DBA can provide higher performance for services in the FTTx systems specified in 5.1.1 and 5.1.2. DBA should allow the network to accommodate more users than in a non-DBA FTTx system. Bursty data applications should benefit significantly from DBA.

5.1.3.1 Compatibility between DBA and conventional systems specified in G.983.1

Systems and components that are controlled by DBA shall maintain backward compatibility and interoperability with existing systems that conform to ITU-T Rec. G.983.1. In particular, interoperability is required for the following combinations:

−   A DBA-OLT can be replaced by a Non-DBA-OLT that supports NSR-ONUs/ONTs without modification of network design.

−   A DBA-OLT shall be able to distinguish between NSR-ONUs/ONTs and SR-ONUs/ONTs without modification to the NSR-ONUs/ONTs.

−   A DBA-OLT running in non-DBA mode shall have the same downstream capabilities and provide the same environment as a non-DBA-OLT. Detailed operations of combined configurations for OLTs and ONUs/ONTs are described in 8.3.5.10.5.

5.1.3.2 Interoperability in multi-vendor environment

Multi-vendor interoperability shall be required for all OLTs and ONUs/ONTs. The following requirements should be met:

−   A DBA-OLT shall dynamically and fairly allocate bandwidth on a PON that includes NSR-ONUs/ONTs from different vendors.

−   A DBA-OLT shall dynamically and fairly allocate bandwidth on a PON that includes SR-ONUs/ONTs from different vendors as long as these SR-ONUs/ONTs conform to the status reporting technique specified in this Recommendation.

−   A DBA-OLT shall dynamically and fairly allocate bandwidth on a PON to any combinations of NSR-ONUs/ONTs and SR-ONUs/ONTs from different vendors.

5.2 Reference configuration

The reference configuration is shown in Figure 7.

The ODN offers one or more optical paths between one OLT and one or more ONUs/ONTs. Each optical path is defined between reference points S and R in a specific wavelength window. The two directions for optical transmission in the ODN are identified as follows:

−   downstream direction is defined as the direction of flow of information from the OLT to the ONU/ONT(s);

−   upstream direction is defined as the direction of flow of information from the ONU/ONT(s)to the OLT.

(a)   Reference point – This reference point is added to differentiate the AF from the ONU
AF   Adaptation Function
ODN   Optical Distribution Network
OLT   Optical Line Termination
ONT   Optical Network Termination
ONU   Optical Network Unit
R   Point on the optical fibre just before the ONU/ONT[Downstream] or OLT[Upstream] optical
      point (i.e. optical connector or optical splice)
S   Point on the optical fibre just after the OLT[Downstream] or ONU/ONT[Upstream] optical
      point (i.e. optical connector or optical splice)

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Figure 7/G.983.4 – Reference configuration for an ATM based PON

The B-PON system consists of Optical Line Termination (OLT), Optical Network Unit/Optical Network Termination (ONU/ONT), fibre cable, and one or more passive optical splitter(s). Light from the OLT is passively split and distributed to multiple ONUs/ONTs on the ODN. Since each ONU/ONT receives all the information emanating downstream from the OLT, additional capabilities are required to provide privacy and security. In the upstream direction a Time-Division Multiple Access (TDMA) protocol is required.

5.2.1   Service node interface

See ITU-T Rec. G.902.

5.2.2   Interface at the reference points S/R and R/S

The interface at reference points S/R and R/S is defined as IF$_{PON}$. This is a PON-specific interface that supports all the protocol elements necessary to allow the transmission between OLT and ONUs/ONTs.

5.3   Functional blocks

5.3.1   Optical line termination

The optical line termination (OLT) interfaces to services nodes via the SNI and to the ONUs/ONTs via the ODN. The OLT is responsible for managing all the PON specific aspects of the ATM transport system. An ONU/ONT and its associated OLT provide transparent ATM transport service between the UNIs and the SNI over the PON. Both Non-DBA-OLTs and DBA-OLTs are covered in this Recommendation.

5.3.1.1 Non-DBA-OLT

This type of OLT supports functions specified in ITU-T Rec. G.983.1.

5.3.1.2 DBA-OLT

A DBA-OLT is capable of assigning upstream bandwidth dynamically based on the service contracts of data traffic in the active T-CONTs, the requested bandwidth of the T-CONTs, and the available bandwidth upstream on the PON. In general, operations for DBA can be categorized into three approaches as follows:

In the first approach, a DBA-OLT updates allocated bandwidth depending on traffic monitoring in the DBA-OLT.

In the second case, the DBA-OLT updates allocated bandwidth based on reports from SR-ONUs/ONTs.

The third case, the DBA-OLT updates allocated bandwidth based on the combination of the traffic monitoring in the DBA-OLT and reports from SR-ONUs/ONTs.

5.3.2 Optical network unit/optical network termination

The ONU/ONT interfaces over the IF_{PON} to the OLT, and to the UNI. Together with the OLT, the ONU/ONT is responsible for providing transparent ATM transport service between the UNI and the SNI.

In this architecture, the ATM transport protocols at an IF_{PON} are described as consisting of Physical Media Dependent layer, Transmission Convergence layer, and ATM layer. This architecture is only intended to address the transport of ATM; further detail is contained in ITU-T Rec. I.732.

The Physical Media Dependent layer includes the modulation schemes for both the upstream and downstream channels (they may be different). It may be possible for the specification to allow for more than one type of Physical Media Dependent layer in a single direction.

The Transmission Convergence layer will be responsible for managing the distributed access to the upstream PON resource across the multiple ONUs/ONTs. This is a key protocol element and will directly affect the resulting ATM QoS.

The ATM protocols should see no change in the way they operate over the PON. Within both the OLT and the ONU/ONT functions performed at the ATM layer at both the OLT and ONU/ONT include cell relaying.

In this Recommendation, ONUs/ONTs are classified into two types: SR-ONU/ONT and NSR-ONU/ONT. These are defined in the following clauses.

5.3.2.1 NSR-ONU/ONT

NSR-ONUs/ONTs do not report T-CONT buffer status explicitly. ONUs/ONTs specified in ITU-T Rec. G.983.1 are NSR-ONUs/ONTs.

5.3.2.2 SR-ONU/ONT

An SR-ONU/ONT reports the status of its T-CONT buffers to the OLT.

5.3.3 Optical distribution network

The Optical Distribution Network provides the optical transport between the OLT and its associated ONUs/ONTs. It uses passive optical components.

5.4 ONU/ONT functional block

As an example, the FTTH ONU/ONT is active and decouples the access network delivery mechanism from the in-house distribution. The ONU/ONT core consists of ODN interface, User Port, Transmission, Services and Customers Multiplexing (MUX)/demultiplexing functions and powering, see Figure 8.

Figure 8/G.983.4 – Example of NSR-ONU/ONT functional blocks

5.4.1 NSR-ONU/ONT functional block

5.4.1.1 Optical Distribution Network interface

The ODN interface handles the optoelectronic conversion process. The ODN interface extracts ATM cells from the downstream PON payload and inserts ATM cells into the upstream PON payload based on synchronization acquired from the downstream frame timing. Moreover, if multiple T-CONTs exist in one ONU/ONT, these operations are invoked for every T-CONT.

5.4.1.2 Multiplexing

The multiplexer (MUX) multiplexes service interfaces to the ODN interface. Only valid ATM cells can be passed through the MUX, so many VPs can share the assigned upstream bandwidth effectively. Moreover, if multiple T-CONTs exist in one ONU/ONT, these operations are invoked for every T-CONT.

5.4.1.3 User port

The specific information is described in ITU-T Rec. G.983.1.

5.4.1.4 ONU/ONT powering

The specific information is described in ITU-T Rec. G.983.1.

5.4.2 SR-ONU/ONT functional block

The FTTH ONU/ONT is active and decouples the access network delivery mechanism from the in-house distribution. The ONU/ONT core consists of the ODN interface, User Port, Transmission, Services and Customers Multiplexing (MUX)/demultiplexing functions, status reporting function, detecting function, and powering, see Figure 9.
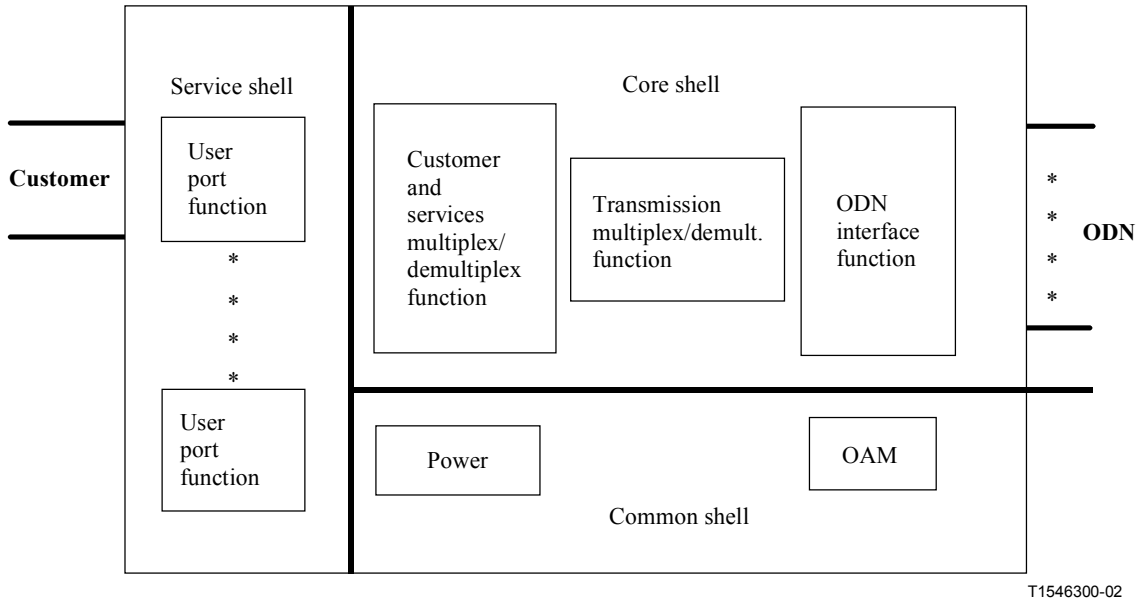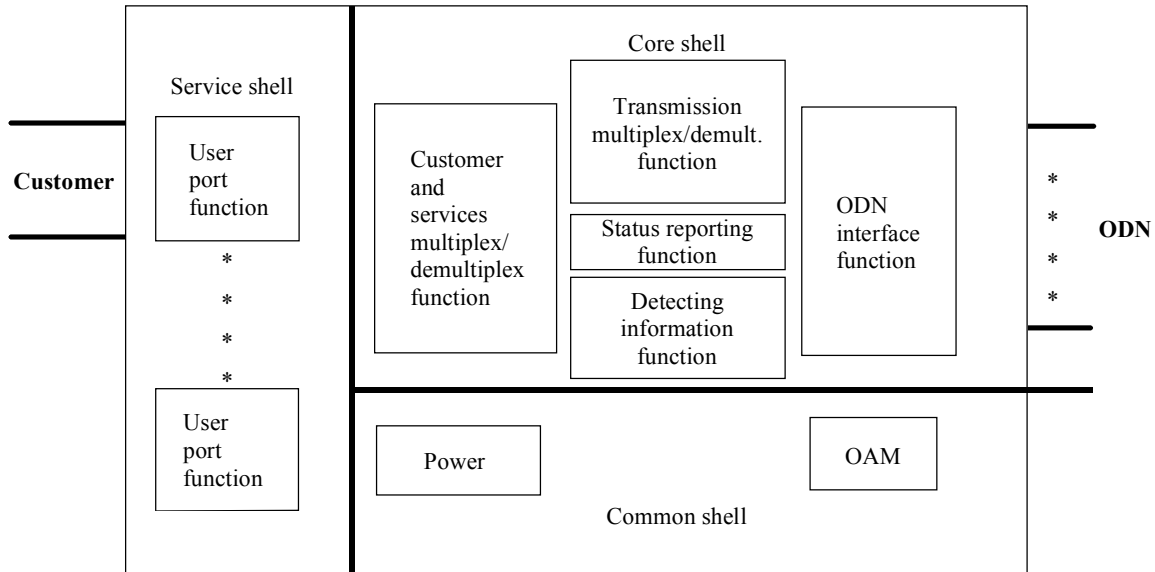

Figure 9/G.983.4 – Example of SR-ONU/ONT functional blocks

5.4.2.1 Optical Distribution Network interface

The ODN interface handles the optoelectronic conversion process. The ODN interface extracts ATM cells from the downstream PON payload and inserts ATM cells into the upstream PON payload based on synchronization acquired from the downstream frame timing. Moreover, if multiple T-CONTs exist in one ONU/ONT, these operations are invoked for every T-CONT.

5.4.2.2 Multiplexing

The multiplexer (MUX) multiplexes service interfaces to the ODN interface. Only valid ATM cells can be passed through the MUX, so many VPs can share the assigned upstream bandwidth effectively. Moreover, if multiple T-CONTs are contained in one ONU/ONT, these operations are invoked in every T-CONT.

5.4.2.3 User port

The specific information is described in ITU-T Rec. G.983.1.

5.4.2.4 ONU/ONT powering

The specific information is described in ITU-T Rec. G.983.1.

5.4.2.5 Reporting function

A DBA reporting function provides information indicating the bandwidth request status in every T-CONT to the DBA-OLT. Variations of the DBA reporting methods and format are described in 8.3.5.10.1.3.

5.4.2.6   Detecting function

The SR-ONU/ONT is capable of performing the status detecting function by monitoring each T-CONT in the SR-ONU/ONT. The queue status of a T-CONT in the ONU/ONT can be detected using this function.

5.5   Optical Line Termination functional block

5.5.1   Non-DBA-OLT functional block

The OLT is connected to switched networks via standardized interfaces (VB5.x, V5.x, and NNI's). At the distribution side, it presents optical access according to the agreed requirements, in terms of bit rate, power budget, etc.

The OLT consists of four parts: the service port function; ODN interface; MUX for VP grooming, and static grant assignment (see Figure 10). This combination is not intended to preclude the Virtual Channel (VC) layer function in the OLT. VC layer function is for further study.

1)   *Service port function*

   The function interfaces to service nodes. The service port function may handle inserting ATM cells into the upstream SDH payload and extracting ATM cells from the downstream SDH payload. The function may be duplicated, in which case the protection switching function is necessary.

2)   *MUX*

   The MUX provides VP connections between the service port function and the ODN interface. Different VPs are assigned to different services at IF_{PON}. Various types of information such as bearer content, signalling, and OAM flows are exchanged by using VCs of the VP.

3)   *ODN interface*

   The PON Line Terminal handles the optoelectronic conversion process. The ODN interface handles inserting ATM cells into the downstream PON payload and extracting ATM cells from the upstream PON payload. The difference in functional blocks between Non-DBA-OLT and DBA-OLT is the functionality of Media Access Control (MAC) in ODN interface. For a Non-DBA-OLT, the MAC assigns grants to each T-CONT contained in one ODN according to the T-CONT's contracted service.
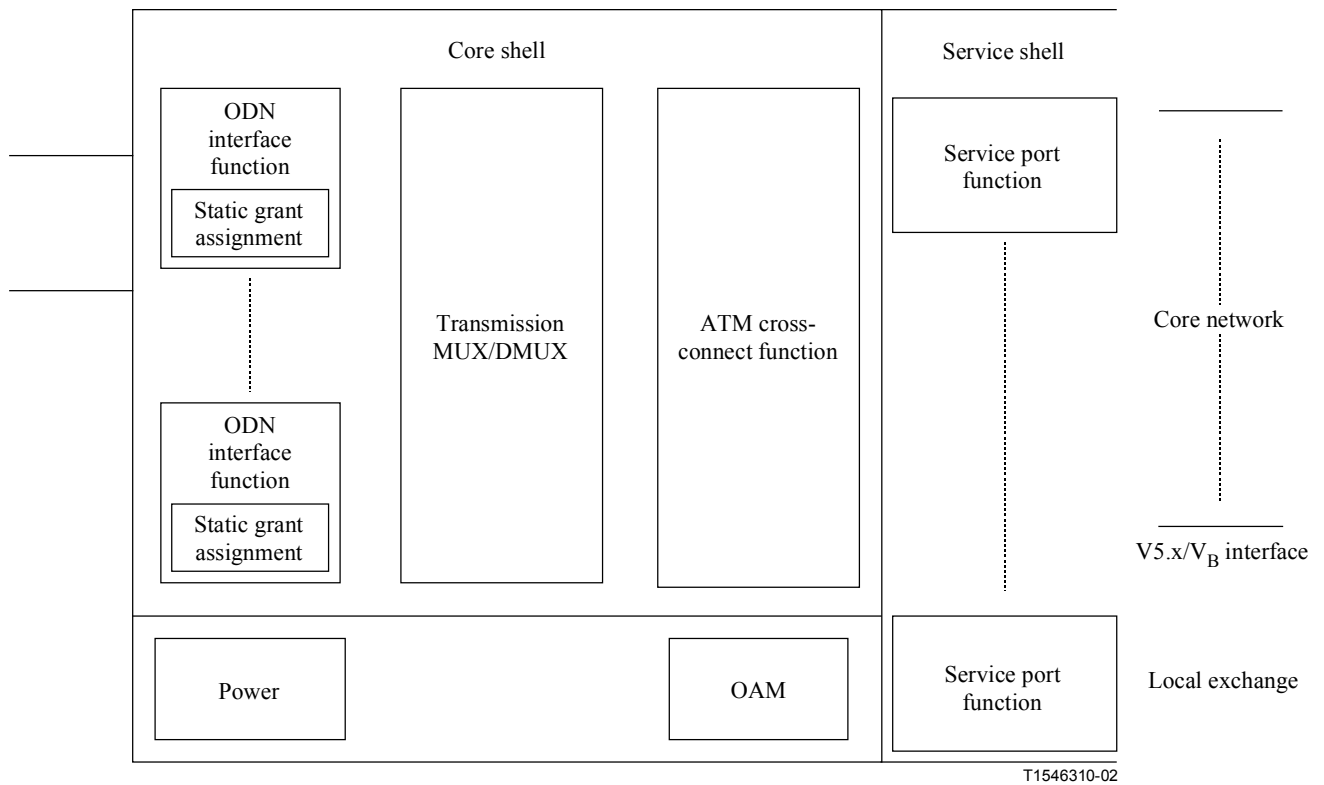
Figure 10/G.983.4 – Example of Non-DBA-OLT functional blocks

5.5.2   DBA-OLT functional block

The DBA-OLT shares many identical functional blocks with the Non-DBA-OLT (see Figure 11). In short, it is connected to the same networks via the same interfaces as the Non-DBA-OLT.

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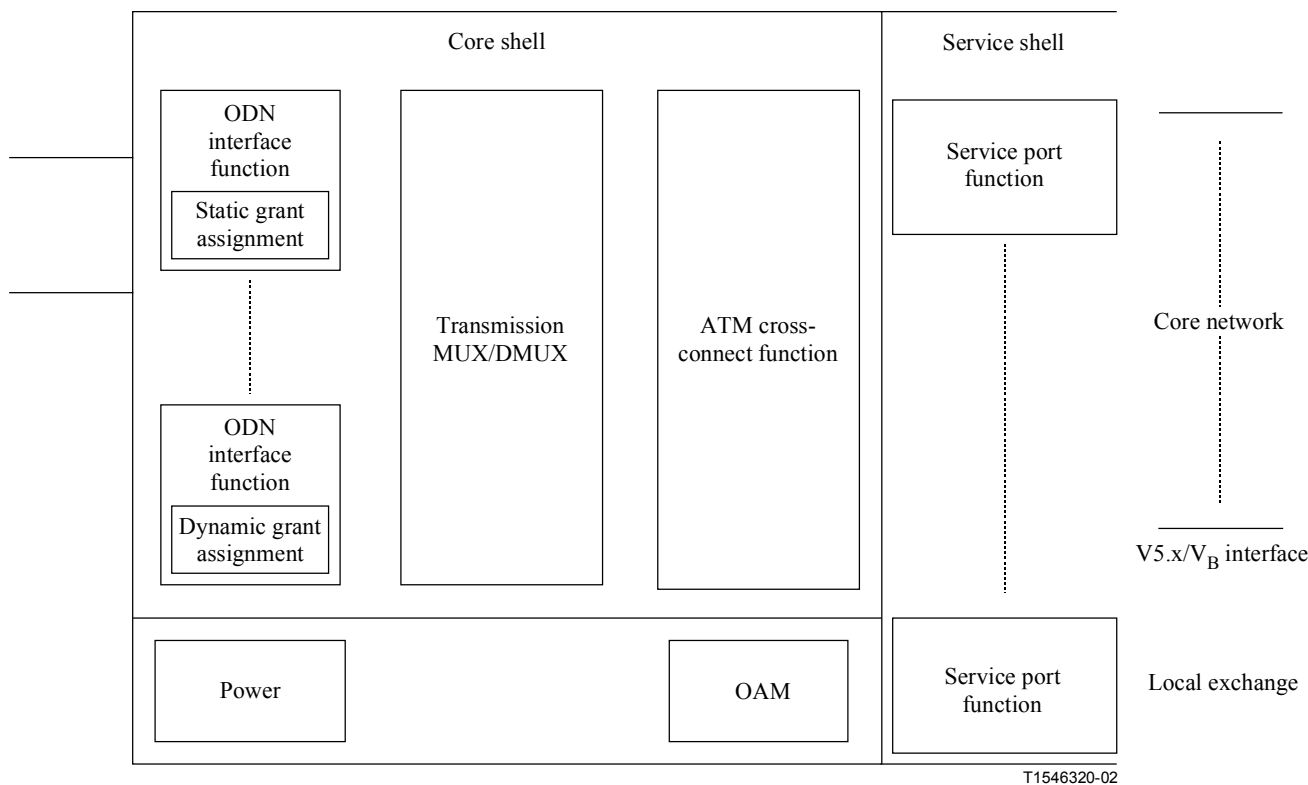
Figure 11/G.983.4 – Example of DBA-OLT functional blocks

The difference between the functional blocks of a Non-DBA-OLT and a DBA-OLT is grant assignment on the ODN interface. In a DBA-OLT, the MAC assigns grants to individual T-CONTs on one ODN statically and/or dynamically according to the contract of these T-CONTs and/or their bandwidth request status. Bandwidth request status is collected from ONU/ONT reports and/or OLT surveillance of incoming cells. Moreover, it may be recognized by other methods, for example, bandwidth request from network interfaces.

5.6   Optical distribution network functional block

In general, the Optical Distribution Network (ODN) provides the optical transport between the ONUs/ONTs and their associated OLT.

Individual ODNs may be combined and extended through the use of optical amplifiers (see ITU-T Rec. Rec. G.982).

5.6.1   Passive optical elements

The ODN consists of passive optical elements:
–   single-mode optical fibres and cables;
–   optical fibre ribbons and ribbon cables;
–   optical connectors;
–   passive branching components;
–   passive optical attenuators;
–   splices.

The specific information required to describe passive optical components is described in ITU-T Rec. G.671.

The specific information for optical fibres and cable is described in ITU-T Rec. G.652.

5.6.2 Optical interfaces

In the context of the reference configuration, Figure 12 shows the generic physical configuration of an ODN.
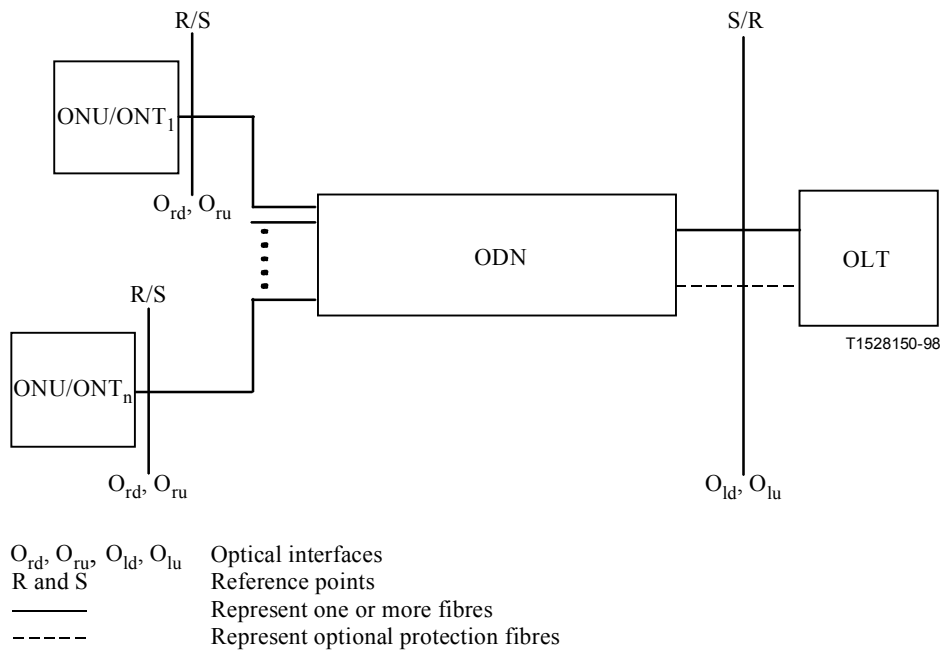
Figure 12/G.983.4 – Generic physical configuration of the Optical Distribution Network

The two directions for optical transmission in the ODN are identified as follows:

– downstream direction for signals travelling from the OLT to the ONU/ONT(s);

– upstream direction for signals travelling from the ONU/ONT(s) to the OLT.

Transmission in downstream and upstream directions can take place on the same fibre and components (duplex/diplex working) or on separate fibres and components (simplex working).

If additional connectors or other passive devices are needed for ODN rearrangement, they shall be located between S and R and their losses shall be taken into account in any optical loss calculation.

The ODN offers one or more optical paths between one OLT and one or more ONUs/ONTs. Each optical path is defined between reference points in a specific wavelength window.

The following optical interfaces are defined in Figure 12:

– O_{ru}, O_{rd} Optical interface at the reference point R/S between the ONU/ONT and the ODN for the upstream and downstream directions respectively.

– O_{lu}, O_{ld} Optical interfaces at the reference point S/R between the OLT and the ODN for the upstream and downstream directions respectively.

At the physical layer, the interfaces may require more than one fibre, e.g. for separation of transmission directions or different types of signals (services).

Specification of the optical interfaces (O_{ru}, O_{rd}, O_{lu}, O_{ld}) are defined in clause 8.

The optical properties of the ODN shall enable the provisioning of any presently foreseeable service, without the need of extensive modifications to the ODN itself. This requirement has an impact on the properties of the passive optical components that constitute the ODN. A set of essential requirements, which have a direct influence on the optical properties of the ODN, are identified as follows:

– *optical wavelength transparency*: devices, such as optical branching devices, which are not intended to perform any wavelength-selective function, shall be able to support transmission of signals at any wavelength in the 1310 nm and 1550 nm regions;

– *reciprocity*: reversal of input and output ports shall not cause significant changes of the optical loss through the devices;

– *fibre compatibility*: all optical components shall be compatible with single-mode fibre as specified in ITU-T Rec. G.652.

5.6.2.1 Optical Distribution Network model loss calculations

This is described in ITU-T Rec. G.982.

5.6.2.2 Optical Distribution Network model loss calculation technique

This is described in ITU-T Rec. G.982.

6 Services

The high-speed access systems described in this Recommendation could provide the complete range of all currently known and new services being discussed for the residential subscribers and business customers. These services could include:

– Data communications, including LAN interconnection.

– Private Line services.

– Telephony.

– Entertainment video distribution and video conferencing.

– Electronic commerce and data transfer

These services imply a broad range of network requirements that include:

– bit rate;

– symmetry/asymmetry;

– delay;

– delay variation;

– transparent Virtual Paths;

– support for ATC/QoS.

In particular, even if DBA is installed to economize network resources, ATM services with any ATC/QoS over PON can be provided without degradation of criteria for quality as described in ITU-T Rec. I.356. Moreover, DBA produces benefits for carrying variable bit rate traffic, such as bursty traffic (e.g. SBR and GFR), which may be particularly useful for data communication and video communication.

What specific services should be provided differs among operators and depends heavily on the particular regulatory conditions in each operator's markets, as well as on market potential. How these services are delivered in a cost effective way is a function not only of legal conditions but also of factors including existing telecommunications infrastructure, dwelling distribution, customer density and residential/business customers mix.

In spite of this varied market background there are some features that have been perceived as common to all parties. They can be summarized as follows:

– Some services require bit rates higher than those supported by PSTN and basic ISDN. These bit rates are best delivered on fibre based or fibre hybrid networks.

– As the services evolve and newer services are introduced the bandwidth and management requirements will increase. This requires the access network to be flexible and easily upgraded.

7 User network interface and service node Interface

The specific information is described in ITU-T Rec.G.983.1.

8 Optical network requirements

8.1 Layered structure of the optical network

Layering is based on ITU-T Rec. G.982. The ODN refers to the fibre distribution network based on passive optical splitter branching components. The OAN is the system between the "V" and "T" reference points (Figure 7). The ONU/ONT may have an adaptation function (AF), for digital subscriber line (DSL) transmission over copper to the customer. The OAN is managed as one element, through a Q3 management interface.

The protocol reference model is divided into physical medium, TC, and path layer (ITU-T Recs. G.902, I.326, and G.982). As an example an ATM-PON is shown in Table 1. In the ATM-PON network, path layer corresponds to the VP (Virtual Path) of the ATM layer.

Table 1/G.983.4 – Layered structure of ATM-PON Network

Path layer			Refer to ITU-T Recs. I.732 and I.326
Transmission medium layer (Note)	TC layer	Adaptation	Refer to ITU-T Recs. I.732 and I.432
		PON transmission	Ranging based on ITU-T Rec. G.983.1 and DBA
			MAC
			Cell slot allocation based on statistical bandwidth assignment and DBA
			Detection of offered traffic load for DBA
			Bandwidth allocation based on traffic contract and bandwidth request
			Privacy and security
			Frame alignment
			Burst synchronization
			Bit/byte synchronization
	Physical medium layer		E/O adaptation
			Wavelength division multiplexing
			Fibre connection
NOTE – The transmission medium layer must provide the related OAM functions.			

The TC layer is divided into PON transmission and adaptation sublayers, which correspond to the transmission convergence sublayer of the B-ISDN (Broadband Integrated Services Digital Network) in ITU-T Rec. I.321. The PON transmission sublayer terminates the required transmission function

on the ODN. The PON specific functions are terminated by the PON transmission sublayer, and are not seen from the adaptation sublayer. The PON transmission sublayer includes MAC functions for cell slot allocation and bandwidth allocation. DBA is positioned as a part of the MAC functions in the PON transmission sublayer. As shown in Table 1, MAC provides cell slot allocation and bandwidth allocation according to the traffic contract based on ITU-T Rec. G.983.1. However, to support DBA, it provides these functions based on traffic load in addition to functions based on ITU-T Rec. G.983.1. Moreover, the Detection of Offered Traffic Load function is required to support the above-mentioned functions based on traffic load, which can be changed dynamically, for DBA. Additionally, Ranging in the PON transmission sublayer and some extensions of procedures in ITU-T Rec.G.983.1 are specified.

8.2 Physical medium dependent layer requirements for the ATM-PON

The specific information is described in ITU-T Rec. G.983.1.

8.3 Transmission convergence layer requirements for the ATM-PON

The specific information is described in ITU-T Rec. G.983.1.

8.3.1 Point-to-multipoint capacities for downstream and upstream

The specific information is described in ITU-T Rec. G.983.1.

8.3.2 Maximum payload capacities for downstream and upstream

The specific information is described in ITU-T Rec. G.983.1.

8.3.3 Downstream interface

The specific information is described in ITU-T Rec. G.983.1.

8.3.4 Upstream interface

The Physical Layer overhead includes: PLOAM cells, minislots for the MAC channel and overhead bytes which are added in front of each upstream ATM cell, PLOAM cell or minislot.

The transfer capacity for the 155.52 Mbit/s interface has an upper limit of 147.2 Mbit/s (155.52*53/56 Mbit/s). Some extra bandwidth is allocated by the OLT for the upstream PLOAM channel and the minislots for MAC channel. Mini-slots can be transferred from several ONUs/ONTs to the OLT synchronously. Bandwidth for minislots can be programmable according to reporting capability. For example, if a large amount of bandwidth is reserved for minislots, the OLT can receive and process the information that is sent by the ONUs/ONTs quickly, although bandwidth for other uses is reduced. This amount of bandwidth reserved for minislots should be determined by several factors, including network configuration, service guidelines and the implementation of OLTs and ONUs/ONTs. Moreover, the OLT can assign multiple minislots to an ONU/ONT in order to change the reporting frequency of any ONU/ONT. Therefore, the ONU/ONT must also manage the multiple minislots. Detailed examples are described in 8.3.5.10.1.3. The number of minislots assigned is also determined by multiple factors.

The upstream transfer capacity is shared between the ONUs/ONTs and/or T-CONTs based on their allocated upstream bandwidth.

8.3.5 Transport specific TC interface

8.3.5.1 Frame structure

The downstream interface structure for both 155.52 Mbit/s and 622.08 Mbit/s consists of a continuous stream of timeslots, each timeslot containing 53 octets of an ATM cell or a PLOAM cell.

Every 28th timeslot a PLOAM cell is inserted. A downstream frame contains two such PLOAM cells and is 56 slots long for the 155 Mbit/s downstream case. For the 622 Mbit/s case, it contains eight PLOAM cells and is 224 slots long.

In the upstream direction the frame contains 53 timeslots of 56 bytes. The OLT requests an ONU/ONT to transmit an ATM cell via grants conveyed in downstream PLOAM cells. At a programmable rate, the OLT requests an ONU/ONT to transmit a PLOAM cell or a minislot. The upstream PLOAM rate depends on the required functionality contained in these PLOAM cells. These PLOAM cells may transfer information concerning the status of ONUs/ONTs in order to support DBA. The minimum PLOAM rate per ONU/ONT is one PLOAM cell every 100 ms. The OLT defines the bandwidth allocated to the upstream minislots. Although allocation of minislots can be programmable, several values will be recommended in order to obtain adequate performance.

The PLOAM cells are used to convey the Physical Layer OAM information. In addition, downstream PLOAM cells carry the grants used by the ONUs/ONTs for upstream access.

A divided_slot occupies a complete upstream timeslot, and contains a number of minislots from a set of ONUs/ONTs. The MAC protocol based on reporting status uses minislots to transfer to the OLT the status of the ONUs/ONTs in order to implement DBA. This serves as the mandatory method for reporting T-CONT status in SR-ONUs/ONTs. Therefore, since an OLT may expect reports from all of the SR-ONUs/ONTs on one physical interface with minimized time lag, divided_slots may be allocated consecutively to gather all of the reports within a short period.

The described frames, cells, bytes and bits are transmitted in the following order referring to their numbering: frames are transmitted in ascending order, cells within a frame are transmitted in ascending order, the bytes within a cell are transmitted in ascending order and within a byte, the most significant bit is transmitted first. The most significant bit in a byte is bit number 1 and the least significant bit is bit number 8, so for example the MSB of 0b10101010 is equal to 1.

8.3.5.1.1 Frame structure for symmetric PON

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.1.2 Frame structure for 622/155 Mbit/s PON

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.1.3 Time relation downstream – upstream frame

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.2 Physical layer cell identification

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.3 Downstream PLOAM structure

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.3.1 PLOAM cell termination

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.3.2 PLOAM identification

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.3.3 Frame synchronization

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.3.4 Synchronization field (SYNC1-SYNC2)

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.3.5 Grants

Each PLOAM cell is filled with 27 grants. These grants are used by the ONUs/ONTs for access to the upstream fibre. Per frame only 53 are needed. The 53 grants are mapped in the first two PLOAM cells of the downstream frame. All 53 grants are non-idle grants. The last grant of the second PLOAM cell is filled with an idle grant. The grant fields of the six remaining PLOAM cells for the 622 Mbit/s downstream case are all filled with idle grants and hence will not be used by the ONU/ONT. The length of a grant is 8 bits and the following types are defined in Table 2.

Table 2/G.983.4 – Specification of the grants

Type	Encoding	Definition
Data grant	Any value except 1111 1101 1111 1110 1111 1111	For indicating an upstream T-CONT-specific data grant. The value of the first data grant is assigned to the ONU/ONT during the ranging protocol using the grant_allocation message. The ONU/ONT can send an OMCI cell by this first assigned data grant to maintain backward compatibility with existing ONU/ONT specified in ITU-T Rec. G.983.1. Moreover the values of the additional data grant are assigned to the T-CONT in an operating state using the additional_grant_allocation message. The T-CONT can send a data cell by first or additional data grant. The ONU/ONT can send a data cell or an idle cell if no data cell is available.
PLOAM grant	Any value except 1111 1101 1111 1110 1111 1111	For indicating an upstream ONU/ONT-specific PLOAM grant. The value of the PLOAM grant is assigned to the ONU/ONT during the ranging protocol using the grant_allocation message. The ONU/ONT always sends a PLOAM cell in response to this grant.
Divided_slot grant	Any value except 1111 1101 1111 1110 1111 1111	For indicating an upstream group of ONU/ONT specific divided_slot grants. The OLT allocates the grant to a set of ONUs/ONTs using the Divided_slot_grant_configuration message. Each ONU/ONT of this set sends a minislot. The divided slot is used to report a queue length of the T-CONT to the OLT. The ONU/ONT processes one or more divided_slot grants up to the maximum specified by its Maximum_divided_slot_grants parameter.
Reserved grants	Any value except 1111 1101 1111 1110 1111 1111	In a future version of this Recommendation other grant types will be used for specific data grants (e.g. to address a specific ONU/ONT interface or QoS class).
Ranging grant	1111 1101	Used for the ranging process. The response to this grant is described in the ranging protocol.
Unassigned grant	1111 1110	For indicating an unused upstream slot.
Idle grant	1111 1111	For decoupling the downstream PLOAM rate from the upstream cell rate. These grants are ignored by the ONU/ONT.

The OLT shall be able to address 32 ONUs/ONTs at the same time on a PON. Optionally the OLT may address up to 64 ONUs/ONTs on a single PON.

8.3.5.3.6 Grants protection

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.3.7 MESSAGE field

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.3.8 Bit Interleaved Parity (BIP)

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.4 Upstream PLOAM structure

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.4.1 PLOAM cell termination

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.4.2 PLOAM identification

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.4.3 MESSAGE field

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.4.4 Bit Interleaved Parity (BIP)

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.4.5 Laser Control Field (LCF)

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.4.6 Receiver Control Field (RXCF)

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.5 Divided_slots

An upstream slot can contain a divided_slot. The divided_slot fits into one upstream slot and contains a number of minislots coming from a set of ONUs/ONTs. The OLT assigns one divided_slot grant to this set of ONUs/ONTs for sending their minislots. The format of the divided_slot is shown in Figure 13.
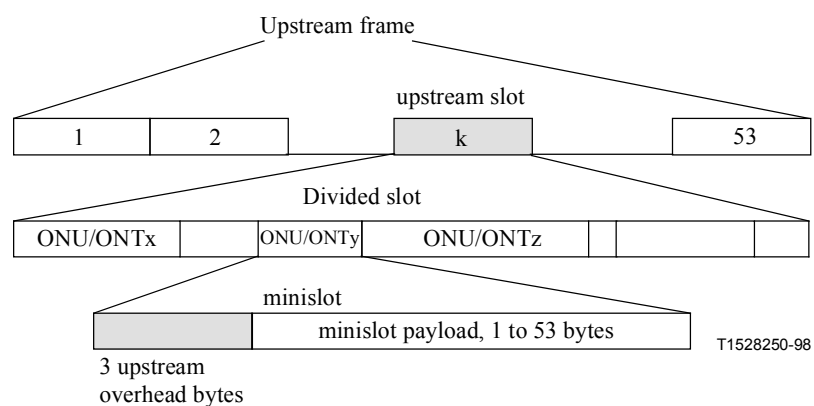

Figure 13/G.983.4 – Format of divided_slot

The minislot is used to report the queue length of the T-CONT to the OLT in the case of SR-ONUs/ONTs.

The length of the minislot is an integral number of bytes, ranging from a minimum of 5 to a maximum of 56 bytes. Each minislot is composed of the physical layer overhead bytes, one or more T-CONT report bytes, and CRC-8 trailer.

NOTE – For exceptionally long minislots where the payload is greater than 15 bytes, additional CRC-8s must be inserted.

The three overhead bytes have the same definition as stated in Table 6/G.983.1.

The minislot payload is protected by a Cyclic Redundancy Check (CRC). The formula for generating the CRC polynomial for the minislot payload is:

$$g(x) = x^8 + x^2 + x + 1$$

8.3.5.6 Churning

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.7 Verification function

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.8 VP/VC for higher layer

The specific information is described in ITU-T Rec. G.983.1.

8.3.5.9 Duplex PON system

In the case of a duplex system where a redundant PON protects the active PON, protection switching will be activated by using specified messages in PLOAM cells. This sequence will require that the line numbers of the OLT must be exactly the same as those of the ONU/ONT. This line identifier is assigned to a transmitter based on the interconnection scheme of OLTs with ONUs/ONTs. The line identifier is sent to both the OLT and the ONU/ONT to check whether the received line identifier is the same as its own identifier. This is defined as the PON Section Trace (PST) message. Then individual equipment can verify that it is connected to the proper transmitter. If the received line number differs from the expected line number, the equipment generates an alarm, MIS (Link Mismatching) to notify the operator or user of the problem.

The PST messages include the K1 and K2 bytes as they are specified in ITU-T Rec. G.783 for performing Automatic Protection Switching.

In case of an unprotected system, link mismatching is optional.

8.3.5.9.1 Relationship between DBA and protection functions

DBA has some impacts on protection functions in the cases of protection Types C and D as defined in Appendix IV/G.983.1. These impacts and outstanding operations in DBA will be discussed in the future. For Types A and B, DBA does not have any impact because each ONU/ONT has only one interface to the OLT. However, in the cases of Types C and D, some additional capabilities in DBA to support the protection functions may be specified, such as provisioned parameters, identification of T-CONTs, and grant allocation.

The typical example is shown in Figure 14. In this example, both side-0 and side-1 are used in the normal state as shown in Figure 14 a). When a failure occurs between the splitter and the ONU/ONT's working side, the other side's extra bandwidth is assigned for the ONU/ONT as shown in Figure 14 b).
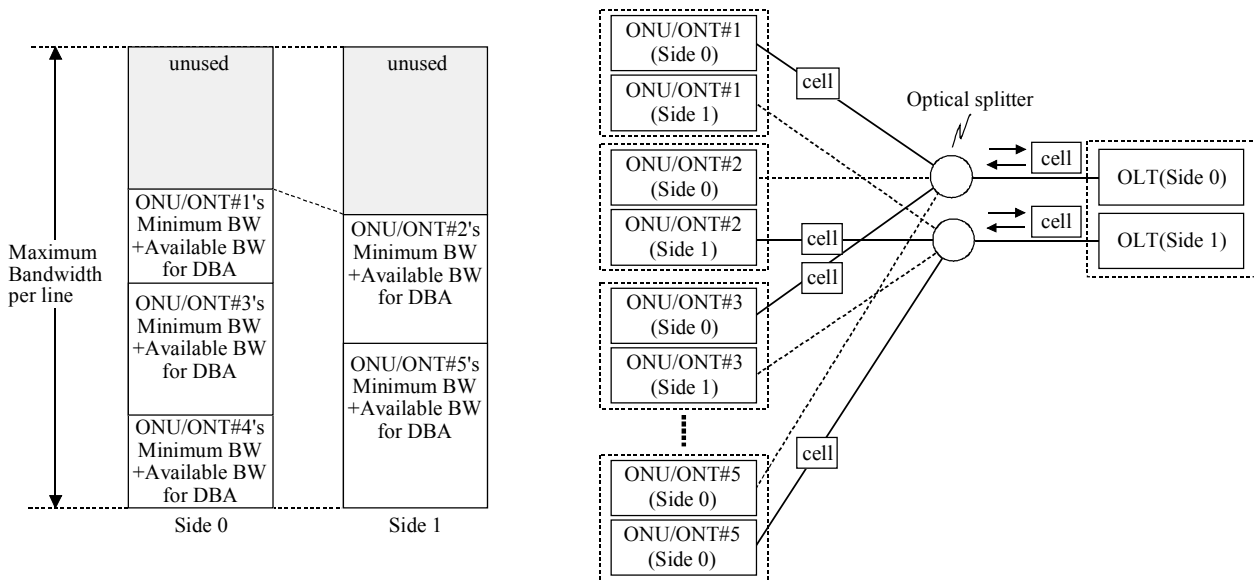
a) Normal state
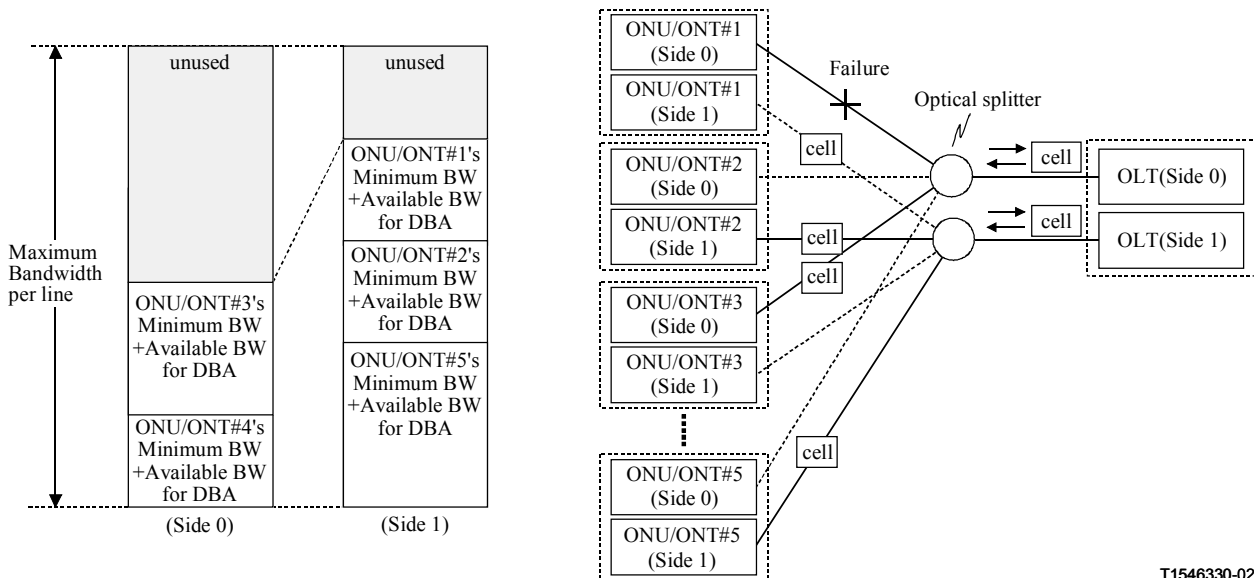
b) After the failure occurred

BW   Bandwidth

Figure 14/G.983.4 – Relationship between DBA and protection function

8.3.5.10   MAC protocol

The MAC layer in the OLT needs specific information to fairly allocate bandwidth between ONUs/ONTs on a PON. The MAC protocol is also referred to as the DBA protocol if the OLT supports dynamic assignment of bandwidth in the upstream direction. The MAC protocol is implemented in the PON transmission part of the TC layer described in 8.1. As the MAC protocol, DBA should ensure transparency to higher layers, such as the ATM layer. In short, ATM cells should be transported through and across the PON in a completely transparent manner without any impact on ATC/QoS.

When a DBA-OLT supports SR-ONUs/ONTs, the required information is mapped into the payload field of the minislot using the mandatory reporting method. An ONU/ONT is allowed to send this minislot after receiving a divided_slot grant. Specifically, the Divided_Slot_Grant_configuration message is used for this type of grant, and the length and offset of the upstream minislot are carried in the same message. The MAC also includes a bandwidth allocation function based on conventional static grant assignment according to the traffic contract.

8.3.5.10.1 DBA protocol

The DBA protocol consists of three strategies, referred to as NSR, SR, and Hybrid types. The NSR type strategy is invoked by monitoring traffic in the OLT. The SR type strategy is invoked by status reports sent from ONUs/ONTs to the OLT. The Hybrid strategy is invoked by both monitoring traffic in the OLT and processing in the OLT the status reports from ONUs/ONTs. This Recommendation does not specify detailed mechanisms or algorithms for these strategies, but rather requirements and the required interfaces at reference points IF_{PON} (S/R and R/S) are described (see clause 5.2). The detailed mechanisms and the scheme for how to combine NSR and SR types in the Hybrid strategy are out of scope for this Recommendation.

8.3.5.10.1.1 Working unit for DBA

The DBA protocol is executed on every T-CONT active in a SR-ONU/ONT. Operations and assigned resources among T-CONTs can be independent from each other. In short, one or more T-CONTs can be defined in one ONU/ONT, if all of the T-CONTs on the reference point S/R can be identified by grant codes specified in 8.3.5.3.5. T-CONTs do not interfere with each other.

8.3.5.10.1.2 DBA protocol with OLT monitoring

This clause describes how an OLT can collect the bandwidth request information from the T-CONTs in its associated ONUs/ONTs without using status reporting. The OLT inspects each incoming cell from a specific T-CONT in a predefined time frame. For example, the OLT calculates the utilization rate of the currently assigned bandwidth by monitoring the number of effective received cells from specific T-CONTs, and uses this value as the bandwidth request information.

These mechanisms are applied to cases where a DBA-OLT supports NSR-ONUs/ONTs and/or SR-ONUs/ONTs that may suspend reporting.

Moreover, if SR-ONUs/ONTs report status, the OLT can work based on monitoring results independently of these reports if the OLT concludes that the monitoring approach is more suitable for the current situation. For example, when the ONU/ONT reports are insufficient, the monitoring operation can be invoked.

8.3.5.10.1.3 DBA protocol with status reporting

This clause describes how an SR-ONU/ONT explicitly reports to its DBA-OLT PON interface. Since a number of ONUs/ONTs and their DBA T-CONTs may report queue lengths of T-CONT buffers, it is imperative to balance the amount of information with the upstream bandwidth consumption of these reports. Reporting methods and reported information are specified as follows.

8.3.5.10.1.3.1 Reporting minislot format

Minislots contained in the divided_slot are specified using the mandatory status reporting method. The reporting cycle is one of the parameters that should be provisioned by the operators to obtain suitable performance.

Generally the OLT will generate divided_slot grants to request a queue length for the specified ONU/ONT according to the service requirements. When an ONU/ONT recognizes a divided_slot grant, the ONUs/ONTs can transfer information in a minislot in the divided_slot. This minislot contains the queue length for every T-CONT using non-linear coding and CRC-8.

In this queue length reporting, fields in a divided_slot are identified by two offset values, minislot_offset and field_offset, as shown in Figure 15. The minislot_offset identifies the location of a minislot for the ONU/ONT. It is specified by a Divided_Slot_Grant_configuration message, which is one of the PLOAM messages and is mentioned in 8.3.8. The field_offset identifies the location of a T-CONT in the minislot, when two or more T-CONTs are specified in an ONU/ONT. It can be specified by the Additional_Grant_Allocation message. A minislot in a divided_slot can report queue length for up to 49 T-CONTs, if the default reported information described in 8.3.5.10.1.3.2 is used. However, if 50 or more T-CONTs are specified in an ONU/ONT, multiple divided_slots can be allocated to report the queue lengths. In this case, mapping between these slots and the reporting field for each T-CONT should be managed by the OLT. On the other hand, when the configuration of T-CONTs is changed and a T-CONT is deactivated, the queue length for this T-CONT should not be reported. In this case, the reporting field for this T-CONT is removed according to the procedures described in 8.6.3.
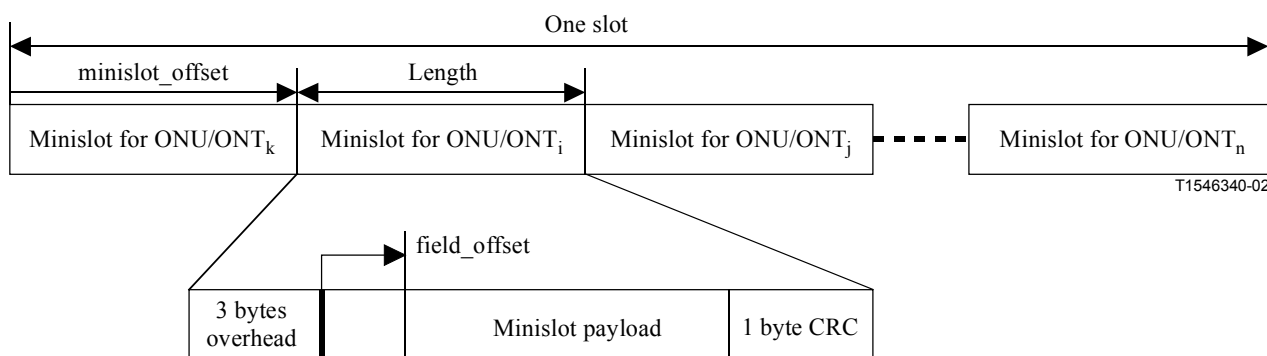
minislot_offset   To identify the starting point for particular ONU/ONT minislot
field_offset   To identify the starting point for particular TCONT within one ONU/ONT minislot

Figure 15/G.983.4 – Relationship between a divided_slot and minislots

8.3.5.10.1.3.2   Reported information

This clause describes reported information from SR-ONUs/ONTs using minislots. The reported information should not be limited by any DBA algorithms that are adopted or restricted by the set-up values of bandwidth types. Moreover, the bandwidth for any T-CONT should be adjustable to any value based on the reported information.

SR-ONUs/ONTs shall report the queue length of their T-CONTs using non-linear coding, when requested to do so by their OLT. The queue length is the sum of the total number of cells in all the class buffers that are connected to a particular T-CONT in an ONU/ONT. All equipment must support the format type, as shown in Figure 16.

The information conveyed in the minislot from the ONU/ONT should be protected by the CRC, and the information should be used only when the CRC check is correct.

Additional reported information may be useful. The additional reported information and the negotiation procedure to use additional reported information are described as an informative option in Appendix II. In Appendix II, standard reported information is dealt with as "default reporting field meaning" and the combination of standard reported information and additional reported information are dealt with as "optional report field meanings". Even if the OLT and the ONU/ONT have applied optional report field definitions in Appendix II, all OLTs and ONUs/ONTs must support the standard reported information definitions or "default reporting field meaning" in Appendix II.

One minislot for ONU/ONTi

3 bytes overhead	1 Byte	1 Byte	- - - - - - -	1 Byte	1 Byte	1 Byte	1 Byte	1 Byte
	T_CONT#1 reporting	T_CONT#2 reporting		T_CONT#14 reporting	CRC	T_CONT#15 reporting	T_CONT#16 reporting	CRC
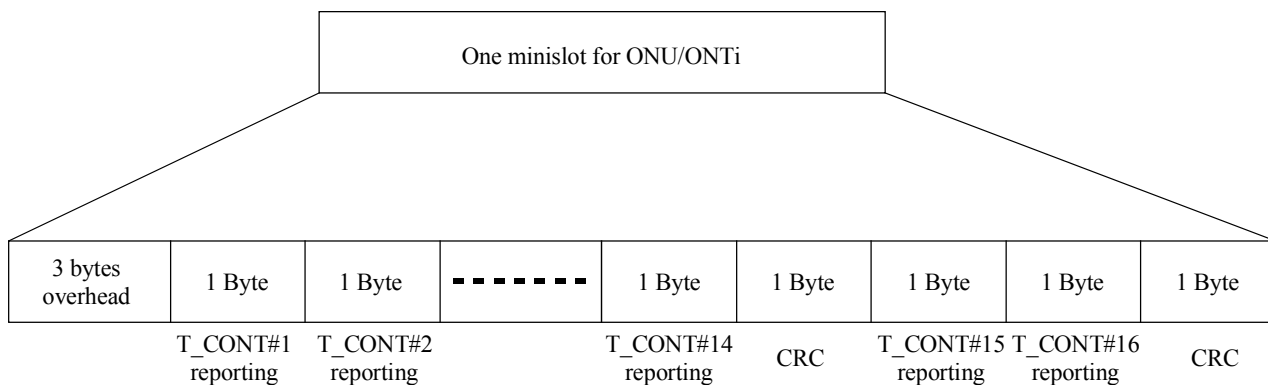
T1546350-02

Figure 16/G.983.4 – The detailed minislot format for one ONU/ONT

One CRC is inserted for every 14 bytes of minislot payload at the ONU/ONT. The CRC shall be the remainder (modulo 2) of the division by the polynomial $x^8 + x^2 + x + 1$ into the report fields between the preceding CRC or the beginning of the minislot and the CRC itself. If the minislot payload is not evenly divisible into 14 byte segments, a CRC byte should be appended to the end of the minislot payload. An example of the detailed minislot format is shown in Figure 16. The maximum number of T-CONTs that can be supported in one minislot is 49 (the whole slot = 56 byte = 3 bytes overhead + 3 * 14 bytes (T-CONTs) + 3 bytes CRC + 7 T-CONTs + 1 CRC). This situation only happens when one complete slot is assigned to one ONU/ONT. This may be caused by one ONU/ONT having 49 or more activated T-CONTs.

8.3.5.10.1.3.3   Report field coding

The default minislot format is shown in Figure 16 in 8.3.5.10.1.3.2. The reported 1 byte queue length is the non-linear coded value of the actual number of cells in a T-CONT of a specific ONU/ONT. The mapping between the number of cells (the input), the 1 byte value (the code) and the decoded message (the output) is given in Table 3 as default code points. Note that the decoded output is effectively rounded up to the largest value that could have resulted in that particular code point. This property ensures that the coding error is always positive.

Table 3/G.983.4 –Non-linear coding for report field of minislot

Queue Length	Binary Input (ONU/ONT)	Coding of octet (minislot)	Binary Output (OLT)
0-127	00000000abcdefg	0abcdefg	00000000abcdefg
128-255	00000001abcdefx	10abcdef	00000001abcdef1
256-511	0000001abcdexxx	110abcde	0000001abcde111
512-1023	000001abcdxxxxx	1110abcd	000001abcd11111
1024-2047	00001abcxxxxxxx	11110abc	00001abc1111111
2048-4095	0001abxxxxxxxxx	111110ab	0001ab111111111
4096-8191	001axxxxxxxxxxx	1111110a	001a11111111111
>8191	001111111111111	11111110	011111111111111
Reserved	N/A	11111111	N/A

The code point described in Table 3 may be changed according to the service situation and the implementation of OLTs and ONUs/ONTs. However, alternative code points have not been specified in this Recommendation.

NOTE – The reserved value (0xFF) is used to indicate an unassigned report field.

8.3.5.10.1.4 DBA protocol with OLT monitoring and status reporting

A DBA-OLT can combine NSR and SR strategies and then apply them to SR-ONUs/ONTs. For example, even if an SR-ONU/ONT reports status, the DBA-OLT is not required to use the information and may instead use cell monitoring results to update the bandwidth. The schemes for how to combine both types depend on the service situation and implementation. A DBA-OLT can select schemes based on either NSR or SR strategies, or the combination of NSR and SR strategies in every SR-ONU/ONT associated with one physical ATM-PON interface.

8.3.5.10.1.5 DBA and upstream congestion of the OLT NNI

As a future extension, the DBA protocol may operate based on not only the requested bandwidth of the T-CONTs and the available bandwidth of the upstream PON links but also the upstream congestion on the OLT NNIs as shown in Figure 17. The DBA-OLT could decrease the grants to T-CONTs carrying VPCs/VCCs that are congested upstream to their assured bandwidth level. The DBA-OLT could also intelligently control distribution of additional bandwidth available in the PON to an SR-ONU/ONT / T-CONT. In short, there are two congestion patterns such as a) and b) in Figure 17. In the first case, the bandwidth for T-CONTs included in the congested NNI may be reduced. However, in the second case, since the group that detected congestion on the network interface cannot band T-CONTs on ATM-PON physical links, blocking the upstream traffic carried by some T-CONTs may be caused as in Figure 17 (b). To avoid this blocking, some mechanisms and implementations can be studied. However, these are not included in this Recommendation.

a) Banded connections in every T–CONT on a network IF

b) Disbanded connections in every T–CONT on a network IF
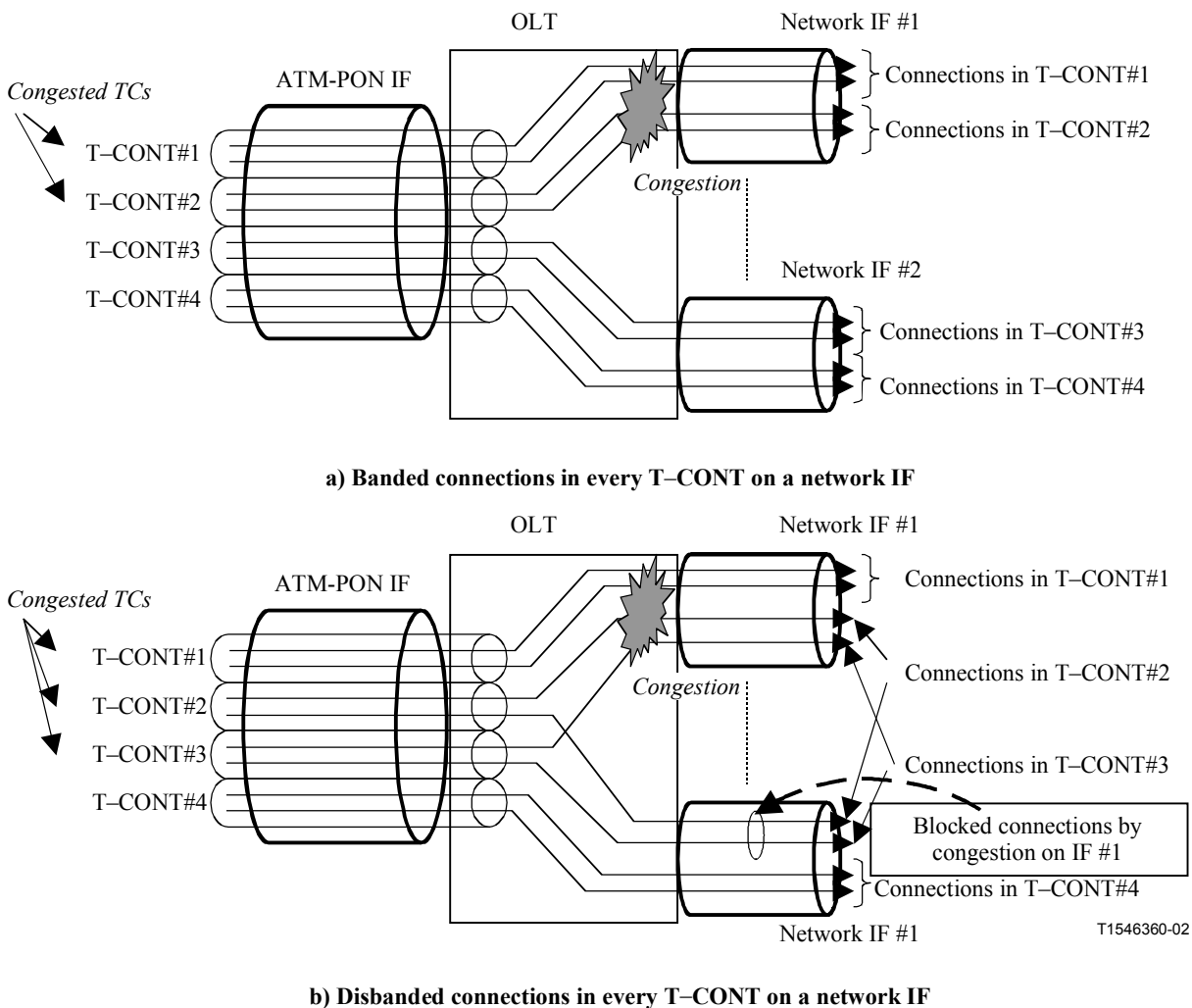
Figure 17/G.983.4 – Configuration of T-CONTs on the network interface

8.3.5.10.2 T-CONT types

This clause presents definitions of T-CONTs, their types and typical applications for each T-CONT type. DBA-OLTs shall support all T-CONT types. ONUs/ONTs can support all or some of them according to the services they support. Basically, T-CONT types are independent of applications, such as ATC/QoS specified in the ATM layer. In short, one T-CONT type can accommodate any ATC/QoS, and can contain multiple different classes. However, typical applications in each type are mentioned to make use of maximal effectiveness of DBA.

8.3.5.10.2.1 Definition of T-CONT

T-CONTs are essentially "pipes" that carry ATM VPs or VCs. Multiplexing of VPs and VCs having different ATC/QoS into one T-CONT is programmable. For example, the following scenarios can be assumed.

– one or more VPs with the same ATC/QoS mapped into one T-CONT (e.g. VP switching case).

– one or more VPs with the different ATC/QoS mapped into one T-CONT (e.g. VP switching case).

– one or more VPs banding VCs with the same ATC/QoS mapped into one T-CONT (e.g. VC switching case).

– one or more VPs banding VCs with the different ATC/QoS mapped into one T-CONT (e.g. VC switching case)

Note that one VP on the PON cannot be assigned to several T-CONTs in the current ATM-PON model specified in ITU-T Rec. G.983.1.

For the sake of convenience, T-CONTs can be classified into 5 types, which are T-CONT Type 1, T-CONT Type 2, T-CONT Type 3, T-CONT Type 4, and T-CONT Type 5.

Recommended supportability of ATC/QoS (or ATM Forum Service Category) in each T-CONT type is summarized in Table 4.

Table 4/G.983.4 – Relationship between ATC/QoS and T-CONT types

ITU ATC/QoS	ATM Forum Service category	T-CONT types				
		1	2	3	4	5
DBR [1]	CBR	X				X
DBR [2]	VBR.1-nrt (SCR = PCR)	X	X	X		X
DBR [U]	UBR.1	X	X	X	X	X
SBR1 [1]	VBR.1-rt	X				X
SBR1 [2]	VBR.1-nrt	X	X	X		X
SBR1 [U]	UBR.1	X	X	X	X	X
SBR2 [3]	VBR.2-nrt	X	X	X		X
SBR2 [U]	UBR.1	X	X	X	X	X
SBR3 [3]	VBR.3-nrt	X	X	X		X
SBR3 [U]	UBR.2	X	X	X	X	X
ABT/DT [1], ABT/IT [1]	–	X				X
ABT/DT [2], ABT/IT [2]	–	X	X	X		X

Table 4/G.983.4 – Relationship between ATC/QoS and T-CONT types

ABT/DT [U], ABT/IT [U]	–	X	X	X	X	X
ABR [3]	ABR	X	X	X		X
ABR [U]	ABR	X	X	X	X	X
GFR	GFR	X	X	X		X

8.3.5.10.2.2 Relationship among assigned bandwidth

Each T-CONT type is characterized by the kinds of assigned bandwidth types it supports. Before a description of T-CONT types, the relationship among assigned bandwidth is clarified as follows.

Assigned bandwidth consists of 4 types: Fixed bandwidth, Assured bandwidth, Non-assured bandwidth and Best-effort bandwidth (Maximum bandwidth can also be set in some cases).

Table 5/G.983.4 – Summary of assignable bandwidth

	Delay sensitive	**Assignment type**	**Applicable T-CONT types**				
			Type 1	**Type 2**	**Type 3**	**Type 4**	**Type 5**
Fixed	Yes	Provisioned	X				X
Assured	No	Provisioned		X	X		X
Non-assured	No	Dynamic			X		X
Best-effort	No	Dynamic				X	X
NOTE – In Types 3, 4 and 5, assignable bandwidth has the upper bound specified by Maximum bandwidth that should be provisioned for these types.							

In the table, Dynamic Assignment type represents additional bandwidth. Non-assured bandwidth is paired with Assured bandwidth. Non-assured bandwidth for each T-CONT that requests additional bandwidth is allocated in proportion to the Assured bandwidth for the T-CONT from the pool of surplus bandwidth. If Assured bandwidth is zero, Non-assured bandwidth is fairly allocated as well as Best-effort bandwidth. For example, T-CONTs which request additional bandwidth and do not have Assured bandwidth fairly share surplus bandwidth. Moreover, Assured bandwidth assignment to any T-CONTs should be guaranteed.

Assignable bandwidth can be prioritized as follows.

    Priority 1 (Highest priority)   Fixed bandwidth

    Priority 2   Assured bandwidth

    Priority 3   Non-assured bandwidth

    Priority 4 (Lowest priority)   Best effort bandwidth

In the bandwidth assignment, Fixed bandwidth is reserved first, including slot location to minimize delay and delay variation. Assured bandwidth is reserved next using the remaining bandwidth. Bandwidth that is still not reserved is released to the pool of surplus bandwidth for Non-assured bandwidth and Best effort bandwidth. Non-assured bandwidth has higher priority than Best effort bandwidth.

8.3.5.10.2.3 T-CONT Type 1

1)   *Definition*

T-CONT Type 1 is characterized by Fixed bandwidth only. For T-CONT Type 1, the bandwidth shall be exclusively and cyclically allocated with a fixed rate and controlled cell transfer delay.

Traffic descriptor for T-CONT Type 1: Fixed bandwidth: Provisioned

2)   *Applications*

T-CONT Type 1 is able to accommodate any ATC/QoS. This T-CONT works in the same manner as the existing G.983.1 and G.983.2 Recommendations. Moreover, a Non-DBA-OLT is able to support any ATC/QoS as an application of T-CONT Type 1. DBA-OLTs accommodate real-time traffic as an application of this T-CONT type. DBA-OLTs always assign fixed bandwidth to connections on a T-CONT Type 1 regardless of whether there are cells to send or not. This T-CONT is not dynamically allocated and can be used to provide existing services (DS-1, E-1, J-1, etc). DBA-OLTs accommodate all of ATC/QoS classes in the ATM layer specified in ITU-T Recs. I.356 and I.371.

Mechanisms to transfer cells in the T-CONT and provisioning policies to guarantee QoS on the ATM level depend on the implementation of the ONU/ONT.

3)   *Behaviours of multiplexed VPCs and VCCs in the ATM layer*

Multiple ATM connections are multiplexed into T-CONTs. Although configuration of T-CONT buffers depends on the implementation, Figure 18 illustrates an example of multiplexing DBR ATM connections using a typical implementation based on FIFO. As shown in Figure 18, though grants are allocated by a strict interval, CDV can be generated according to the behaviour of each ATM connection and/or contention among multiplexed connections.

Figure 18/G.983.4 – Behaviours of multiplexed connections on T-CONT type 1

8.3.5.10.2.4   T-CONT Type 2

1)   *Definition*

T-CONT Type 2 is characterized by Assured bandwidth only. Assured bandwidth means Fixed average bandwidth over some specified time interval. In traffic engineering, this bandwidth is distinguished from Fixed bandwidth in T-CONT Type 1 (Deterministic assignment) which is controlled for the short-term range from a delay-sensitive point of view. In short, although T-CONT Type 1 guarantees cell transfer delay and delay variation

in addition to the transmission rate, T-CONT Type 2 guarantees the average transmission rate only. T-CONT Type 2 is supported only by DBA-OLTs.

Traffic descriptor for T-CONT Type 2: Assured bandwidth: Provisioned

2) *Application*

T-CONT Type 2 accommodates all ATC/QoS classes with the exception of class 1, that is non-real time service. The ATC/QoS in the ATM layer shown in Table 4 can be accommodated in this T-CONT type.

Mechanisms to transfer cells in the T-CONT and provisioning policies to guarantee QoS at the ATM level depend on the implementation of the ONU/ONT.

3) *Behaviours of multiplexed VPCs and VCCs in the ATM layer*

Multiple ATM connections are multiplexed into T-CONTs. Although configuration of T-CONT buffers depends on the implementation, Figure 19 illustrates an example of multiplexing DBR ATM connections using a typical implementation based on FIFO. As shown in Figure 19, since grants are allocated by interval with a variation, CDV for each ATM connection can be generated by such variation in addition to the behaviour of each ATM connection and/or contention among multiplexed connections.

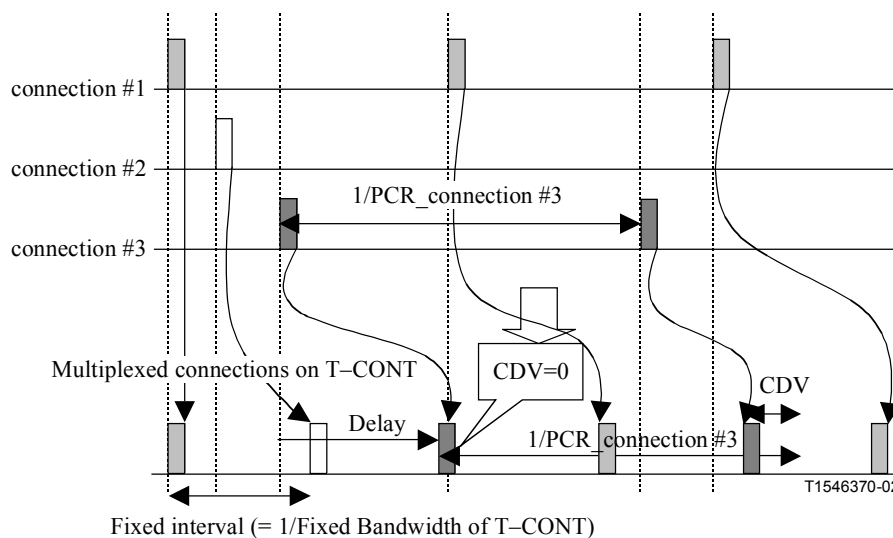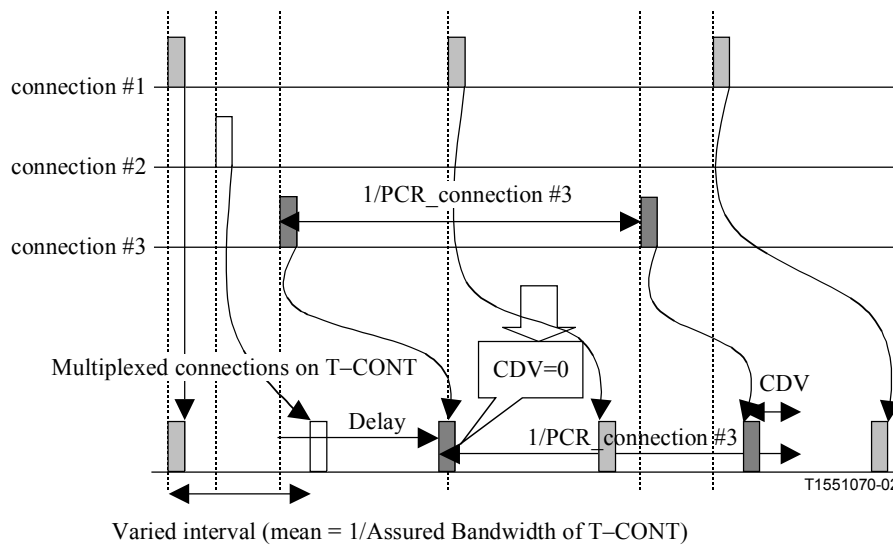

Figure 19/G.983.4 – Behaviours of multiplexed connections on T-CONT type 2

8.3.5.10.2.5   T-CONT Type 3

1) *Definition*

T-CONT Type 3 has Assured bandwidth and Non-assured bandwidth. T-CONT Type 3 shall be allocated bandwidth equivalent to its Assured bandwidth, only when it has cells at a rate equivalent to Assured bandwidth or more than Assured bandwidth. Non-assured bandwidth shall be allocated across all T-CONTs with Assured bandwidth that are requesting additional bandwidth in proportion to the Assured bandwidth of the individual T-CONTs on the PON, e.g. Weighted Round Robin method. The sum of the Assured bandwidth and Non-assured bandwidth allocated to this T-CONT should not exceed its Maximum bandwidth, which is a provisioned value.

Traffic descriptor for T-CONT Type 3:

Assured bandwidth: Provisioned

Non-assured bandwidth: Dynamic assignment

Maximum bandwidth: Provisioned

2) *Application*

T-CONT Type 3 accommodates variable bit rate transmission having QoS classes with the exception of class 1, that is non-real time service. ATC/QoS in the ATM layer described in Table 4 can be accommodated in this T-CONT type.

Mechanisms to transfer cells in the T-CONT and provisioning policies to guarantee QoS on the ATM level depend on the implementation of the ONU/ONT.

3) *Behaviours of multiplexed VPCs and VCCs in the ATM layer*

Multiple ATM connections are multiplexed into T-CONTs. Although the configuration of T-CONT buffers depends on the implementation, Figure 20 illustrates an example of bandwidth assignment based on the characteristics of T-CONT type 3. As shown in Figure 20, behaviours can be divided into four parts: Phases 1, 2, 3, and 4. In stable phases, such as Phases 1 and 3, these behaviours are the same as the case of T-CONT type 2. Multiplexing behaviours in transition phases, such as Phases 2 and 4, are illustrated in Figures 21 and 22, respectively, in the case of DBR connections.

Figure 20/G.983.4 – Outline of bandwidth assignment in T-CONT type 3
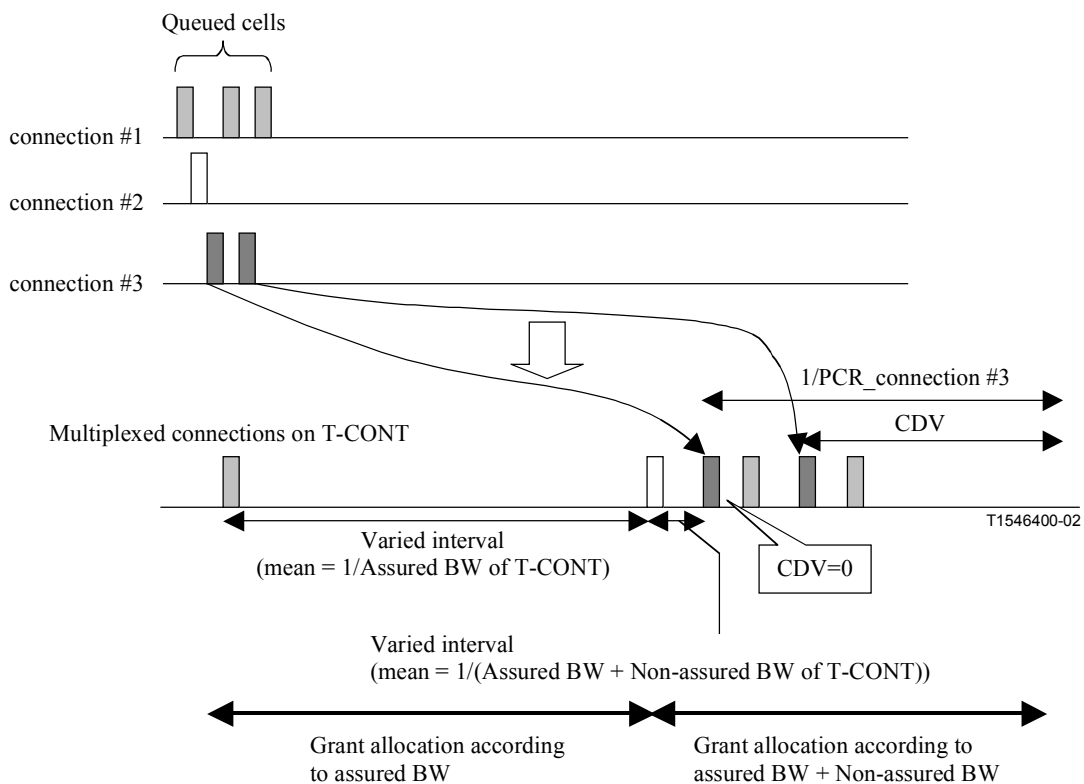
Figure 21/G.983.4 – Behaviour of multiplexed connections in Phase 2 in T-CONT type 3

Figure 22/G.983.4 – Behaviour of multiplexed connections in Phase 4 in T-CONT type 3

8.3.5.10.2.6   T-CONT Type 4

1)   *Definition*

T-CONT Type 4 has Best-effort bandwidth only and does not have any Guaranteed bandwidth. T-CONT Type 4 shall only use bandwidth that has not been allocated as Fixed bandwidth, Assured bandwidth or Non-assured bandwidth to T-CONTs in the PON. Best-effort bandwidth is allocated to each T-CONT Type 4 equally, e.g. based on the Round Robin method, up to the Maximum bandwidth.

Traffic descriptor for T-CONT Type 4:

Best-effort bandwidth: Dynamic assignment

Maximum bandwidth: Provisioned

2)   *Application*

T-CONT Type 4 accommodates unspecified class as shown in Table 4.

Mechanisms to transfer cells in the T-CONT and provisioning policies to guarantee QoS on the ATM level depend on the implementation of the ONU/ONT.

3)   *Behaviours of multiplexed VPCs and VCCs in the ATM layer*

Multiple ATM connections are multiplexed into T-CONTs. Although configuration of T-CONT buffers depends on the implementation, Figure 23 illustrates an example of bandwidth assignment based on the characteristics of T-CONT type 4. As shown in Figure 23, behaviours can be divided into four parts, such as Phases 1, 2, 3, and 4. In stable phases, such as Phases 1 and 3, these behaviours are the same as the cases of T-CONT types 2 and 3. Multiplexing behaviours in transition phases, such as Phases 2 and 4, are the same as the case of T-CONT type 3.
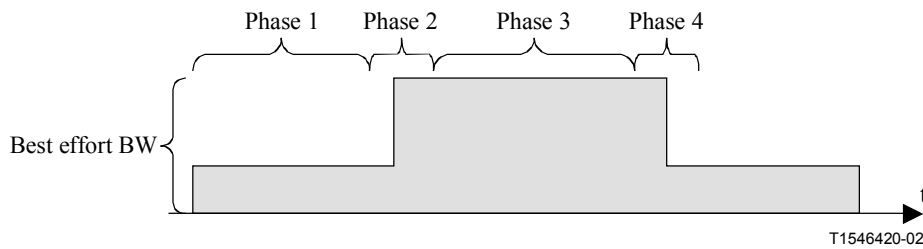
Figure 23/G.983.4 – Outline of bandwidth assignment in T-CONT type 4

8.3.5.10.2.7   T-CONT Type 5

1)   *Definition*

T-CONT Type 5 is the super set of all of T-CONT types. T-CONT Type 5 may accommodate any ATC/QoS described in Table 4, and can be downgraded to one or more of the other T-CONT types. T-CONT Type 5 is characterized by the following descriptors.

Traffic descriptor for T-CONT Type 5:

Fixed bandwidth: Provisioned

Assured bandwidth: Provisioned

Non-assured bandwidth: Dynamic assignment

Best-effort bandwidth: Dynamic assignment

Maximum bandwidth: Provisioned

Assignment mechanisms depend on the implementation. For example, the following mechanisms can be assumed.

Step 1: Fixed bandwidth and Assured bandwidth are assigned.

Step 2: Non-assured bandwidth is assigned in proportion to Assured bandwidth.

Step 3: If additional bandwidth is still requested, Best-effort bandwidth is assigned up to the Maximum bandwidth.

2)   *Application*

T-CONT type 5 can accommodate any application including real-time or resource-guaranteed applications. It can be applied to any ATC/QoS as shown in Table 4.

Mechanisms to transfer cells in the T-CONT and provisioning policies to guarantee QoS on the ATM level depend on the implementation of the ONU/ONT.

3)   *Behaviours of multiplexed VPCs and VCCs in the ATM layer*

Multiple ATM connections are multiplexed into T-CONTs. Although configuration of T-CONT buffers depends on the implementation, Figure 24 illustrates an example of bandwidth assignment based on the characteristics of T-CONT type 5. As shown in Figure 24, behaviours can be divided into four parts: Phases 1, 2, 3, and 4. In stable Phases, such as Phases 1 and 3, these behaviours are shown in Figure 25. Multiplexing behaviours in transition phases, such as Phases 2 and 4, are the same as the cases of T-CONT type 3.
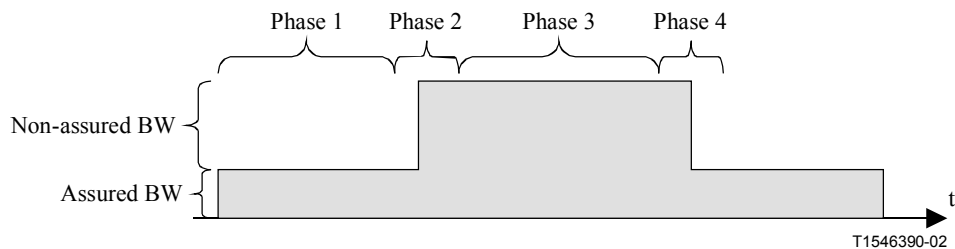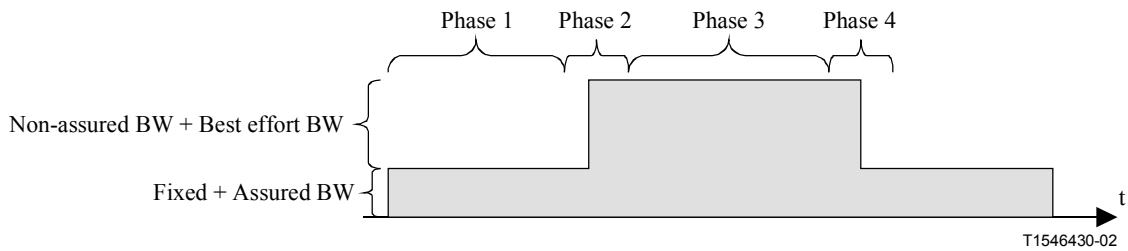
Figure 24/G.983.4 – Outline of bandwidth assignment in T-CONT type 5
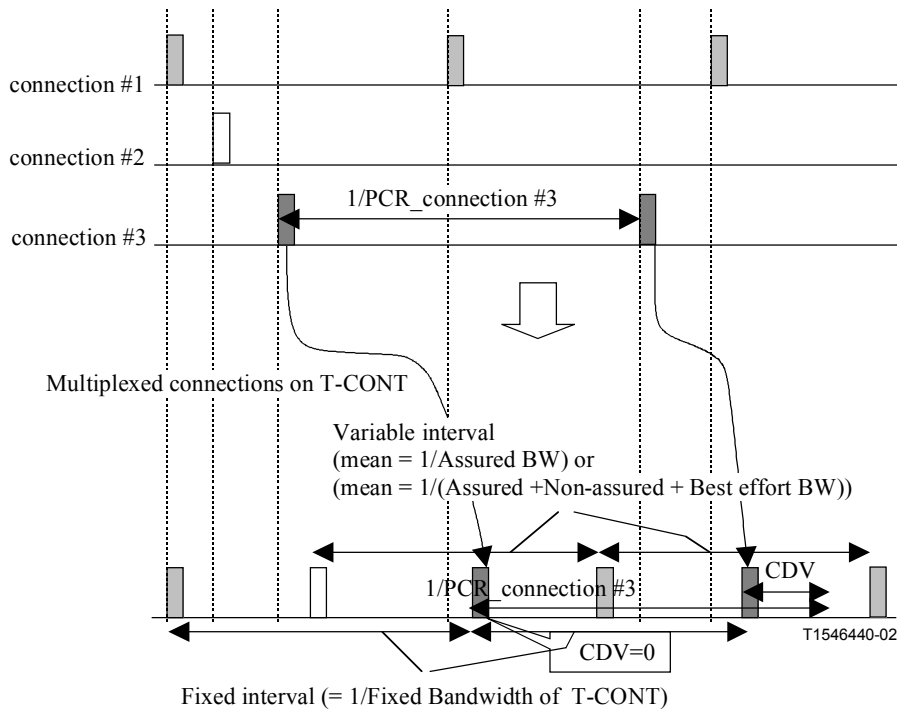
**Figure 25/G.983.4 – Behaviour of multiplexed connections in Phases 1 and 3
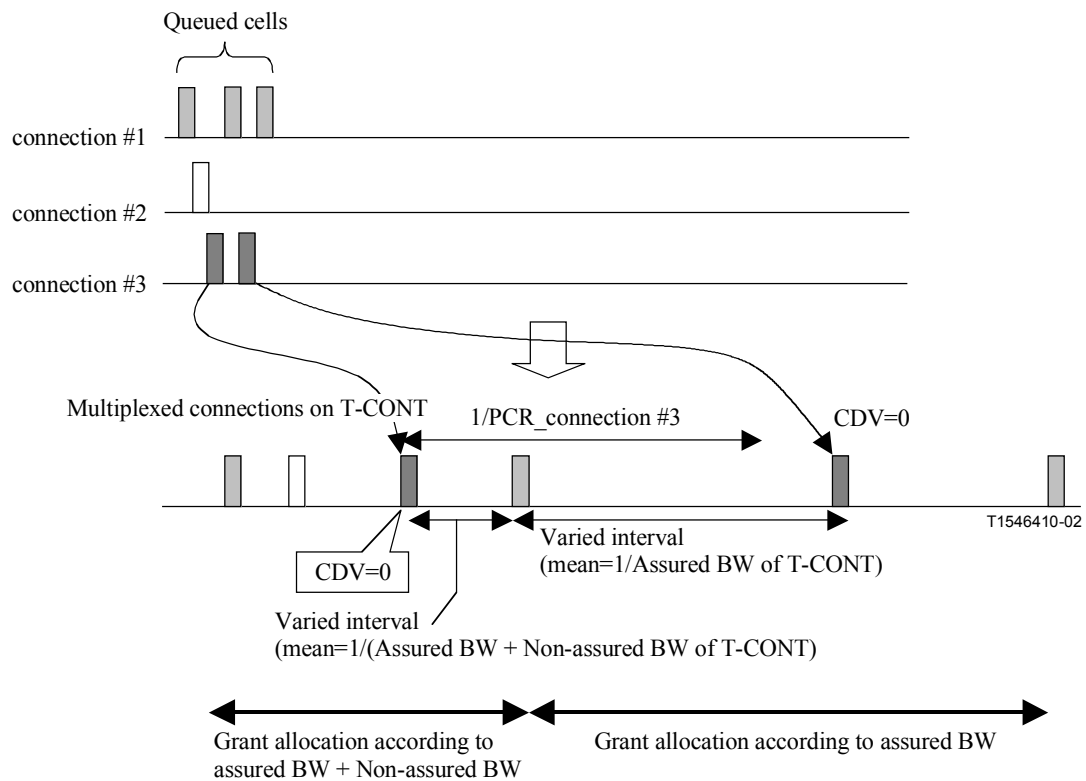in T-CONT type 5**

8.3.5.10.2.8 Notes for traffic behaviours

When the PCR of a connection is smaller than the maximum bandwidth, implementing DBA may increase the CDV of the connection. Figure 26 shows a case of increasing CDV. In order to avoid cell discard by UPC, traffic descriptors for the T-CONT and the CDVT value for each connection should be considered carefully.
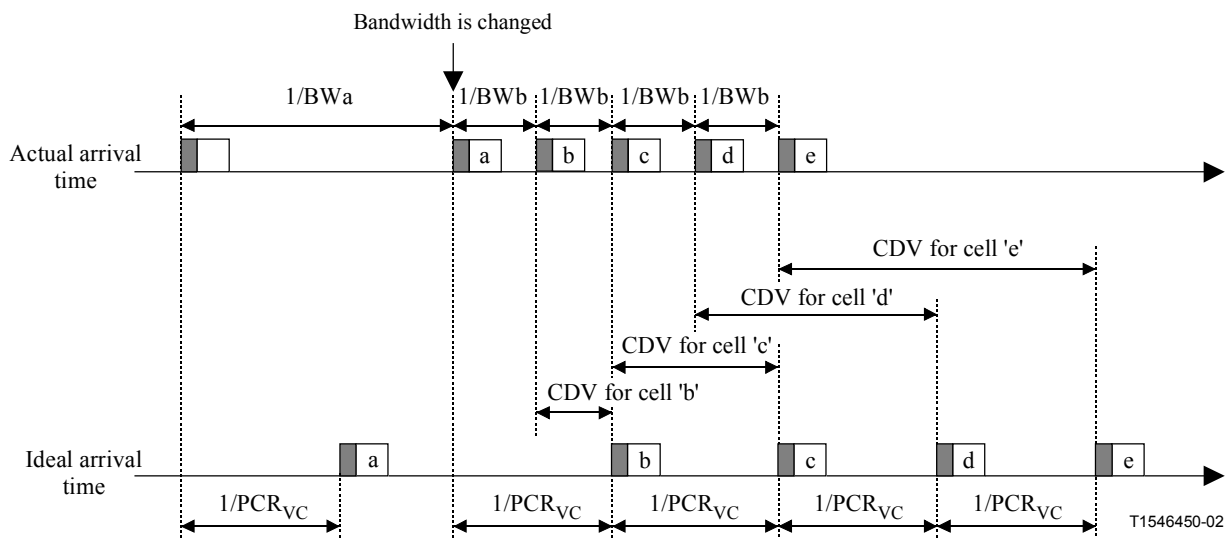
In case of "BW_min ≤ BWa < PCR < BWb ≤ BW_max"

Figure 26/G.983.4 – CDV caused by DBA

8.3.5.10.3   Additional requirements for surplus bandwidth assignment

8.3.5.10.3.1   Surplus bandwidth sharing and fairness on an ONU/ONT

Surplus bandwidth in one ONU/ONT can be fairly shared with other DBA-T-CONTs in the same ONU/ONT and that can use surplus bandwidth (T-CONT type 3, T-CONT type 4 and T-CONT type 5). In short, one T-CONT working for T-CONT Types 3, 4 or 5 in one ONU/ONT can capture grants for surplus bandwidth which are then allocated to other T-CONTs in the ONU/ONT, if the other T-CONTs do not have transmission cells available. However, mechanisms to maintain a long-term balance of used grants among T-CONTs is for further study.

8.3.5.10.4   Requirements for grant allocation mechanisms

This clause specifies the requirements for grant allocation mechanisms and their backgrounds.

8.3.5.10.4.1   Grant assignment for fixed bandwidth

1) *Requirements*

   This requirement is to restrict the fluctuation in the grant allocation interval to T-CONT Type 1 and the fixed bandwidth part of T-CONT Type 5 (this requirement is based on Peak-to-Peak CDV and maximum Cell Transfer Delay specified in ATM QoS parameters for Class 1). The maximum fluctuation of the interval between data grants in one T-CONT should take into account the following factors:

   –   the time of the ranging window;

   –   the number of T-CONT Type 1 and T-CONT Type 5 in the same PON-IF;

   –   one cell time for one PLOAM cell or Divided_slot;

   –   plus several cell times as margin.

2) *Background*

   These T-CONTs are used for DBR [Class 1] the same as the existing G.983.1 and G.983.2 Recommendations. Therefore, the limitation on burst allocation is the same as that of the system in the existing G.983.1 and G.983.2 Recommendations. In short, grant assignment for fixed bandwidth in a T-CONT can emulate the T-CONT as a physical link without

contention among T-CONTs. Therefore, although it can be applied to all ATC/QoS; time sensitive applications, such as Class 1, are the most suitable. For example, in the case of T-CONT type 1 which uses only fixed bandwidth, when the sum of the PCRs of all ATM connections in this T-CONT are less than the fixed bandwidth assigned to this T-CONT and each connection has no CDV, maximum Cell Transfer Delay (CTD) and CDV can be specified logically as follows (see Figure 27).

CTD<N*1/Fixed bandwidth

CDV<1/PCR for the target connection − 1/Fixed bandwidth,

where N is the number of multiplexing connections in one T-CONT.
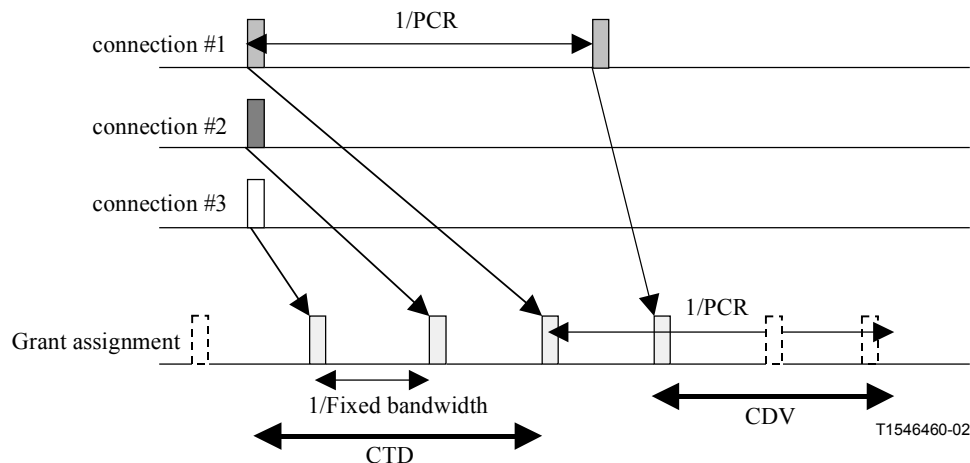
Figure 27/G.983.4 – CTD and CDV on T-CONT using only Fixed bandwidth

8.3.5.10.4.2 Grant assignment for other bandwidth

1) *Requirements*

This requirement is to restrict the fluctuation in the grant allocation interval in every T-CONT to comply with the CDVT specified in each VPC or VCC at the UPC.

2) *Background*

DBA should not cause cell loss by violating the CDVT at the UPC. Therefore, grant assignment should take this into account. There are two situations that may increase CDV. One is by burst grant assignment, and the other is by radical bandwidth update.

The first case can be illustrated by the following examples. Figure 28 shows comparison of grant assignment methods. Figure 28 a) shows the case of grant assignment as Fixed bandwidth assignment. Figure 28 b) shows burst assignment. Figure 29 shows examples of performance in each grant assignment method. These examples show cases where the utilization rate in one T-CONT is 0.8.

a) Continuous grant assignment

b) Burst grant assignment

T1546470-02
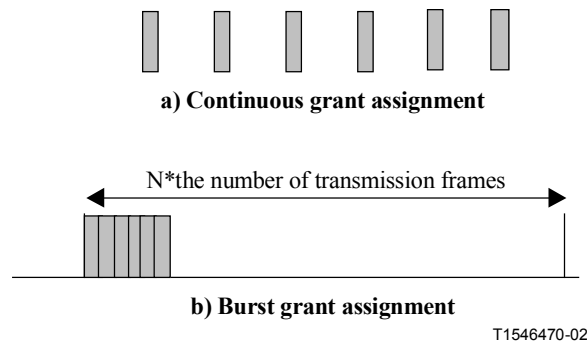
Figure 28/G.983.4 – Comparison between grant assignment methods
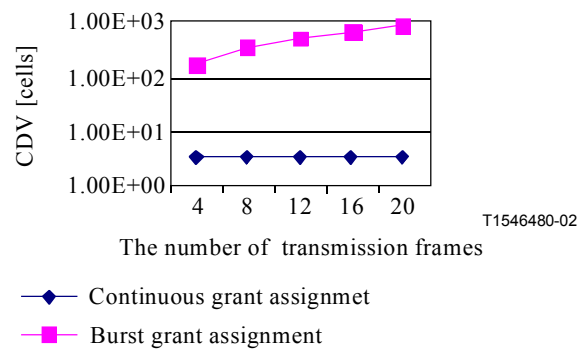
Figure 29/G.983.4 – Examples of performance in each grant assignment method

However, other methods to prevent the violation of CDVT, such as the new provisioning schemes for CDVT in the ATM-PON environment with DBA, may be required as future extensions.

8.3.5.10.4.3   Limitation of burst allocation for grant assignment

1)   *Requirements*

The burst allocation for grants to T-CONTs shall be limited to within a few milliseconds, if the DBA-T-CONTs have enough traffic to use those grants.

2)   *Backgrounds*

An excessively large burst allocation would result in discarded upstream cells by the UPC or would burden upstream shaping functions. Additionally, an excessively large burst allocation implies a long waiting time after the burst allocation. This causes large round trip times. TCP/IP Van-Jacobson slow start algorithm prevents very steep bandwidth ramp ups. The detailed criteria for the limitation of burst grant allocation and performance are under study.

8.3.5.10.5   Operations of grant assignment in combined environment

Table 6 presents operations concerning grant assignment for possible combinations of these OLTs and ONUs/ONTs when DBA functions are activated. It shows the bandwidth allocation schemes that may be used for each specific combination. The DBA enhancement should inherit the G.983.1 downstream frame format. OLTs and ONUs/ONTs from different equipment manufacturers should be interoperable based on Table 6.

Table 6/G.983.4 – Operations of grant assignment

	NSR-ONU/ONT	**SR-ONU/ONT**	**NSR-ONU/ONT and SR-ONU/ONT**
Non-DBA-OLT	(non-DBA)	(non-DBA)	(non-DBA)
DBA-OLT	NSR-DBA	SR-DBA	NSR-DBA for NSR-ONUs/ONTs and SR-DBA for SR-ONUs/ONTs
		Or NSR-DBA	Or NSR-DBA for both ONU/ONT types

The operation of NSR-DBA and SR-DBA described in this table are detailed in 8.3.5.10.1.2 and 8.3.5.10.1.3, respectively.

8.3.5.10.6 Target performance

This clause recommends some performance targets for the DBA protocol. The first two subclauses show performance targets that should be met regardless of input traffic or other variables. The remainder of this clause shows target performance for a standardized model for input traffic.

8.3.5.10.6.1 Waiting time

1) *Definition*

   This is the waiting time for dynamic bandwidth allocation to a T-CONT with Assured bandwidth (T-CONT Types 2, 3, and 5) since the T-CONT buffer in the ONU/ONT receives new cells under the condition that it has not been allocated grants (See Figure 30).
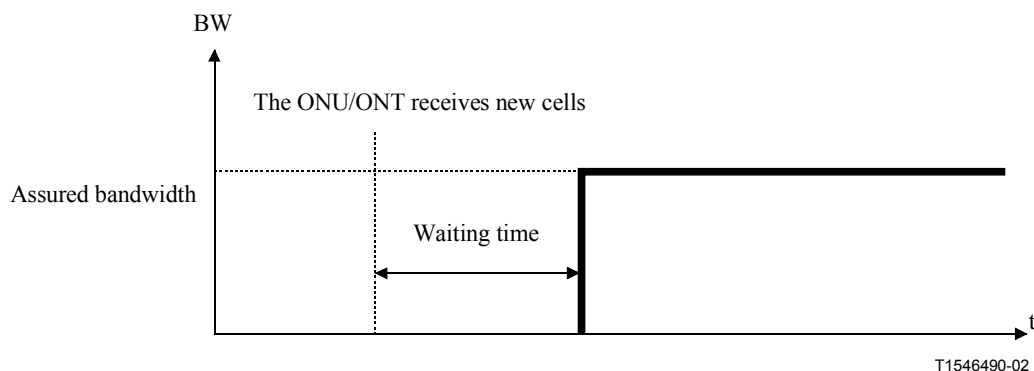
Figure 30/G.983.4 – Waiting time

2) *Target performance*

   A few milliseconds shall be required (target of 2 ms).

3) *Background*

   Longer waiting time means that greedier traffic gets more bandwidth. The waiting time should be kept short so that users generating less traffic are still allocated sufficient bandwidth. This requirement is related to allocation delay (based on reporting cycle, transmission delay, updating cycle of bandwidth allocation and so on) after rest time.

8.3.5.10.6.2   Transition time

1)   *Definition*

The transition time is defined as the time from an ONU/ONT's status change to a state where the ONU/ONT is consistently allocated the proper bandwidth (See Figure 31).
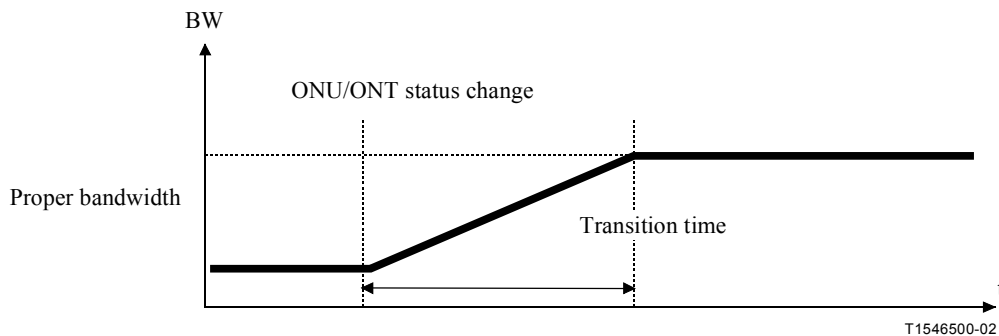
Figure 31/G.983.4 – Transition time

2)   *Target performance*

Ten milliseconds shall be required (target of 6 ms).

3)   *Background*

During transition time, bandwidth allocation is not fair. This requirement is related to the convergence time to achieve steady bandwidth allocation.

8.3.6   ATM specific TC functions

The specific information is described in ITU-T Rec. G.983.1.

8.3.7   OAM functions

The OAM functions that are installed in the ONU/ONT and OLT are shown in Figure 32. This figure also shows the notification signals between OLT and ONU/ONT. These signals are mapped into the message fields of the PLOAM cells. The general principles as defined in ITU-T Rec. I.610 can be applied to the PON. However, due to the point-to-multipoint nature of the physical medium, some notifications from OLT to ONU/ONT are obsolete principally due to the fact that the ONU/ONT is a slave to the OLT and the ONU/ONT is unable to do anything with these notifications.
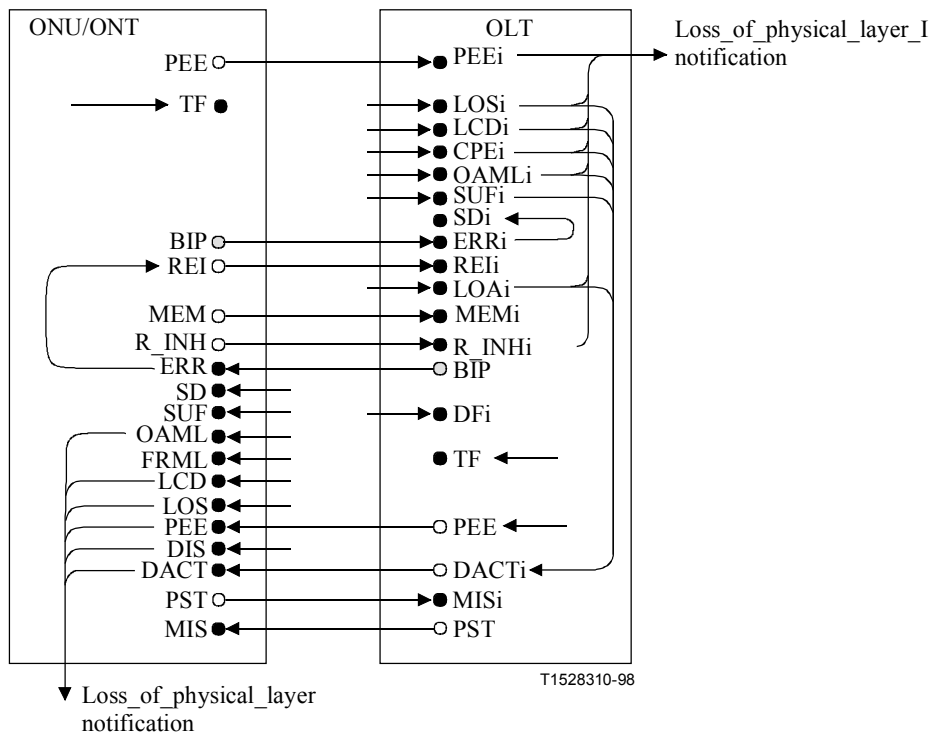
Figure 32/G.983.4 – OAM functions

When multiple T-CONTs are specified in the ONU/ONT, alarms in each T-CONT are merged and represented as alarms for the ONU/ONT accommodating these T-CONTs. Moreover, the specific alarm for divided_slots shall be defined to support SR-DBA. Figure 33 shows this alarm. This alarm is detected at the OLT and is described in 8.3.7.1.
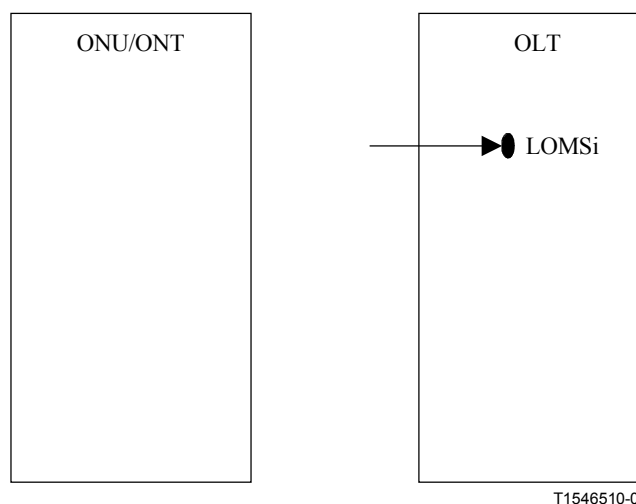
Figure 33/G.983.4 – OAM functions for divided_slot

8.3.7.1 Items detected at OLT

This clause describes the items detected at the OLT. The items are captured in Table 7 and are listed according to type. Detail is provided for the detection conditions and associated actions as well as the cancellation conditions and associated actions.

Table 7/G.983.4 – Items detected at OLT

Type	Description	
	Detection conditions	*Actions*
	Cancellation conditions	*Actions*
TF	**Transmitter failure**	
	The OLT transmitter is declared in failure when there is no nominal backfacet photocurrent or when the drive currents go beyond the maximum specification.	
SUFi	**Startup failure of ONUi/ONTi**	
	The ranging of ONU/ONTi has failed n times (n = 2; refer to 8.4.4.3.3) while the OLT has received optical bursts from this ONU/ONT.	Send three times deactivate_PON_ID messages.
	The ONU/ONT is reranged successfully.	
PEEi	**Physical equipment error of ONUi/ONTi**	
	When the OLT receives a PEE from the ONU/ONT.	Generate Loss_of_physical_layer_I notification.
	When the OLT does not receive a PEE message from the ONUi/ONTi in three seconds.	Stop Loss_of_physical_layer_I notification.
LCDi	**Loss of cell delineation of ONUi/ONTi**	
	When eight consecutive invalid delimiters or invalid HECs from ONUi/ONTi are received.	Send three times deactivate_PON_ID messages. Generate Loss_of_physical_layer_I notification.
	When cell delineation for ONUi/ONTi is achieved in the operating state.	
OAMLi	**PLOAM cell loss for ONUi/ONTi**	
	When three consecutive PLOAM cells of ONUi/ONTi are missing.	Send three times deactivate_PON_ID messages. Generate Loss_of_physical_layer_I notification.
	When the OLT receives a PLOAM cell corresponding to its PLOAM grant in the Operating state.	
CPEi	**Cell phase error for ONUi/ONTi**	
	When the OLT is able to receive the correct delimiter and the received cell phase is beyond the limits and the corrective actions of the OLT do not solve the problem.	Send three times deactivate_PON_ID messages. Generate Loss_of_physical_layer_I notification.
	When the OLT receives a cell in the correct position in the operating state.	

Table 7/G.983.4 – Items detected at OLT

	Description	
	Loss of signal of ONUi/ONTi	
LOSi	No valid optical signal at the O/E receiver received when expected for ONUi/ONTi during eight upstream sequential cells.	Send three times deactivate_PON_ID messages. Generate Loss_of_physical_layer_I notification.
	When the OLT receives a valid optical signal corresponding to its grant in the Operating state.	
	Loss of acknowledge with ONUi/ONTi	
LOAi	The OLT does not receive an acknowledge from ONUi/ONTi after a set of downstream messages that imply an upstream acknowledge.	Send three times deactivate_PON_ID messages. Generate Loss_of_physical_layer_I notification.
	When the OLT receives an acknowledge.	
	Deactivate failure of ONUi/ONTi	
DFi	The ONU/ONT does not react correctly after three DACT messages.	
	Cancelled by the operator.	
	Block error detection of ONUi/ONTi	
ERRi	The upstream received BIP8 is compared with the calculated BIP8 on the received stream. When there is a difference between them, the OLT issues ERRi.	
	ERRi should be renewed when the next upstream PLOAM cell is received at the OLT from ONUi/ONTi.	
	Signal degraded of ONUi/ONTi	
SDi	The number of differing bits is accumulated in Error_I during interval Tmeasure. The BER is defined as BER=Error_i/(BW*Tmeasure) where BW is the allocated upstream bandwidth. When the upstream BER of ONUi/ONTi becomes $\geq 10^{-5}$, this state is entered.	
	When the upstream BER of ONUi/ONTi becomes $<10^{-5}$, this state is cleared.	
	Remote error indication of ONUi/ONTi	
REIi	When the OLT receives a REI message it issues REIi.	
	ERRi should be renewed when the REI message is received at OLT from ONUi/ONTi.	

Table 7/G.983.4 – Items detected at OLT

		Description	
MEMi		**Message_error message from ONUi/ONTi**	
	When the OLT receives an unknown message from ONUi/ONTi or received message_error message.		
	When the operator is informed.		
R-INHi		**Receive alarm inhibition of ONUi/ONTi**	
	When the OLT receives R-INH message from ONUi/ONTi, R-INHi is detected.	Ignore received alarms from this ONU/ONT. Generate Loss_of_physical_layer_I notification.	
	When the OLT receives a PLOAM cell in the ranging process of ONUi/ONTi.		
MISi		**Link mismatch of ONUi/ONTi**	
	The OLT detects that the received PSTi and the transmitted PST are different.		
	The OLT detects that received PSTi and the transmitted PST are the same.		

Table 8 lists the items detected at the OLT that are specific to divided slots.

Table 8/G.983.4 – Specific items for divided_slots detected at OLT

Type	Description	
	Detection conditions	*Actions*
	Cancellation conditions	*Actions*
LOMSi	**Loss Of MiniSlot for ONUi/ONTi**	
	When eight consecutive minislots of ONUi/ONTi are missing.	
	When the OLT receives a minislot corresponding to its divided slot grant in the operating state.	

NOTE – Detailed specifications of detection and cancellation conditions are defined as follows.

Detection conditions:

– When one or more of following conditions is detected, LOMSi is generated.

– No valid optical signal at the O/E receiver received for ONUi/ONTi when expected during eight upstream sequential mini-slots.

– When eight consecutive invalid delimiters of mini-slots from ONUi/ONTi are received.

– When the OLT can receive the correct delimiter and the received mini-slot cell phase is beyond the limits and the corrective actions of the OLT do not solve the problem.

Cancellation conditions:

– When all of following conditions are recognized, LOMSi is cancelled.

- When the OLT receives a valid optical signal corresponding to its mini-slot grant in the DBA operating state.
- When mini-slot cell delineation for ONUi/ONTi is achieved in the operating state.
- When the OLT receives a mini-slot cell in the correct position in the operating state.

8.3.7.2   Items detected at ONU/ONT

The specific information is described in ITU-T Rec. G.983.1.

8.3.8   Messages in the PLOAM channel

The specific information is described in ITU-T Rec. G.983.1.

8.3.8.1   Message definition

Message definitions for communication between the OLT and ONUs/ONTs are detailed in Table 9.

Table 9/G.983.4 – Message definition

	Message Name	Function	Direction	Trigger	Number of times sent	Effect of receipt
1	No message	No message available when a PLOAM cell is transmitted.	OLT → ONU/ONT	Empty message queue.	–	Discard.
2	New_churning_key_rq	Requests a new churning key from the ONU/ONT.	OLT → ONU/ONT	OLT needs a new key for the churning mechanism.	1	ONU/ONT generates a new key and sends the key to the OLT with a new_churning_key message.
3	Upstream_RX_control	Instruct the ONU/ONT which pattern to fill in the RXCF part of the upstream PLOAM cell.	OLT → ONU/ONT	Each time a ranging process is started.	3	The ONU/ONT sets the upstream RXCF field of the upstream PLOAM cell.
4	Upstream_overhead	Instruct the ONU/ONT which overhead and pre-assigned equalization delay to use in the upstream direction.	OLT → ONU/ONT	Each time a ranging process is started.	3	The ONU/ONT sets the upstream overhead and the pre-assigned equalization delay.
5	Serial_number_mask	Provides a serial number and a mask masking a part of this serial number.	OLT → ONU/ONT	To find the serial number of a unique ONU/ONT.	1	If serial number and mask match the ONU/ONT's serial number, the ONU/ONT is enabled to react on ranging grants.
6	Assign_PON_ID	Links a free PON_ID number with the serial number also provided in this message.	OLT → ONU/ONT	When the OLT has found the serial number of a unique ONU/ONT.	3	The ONU/ONT with this serial number uses the returned PON_ID and will be addressed by this PON_ID.
7	Ranging_time	It indicates the value expressed in number of upstream bits that an ONU/ONT with the corresponding PON_ID must fill in into its equalization delay register.	OLT → ONU/ONT	When the OLT decides that the delay must be updated, see ranging protocol.	3	The ONU/ONT fills in the equalization delay register with this value.
8	Deactivate_PON_ID	It instructs an ONU/ONT with this PON_ID to stop sending upstream traffic and reset itself. It can also be a broadcast message.	OLT → ONU/ONT	When the LOSi, LCDi, OAMLi, LOAi, SUFi or CPEi are detected.	3	The ONU/ONT with this PON_ID switches off its laser and the PON_ID is discarded. It should be activated when the MPU is out of order.
9	Disable_serial_number	To disable an ONU/ONT with this serial number.	OLT → ONU/ONT	On command from the OpS.	3 or until no burst is detected.	Moves the ONU/ONT to the emergency stop state. The ONU/ONT cannot respond to grants.

Table 9/G.983.4 – Message definition

10	Churning_key_update	To indicate to the ONU/ONT when the new churning key becomes valid. Priority level is 1.	OLT → ONU/ONT	When the OLT is ready to churn data for ONU/ONT with PON_ID.	3	The ONU/ONT switches to the new churning key 48*Tframe after the first update message. Send one acknowledge after each correctly received message.
11	Grant_allocation message	To allocate a data and PLOAM grant to an ONU/ONT.	OLT → ONU/ONT	After a PON_ID is allocated to the ONU/ONT, it needs a data and PLOAM grant for sending the upstream data and PLOAM cells.	3	The ONU/ONT stores the two grant types.
12	Divided_slot_grant_ configuration message	To allocate or deallocate a Divided_slot_grant to an ONU/ONT and identify the minislot length and offset position.	OLT → ONU/ONT	The OLT needs/no longer needs the service provided by the minislot.	3	The ONU/ONT sends the minislot after receiving this allocated divided_slot grant. If deallocated, it no longer reacts to this Divided_Slot_grant.
13	Configure_VP/VC	This message activates or deactivates a VP/VC in downstream and upstream for communication at the ATM layer.	OLT → ONU/ONT	When the OLT wants to set up or tear down a connection with the ONU/ONT, for example, for configuration of the UPC function, filling filtering tables or configuration of the interfaces of the ONU/ONT.	3	The ONU/ONT activates/deactivates these VP/VCs for the communication channel. Send one acknowledge after each correctly received message.
14	BER_interval	This defines the accumulation interval per ONU/ONT expressed in the number of downstream frames for the ONU/ONT counting the number of downstream bit errors. Same time-out as for Configure_VP/VC.	OLT → ONU/ONT	OpS defines this interval and can focus on one particular ONU/ONT.	3	The ONU/ONT starts a BER_interval timer and accumulates the downstream bit errors. Send one acknowledge after each correctly received message. The sequence number in the REI messages is reset.
15	PST message	To check the OLT-ONU/ONT connectivity in a redundant configuration and perform APS.	OLT → ONU/ONT	Send it at a certain rate.	1 time/second	ONU/ONT checks link number with own link number and generates a Link Mismatch MIS if different.
16	Physical_equipment_error message (PEE)	To indicate to the ONUs/ONTs that the OLT is unable to send both ATM cells and OMCC cells in the direction from ATM layer to TC layer.	OLT → ONU/ONT	When the OLT detects it cannot send both ATM cells and OMCC cells in the direction from ATM layer to TC layer.	1 time/second	System specific.

Table 9/G.983.4 – Message definition

17	Churned_VP	To indicate to the ONUs/ONTs which VP/VC are churned or not.	OLT → ONU/ONT	When a new VP must be churned or not.	3	(Un)Mark this VP as churning. Send one acknowledge after each correctly received message.
18	Request_password message	Request the password from an ONU/ONT in order to verify it. The OLT has a local table of passwords for the connected ONUs/ONTs. If after a reranging, the password has changed, it will not activate this ONU/ONT.	OLT → ONU/ONT	After an ONU/ONT is ranged. This is optional.	1	Send the password message three times.
19	POPUP message	The OLT can request all connected ONUs/ONTs to restore their settings with the exception of the equalization delay and force the ONUs/ONTs to go from POPUP state to Operating standby state 3 (O7).	OLT → ONU/ONT	To speed up the reranging of a subset or all of the connected ONUs/ONTs.	3	The ONU/ONT restores the parameters it was using in operating state before it detected an LOS, LCD, OAML or FRML, with the exception of the equalization delay which is set to the pre-assigned equalization delay value.
20	Vendor_specific message	A number of Message_IDs are reserved for vendor specific messages.	OLT → ONU/ONT	Vendor specific.	Vendor specific.	Vendor specific.
21	No message	No message available when a PLOAM cell is transmitted.	OLT ← ONU/ONT	Empty message queue.		Discard.
22	New_churning_key	Contains a new key to be used on the downstream churned cells to this ONU/ONT. Priority level is 1.	OLT ← ONU/ONT	After the OLT request, the ONU/ONT fetches a new key and sends it to the OLT.	3 times	The OLT initializes the churning engine with this new key if it receives three consecutive identical keys and switches to the new key 48*Tframe after the first churning_key_update message.
23	Acknowledge	This is used by the ONU/ONT to indicate the reception of a downstream Configure_VP/VC, Churning_key_update, Churned_VP, BER_interval message or Additional_Grant allocation message. Priority is 1 for the acknowledge on the churning_key_update message. The priority level is 0 for the others. The time-out for the acknowledge is 300 ms.	OLT ← ONU/ONT	After receiving every correct corresponding downstream message.	1 time	The OLT is informed of good reception of the downstream message it was sending and performs the corresponding actions.

Table 9/G.983.4 – Message definition

24	Serial_number_ONU/ONT	This message contains the serial number of an ONU/ONT.	OLT ← ONU/ONT	The ONU/ONT sends this message when in ranging mode and on receipt of a ranging grant or a PLOAM grant.	X (may be sent several times during the ranging protocol).	The OLT extracts the serial number and can assign a free PON_ID to this ONU/ONT.
25	Message_error message	This indicates that the ONU/ONT is unable to comply with a message from the OLT.	OLT ← ONU/ONT	When the ONU/ONT is unable to comply with a message contained in a downstream PLOAM cell.	3	Inform the operator.
26	REI (Remote Error Indication)	This contains the number of downstream BIP mismatches (one count per bit mismatch) counted during the BER_interval.	OLT ← ONU/ONT	When the BER_interval has expired.	1 time/BER_interval	The OLT can show the average BER in function of time for an ONU/ONT.
27	R-INH	Used to inform the OLT that the ONU/ONT will power-off in a normal manner. This is to prevent the OLT from issuing unnecessary alarm reports. Priority level is 2.	OLT ← ONU/ONT	The ONU/ONT generates this message when the power-off (such as the power switch off or the power cord extraction without battery backup) is activated in a normal operation.	At least 3 times	Discard any following alarms from this ONU/ONT. Inform OpS.
28	PST message	To check the OLT-ONU/ONT connectivity in a redundant configuration and perform APS.	OLT ← ONU/ONT	Send it at a certain rate.	1 time/second	OLT checks link number with own link number and generates a Link Mismatch MISi if different.
29	Physical_equipment_error	To indicate to the OLT that the ONU/ONT is unable to send both ATM cells and OMCC cells in the direction from ATM layer to TC layer.	OLT ← ONU/ONT	When the ONU/ONT detects it cannot send both ATM cells and OMCC Cells in the direction from ATM layer to TC layer.	1 time/second	System specific
30	Password	Used to verify an ONU/ONT based on its password.	OLT ← ONU/ONT	When the OLT requests the password by the request_ password message.	3	If OLT receives three identical passwords, it is declared as valid. Further processing is system dependent.
31	Vendor_specific message	A number of Message_Ids are reserved for vendor specific messages.	OLT ← ONU/ONT	Vendor specific.	Vendor specific	Vendor specific.
32	Additional_Grant_allocation message	To allocate 2nd or additional data grants to ONU/ONT.	OLT → ONU/ONT	After a PON_ID is allocated to the ONU/ONT, it needs a data grant for sending the upstream data.	3	ONU/ONT has 2nd or additional data grant. Send one acknowledge after each correctly received message.

8.3.8.2 Message formats

This clause defines the contents of messages in the previous clause .

8.3.8.2.1 Downstream message formats

This clause describes the downstream message formats.

The following messages are described in ITU-T Rec. G.983.1:

No message

Upstream_Rx_Control message

Upstream_overhead message

Ranging_time message

Serial_number_mask message

Assign_PON_ID message

Deactivate_PON_ID message

Disable_serial_number message

New_churning_key_request message

Churning_key_update message

Configure VP/VC message

Physical_equipment_error message

Request_password message

Churned_VP message

POPUP message

Vendor_specific message

PST message

BER_interval message

Additional messages are used to accommodate DBA. Given the ONU/ONT's DBA parameters, the OLT can then configure the ONU/ONT to recognize additional data grants, send reports containing T-CONT buffer status via the divided slot channel, and reconfigure the reporting of T-CONTs without interruption of the reporting service. The three messages in the PLOAM channel that are used to perform this are the Grant_allocation_message, the Additional_grant_allocation message, and the Divided_slot_configuration message. The formats of these messages are given below.

1)   *Grant_allocation message*

This message is applied to the first grant allocation. The format of this message is described in Table 10 and is the same as in ITU-T Rec. G.983.1.

2)   *Additional_grant_allocation_message*

A new message called Additional_grant_allocation message is defined as follows to address the grant assignment to T-CONTs. The message id is 32. This message is used for the DBA system. The original Grant_allocation message is only used initially during the ranging process. After that, the new Additional_grant_allocation message should be used to specify the divided slot grant, field offset, report type of this T-CONT, and grant. The format of this message is shown in Table 11.

This message is sent to an ONU/ONT for each T-CONT inside the ONU/ONT. Each T-CONT is assigned a unique data grant. In other words, there is a one–to-one mapping between each data grant and each T-CONT. The T-CONT_ID is used to provide an extra layer of abstraction between the grant number and the T-CONT buffer in the ONU/ONT. These must always exist in a one-to-one mapping between an active T-CONT_ID and data grant. This abstraction allows for the grant number to be changed while maintaining the VP/VC configuration with the T-CONT_ID, which is likely to occur in reranging or provisioned scenarios.

3)   *Divided_slot_grant_configuration message*

Divided_slot_grant_configuration message is unchanged from its definition in ITU-T Rec. G.983.1. For ease of reference, this message is shown in Table 12.

Table 10/G.983.4 – Grant_allocation message

Octet	Content	Description
35	PON_ID	Directed message to one ONU/ONT
36	0000 1010	Message identification "Grant_allocation"
37	dddd dddd	data grant allocated to the ONU/ONT with this PON_ID
38	0000 000a	a:1 = Activate data grant for this ONU/ONT a:0 = Deactivate data grant for this ONU/ONT
39	pppp pppp	PLOAM grant allocated to the ONU/ONT with this PON_ID
40	0000 000a	a:1 = Activate PLOAM grant for this ONU/ONT a:0 = Deactivate PLOAM grant for this ONU/ONT
41..46	0000 0000	Reserved
NOTE – Grant_allocation message is used for first data grant and is the same in ITU-T Rec. G.983.1.			

Table 11/G.983.4 – Additional_grant_allocation message

Octet	content	Description
35	PON_ID	Directed message to one ONU/ONT
36	0010 0000	Message identification for "Additional_grant_allocation"
37	dddd dddd	Data grant allocated to a T-CONT within the ONU/ONT with this PON_ID
38	0000 000a	a: 1 – Activate data grant for this T-CONT a: 0 – Deactivate data grant for this T-CONT
39	T-CONT_ID	The T-CONT_ID associated with this grant
40	DS_GR	Divided slot grant that this T-CONT will use to report status. 255 = no reporting for this T-CONT
41	RPT_type	Report type for this T-CONT 0 = default (1 byte, non-linear, total cells in buffer) Other values are for future use, described in Appendix II
42	FLD_offset	field_offset for this T-CONT. Within the range [0, 52]. field_offset = 0 means T-CONT report starts right after the 3 bytes of overhead within the minislot. Offsets include any CRC fields contained within the minislot, hence an offset of 14, 29, 44, or 52 is always invalid here.
43…46	0000 0000	Reserved

Table 12/G.983.4 – Divided_Slot_Grant_configuration message

Octet	Content	Description
35	PON_ID	Directed message to one ONU/ONT
36	0000 1011	Message identification "Divided_slot_grant_configuration"
37	0000 000a	a:1 = Activate grant for this ONU/ONT a:0 = Deactivate grant for this ONU/ONT
38	DS_GR	Defines the grant value allocated to this ONU/ONT for sending a minislot. NOTE – the OLT can assign plural data grants.
39	LENGTH	Defines the length of the minislot payload in number of bytes.
40	OFFSET	Defines the offset of the start of the minislot in number of bytes from the start of an upstream cell slot. OFFSET = 0 means minislot starts at the first byte of the upstream slot.
41	Service_ID	Defines the service to be mapped into the minislot. 0000 0000 is used for the MAC protocol. Other values are for reserved for expansion.
42..46	0000 0000	Reserved

8.3.8.2.2 Upstream message formats

The specific information is described in ITU-T Rec. G.983.1.

8.3.9 Automatic protection switching

The specific information is described in ITU-T Rec. G.983.1.

8.4 Ranging method

8.4.1 Scope of the applied ranging method

The specific information is described in ITU-T Rec. G.983.1.

8.4.2 Features of ranging method for DBA

Basically, the ranging method for DBA is the same as that in ITU-T Rec. G.983.1 to maintain backward compatibility with the existing ONU/ONT specified in ITU-T Rec. G.983.1. Moreover, the ONU/ONT should accept Additional_grant_allocation messages when in an operating state in order to be sent multiple data grants by the OLT.

8.4.3 Phase relation specification between downstream and upstream

The specific information is described in 8.4.2/G.983.1.

8.4.4 Definition of messages used in the ranging protocol

The specific information is described in 8.4.3/G.983.1.

8.4.5 Ranging procedure

8.4.5.1 Overall ranging procedure

The specific information is described in ITU-T Rec. G.983.1.

8.4.5.2 Ranging procedure in the ONU/ONT

The specific information is described in ITU-T Rec. G.983.1.

8.4.5.3   States of the ONU/ONT

The states and state transitions for the ONU/ONT are shown in Table 13. This table is similar to the state table found in Table 28/G.983.1 but includes an Additional_Grant_Allocation message.

8.4.5.4   Behaviour specification in the ONU/ONT

The ability to support multiple T-CONTs is achieved by allocating a new grant in the Operating state when the PON_ID matches its own PON_ID.

8.4.5.4.1   Message reception

The messages conveyed in the PLOAM cells from the OLT should be protected by the CRC, and the message receive-event should be generated when the CRC check is correct. In the case of a), c), d), and e) below, these messages are sent three times to ensure correct reception at the ONU/ONT. In these cases the message receive-event is generated after the message has been received correctly at least once.

a)   *The receive-event of Upstream_overhead message*

    The specific information is described in 8.4.4.2.2.1/G.983.1.

b)   *The receive-event of Serial_number_mask message*

    The specific information is described in 8.4.4.2.2.1/G.983.1.

c)   *The receive-event of Assign_PON_ID message*

    The specific information is described in 8.4.4.2.2.1/G.983.1.

d)   *The receive-event of the Grant_allocation message*

    The specific information is described in 8.4.4.2.2.1/G.983.1.

e)   *The receive-event of Ranging_time message*

    The specific information is described in 8.4.4.2.2.1/G.983.1.

f)   *The receive-event of Deactivate_PON_ID message*

    The specific information is described in 8.4.4.2.2.1/G.983.1.

g)   *The receive-event of Disable_serial_number message*

    The specific information is described in 8.4.4.2.2.1/G.983.1.

h)   *The receive-event of POPUP message*

    The specific information is described in 8.4.4.2.2.1/G.983.1.

i)   *The receive-event of the Additional_grant_allocation message*

    When the PON_ID in the Additional_Grant_allocation message matches its own PON_ID, an additional data grant is assigned and an acknowledgement is sent.

8.4.5.4.2   Grant reception

The specific information is described in ITU-T Rec. G.983.1.

8.4.5.4.3   Other events

The specific information is described in ITU-T Rec. G.983.1.

Table 13/G.983.4 – The state diagram of the ONU/ONT

	Initial state (O1)	Ranging standby state-1 (O2)	Ranging standby state-2 (O3)	Ranging standby state-3 (O4)
Upstream_overhead message	–	extract overhead set pre-assigned delay Te ⇒ O3	–	–
Optical power set-up complete	–	–	timer TO1 start ⇒ O5	timer TO1 start ⇒ O5
Serial_number_mask message	–	–	match SN(valid bits)? ⇒ O4	unmatch SN(valid bits)? ⇒ O3
Assign_PON_ID message	–	–	–	–
Grant_allocation message	–	–	–	–
POPUP message	–	–	–	–
timer TO2 expire	–	–	–	–
timer TO1 expire	–	–	–	–
Ranging_time message	–	–	–	–
data grant	–	–	–	–
PLOAM grant	–	–	–	–
ranging grant	–	–	–	send PLOAM cell
Deactivate_PON_ID message (Note)	–	–	match PON_ID? ⇒ O2	match PON_ID? ⇒ O2
Disable_serial_number message	–	Match SN and enable = FFh? ⇒ O9	match SN and enable = FFh? ⇒ O9	match SN and enable = FFh? ⇒ O9
detect LOS or LCD or OAML or FRML	–	⇒ O1	⇒ O1	⇒ O1
clear LOS and LCD and OAML and FRML	⇒ O2	–	–	–
Additional_grant_allocation message	–	–	–	–

Table 13/G.983.4 – The state diagram of the ONU/ONT

	Operating standby state-1 (O5)	Operating standby state-2 (O6)	Operating standby state-3 (O7)
Upstream_overhead message	–	–	–
Optical power set-up complete	–	–	–
Serial_number_mask message	match SN(valid bits)? ⇒ O6	unmatch SN(valid bits)? ⇒ O5	–
Assign_PON_ID message	match SN? → assign PON_ID	match SN? → assign PON_ID	–
Grant_allocation message	match PON_ID? → allocate data/PLOAM grant ⇒ O7	match PON_ID? → allocate data/PLOAM grant ⇒ O7	–
POPUP message	–	–	–
timer TO2 expire	–	–	–
timer TO1 expire	⇒ O3 (alarm SUF)	⇒ O3 (alarm SUF)	⇒ O3 (alarm SUF)
Ranging_time message	–	–	match PON_ID? → timer TO1 stop → set equalization delay ⇒ O8
data grant	–	–	–
PLOAM grant	–	–	send PLOAM cell
ranging grant	–	send PLOAM cell	–
Deactivate_PON_ID message (Note)	match PON_ID? → timer TO1 stop ⇒ O2	match PON_ID? → timer TO1 stop ⇒ O2	match PON_ID? → timer TO1 stop ⇒ O2
Disable_serial_number message	match SN and enable = FFh? → timer TO1 stop ⇒ O9	match SN and enable = FFh? → timer TO1 stop ⇒ O9	match SN and enable = FFh? → timer TO1 stop ⇒ O9
detect LOS or LCD or OAML or FRML	Timer TO1 stop ⇒ O1	timer TO1 stop ⇒ O1	timer TO1 stop ⇒ O1
clear LOS and LCD and OAML and FRML	–	–	–
Additional_grant_allocation message	–	–	–

Table 13/G.983.4 – The state diagram of the ONU/ONT

	Operating state (O8)	Emergency stop state-1 (O9)	POPUP state (O10)
Upstream_overhead message	–	–	–
Optical power set-up complete	–	–	–
Serial_number_mask message	–		
Assign_PON_ID message	–	–	–
Grant_allocation message	–	–	–
POPUP message	–	–	Restore laser settings, Upstream_overhead, LCF and RXCF fields, Te, PON_ID, and Grant allocation, timer TO1 start ⇒ O7
timer TO2 expire	–	–	⇒ O1
timer TO1 expire	–	–	–
Ranging_time message	match PON_ID? → update equalization delay	–	–
data grant	send ATM cell	–	–
PLOAM grant	send PLOAM cell	–	–
ranging grant	–	–	–
Deactivate_PON_ID message (Note)	match PON_ID? ⇒ O2	–	–
Disable_serial_number message	match SN and enable = FFh? ⇒ O9	match SN and enable = 00h? or enable = 0Fh and SN irrelevant ⇒ O1	–
detect LOS or LCD or OAML or FRML	Start timer TO2 ⇒ O10	–	⇒ O10
clear LOS and LCD and OAML and FRML	–	–	–
Additional_grant_allocation message	match PON_ID? → allocate data grant and send acknowledge	–	–

NOTE – Receive-event of a broadcast Deactivate_PON_ID message (the 35th octet of PON_ID = 40h) is also assumed.
An ONU/ONT will leave the Operating state if a fault occurs or power is removed from the ONU/ONT.
Only maintenance signals of LOS, LCD, OAML, and FRML are considered in this state diagram.
"–" means no action for corresponding event.
PLOAM cell in the state of O4 should be transmitted in pre-assigned delay Te.
PON_ID and Grant allocation should be cleared or discarded when the state transitions to O1, O2, O3, and O9 occur, and pre-assigned delay Te should be cleared in transitions to O1 and O2.

8.4.5.4.4 Ranging procedure in the OLT

The specific information is described in ITU-T Rec. G.983.1.

8.4.6 Ranging time requirements

The specific information is described in 8.4.5/G.983.1.

8.5 Handshake procedures

8.5.1 Overall handshake procedure

The typical model of class queues and T-CONTs in the ONU/ONT is shown in Figure 34. The procedures relating T-CONTs to grants are defined in this Recommendation; the procedures relating VPs to class queues are defined in ITU-T Rec. G.983.2, and the procedures relating queues to T-CONTs are defined in ITU-T Rec. G.983.7.
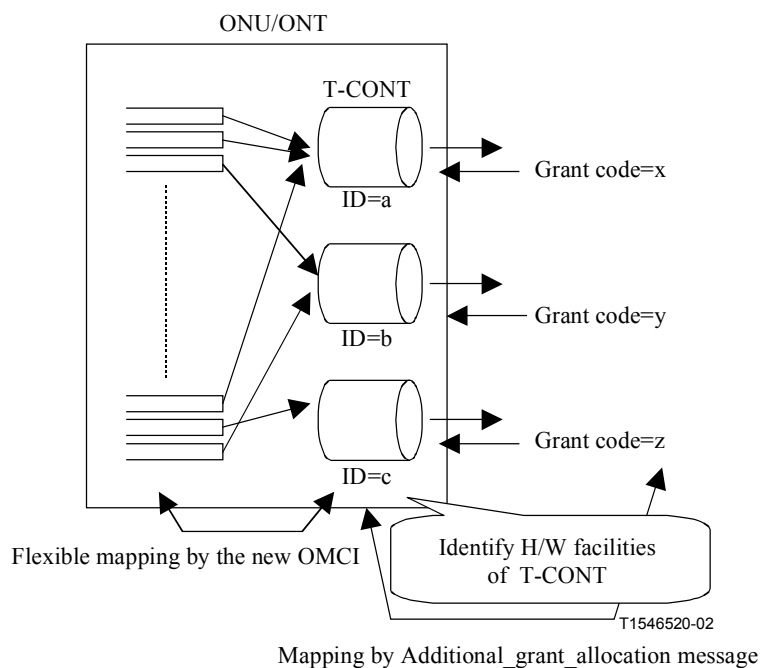
Figure 34/G.983.4 – Typical model of class queue and T-CONTs in the ONU/ONT

8.5.2 Negotiated parameters

To configure the additional data grants and divided slot reporting, the OLT must learn the capabilities of the ONU/ONT in question. This information shall be obtained using the OMCI channel. The detailed procedures of the information exchange are described in ITU-T Rec. G.983.7. The key parameters for the TC layer functions described here are listed in Table 14.

Table 14/G.983.4 – ONU/ONT parameters obtained via the DBA OMCI handshake

Parameter Name	Valid range
Maximum_data_grants	1..252
Maximum_divided_slot_grants	0..252
T-CONT_buffer_reporting_types	0..255

The maximum_data_grants parameter can range from 1 (for an ONU/ONT with a single T-CONT) up to the theoretical maximum of 252 data grants (all the data grants on a PON with one ONU/ONT, although this is unlikely).

The maximum_divided_slot_grants parameter can range from 0 to 252. The minimum in this case (0) is for NSR-ONUs/ONTs. The cases of one or more divided_slot_grants are applied to SR-ONUs/ONTs. If operations of glitch-free reconfiguration specified in 8.6.2 are applied, two or more divided_slot_grants should be reserved. One of these divided_slot_grants cannot be used for real service, and should be used to step aside in transition of glitch-free operations according to 8.6.2. In SR-DBA, when glitch-free reconfiguration is not required, the case of one divided_slot_grant can be applicable. Moreover, if glitch-free operations that do not require one reserved divided_slot_grant besides operations in 8.6.2 are specified in the future, the case of one divided_slot_grants can be applicable even if glitch-free reconfiguration can be supported. The maximum is the same as for the data grants.

The T-CONT-buffer_reporting_types is a special code that indicates the kinds of reports that this ONU/ONT can perform. Only one code (0) is defined as a normative default, and this signifies that the ONU/ONT shall report the total number of cells in the T-CONT buffer. Other codes are described in Appendix II.

8.5.3   Detailed procedures

Figure 35 shows the handshake sequence between the OLT and the ONU/ONT.

Step 1 – Basic configuration of ONU/ONT

This procedure is specified in UIT-T Rec. G.983.1. A grant is allocated in the ranging procedure, although the ONU/ONT is assumed to be NSR for the moment.

Step 2 –The OLT gets the information about ONUs/ONTs

This procedure is specified in UIT-T Rec. G.983.7. The OLT gets the following DBA support information from ONU/ONT:

– The number of divided slot grants supported in this ONU/ONT.

– The number of T-CONTs supported in this ONU/ONT.

– The capability of T-CONT buffer reporting types for this ONU/ONT.

Step 3 – Allocating a Divided-slot grant to the ONU/ONT

If the ONU/ONT is able to report buffer status, the OLT sends "Divided_Slot_Grant_configuration message" to the ONU/ONT.

In this message the OLT specifies:

– The minislot grant for this ONU/ONT.

– The minislot length for this ONU/ONT.

– The minislot offset for this ONU/ONT.

Step 4 – Allocating a new data grant to the T-CONTs, or re-binding an existing data grant to a reporting field

The OLT sends Additional_grant_allocation message to the ONU/ONT. In this message the OLT specifies:

– The additional data grant for this ONU/ONT.

– The T-CONT ID associated with this data grant.

- The minislot report type of this T-CONT.

- The divided slot grant for this T-CONT to use for reporting.

- The minislot field_offset for this T-CONT within the minislot.

After receiving this message, the ONU/ONT is able to associate the new or existing data grant to the appropriate minislot report field.

If the ONU/ONT has multiple T-CONTs (grants), then the OLT needs to send this message multiple times, once per T-CONT.

Step 5 –Configuration of user VPs

This procedure is specified in ITU-T Recs. G.983.1, G.983.2 and G.983.7. The class queue is related to the T-CONT by the OMCI message.

Step 6 – Status reporting

This is the actual transmission of minislot reports in response to divided slot grants, as described in this Recommendation.
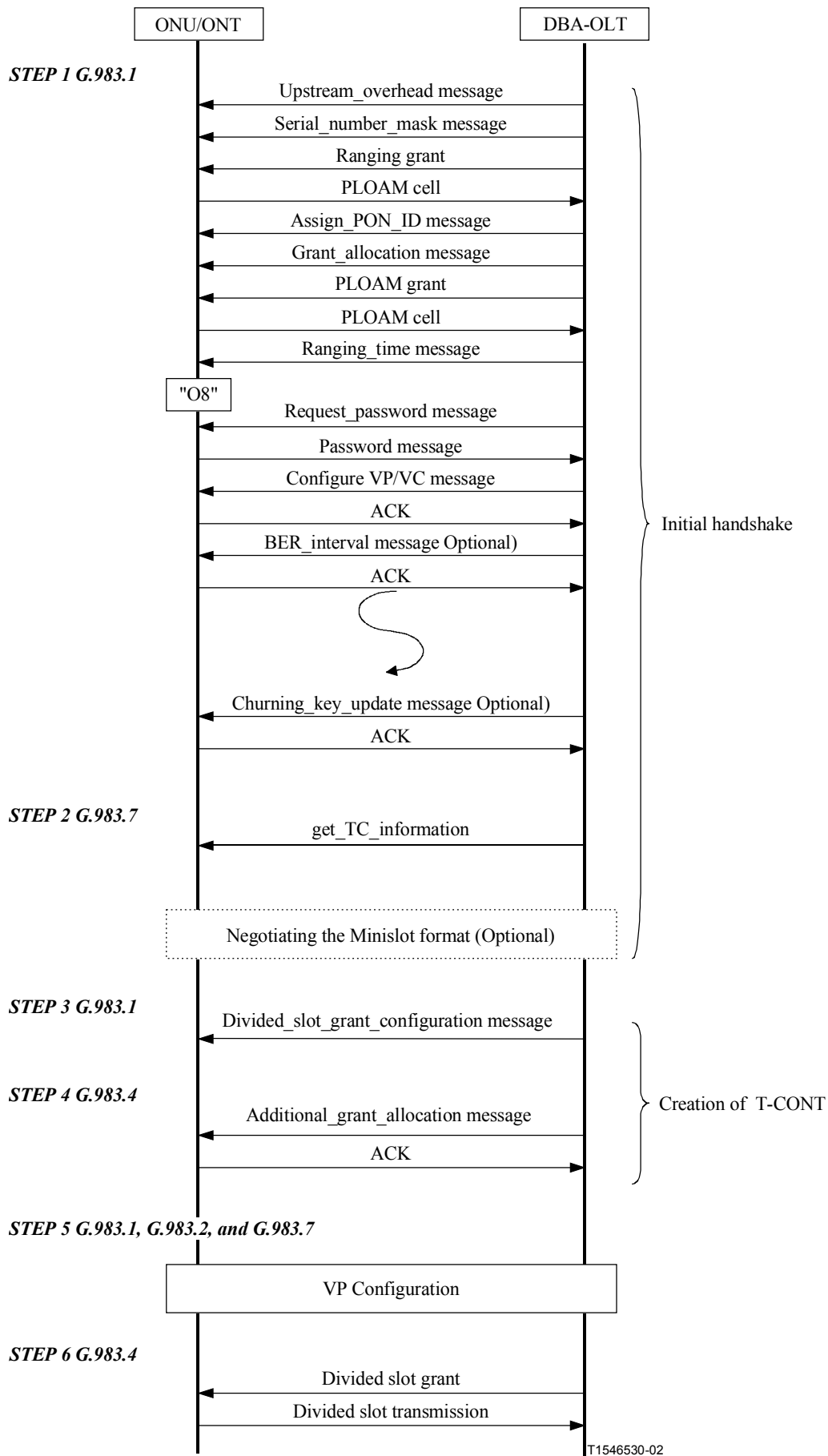
Figure 35/G.983.4 – The sequence between the OLT and the ONU/ONT

8.6 Operations for creation and deletion of T-CONTs

8.6.1 Requirements for operations of T-CONT status change

T-CONTs on the ONU/ONT will be activated or deactivated according to user services in the operating status. In this situation the following requirements shall be met:

a)   *Partial activation of T-CONTs in a single SR-ONU/ONT*

The OLT shall be able to activate individual T-CONTs in an SR-ONU/ONT as necessary. (R)

The number and configuration of T-CONTs is expected to vary from SR-ONU/ONT to SR-ONU/ONT. The number of T-CONTs activated for any SR-ONU/ONT may not be the maximum number of T-CONTs that particular SR-ONU/ONT is capable of physically supporting.

b)   *The modification of the number of activated T-CONT in operating state (O8)*

In operating state (O8), the number of activated T-CONTs inside an individual ONU/ONT shall be able to be modified according to changes of user configuration, operational situation, etc. (R)

c)   *Impact of addition or deletion of T-CONTs*

Addition or deletion of individual T-CONTs shall not affect other T-CONTs serviced by an individual ONU/ONT. (R)

Addition or deletion of individual T-CONTs or groups of T-CONTs shall not affect service to other T-CONTs served from an individual PON-IF board (or any other PON-IF board – this includes connections and ATM traffic).

The change of set-up values of one T-CONT shall not affect the other T-CONTs serviced by the same ONU/ONT and serviced by the same PON-IF board, their connections, nor their ATM traffic.

d)   *Selection of T-CONT buffers*

Any T-CONT buffer shall be individually selectable to support operational requirements.

When a T-CONT number is mapped to a specific T-CONT buffer, the selection of the T-CONT number inside the ONU/ONT shall also be selected.

8.6.2 Operations for creation of T-CONTs

Reconfiguration of minislot reporting without impairments

Configuration and reconfiguration of the minislot reporting system shall not cause any data errors or omissions in the underlying MAC information. There are two major parts of configuration:

–   Configuration of the divided slots,

–   Configuration of the T-CONT reports within the minislots.

The divided slots are configured using the Divided_slot_grant_configuration message. The configuration of the divided slot has the properties that:

1)   multiple ONUs/ONTs can be affected by a change;

2)   the timing recovery at the OLT must be coordinated with the configuration, and

3)   the CRC checking must be coordinated with the configuration. For these reasons, it is not practical to modify a divided slot configuration.

The only allowed operations are activate and deactivate. Specifically, for any divided slot grant/PON_ID combination, it may be illegal to send consecutive activating Divided_slot_grant_configuration messages with a different offset or size.

For example, suppose an ONU/ONT has a divided slot configured that contains 4 report fields and then needs a fifth reporting field. It is not permissible to send a new configuration with a longer length, even if space exists in the divided slot. This is because the ONU/ONT will respond asynchronously to the new configuration, and the OLT will not know where to look for the trailing CRC. A similar problem occurs with changing the offset (start) of the minislot. The OLT will not know when to start looking for the start of the minislot. In either case, the OLT will not receive the information, and there will be a reporting impairment.

Therefore, to achieve a resizing or relocation of a minislot retransmission, the procedure will be to first create a new minislot, transfer the reporting functionality to this new minislot, and then delete the old minislot. Since an ONU/ONT can only transmit one minislot per divided slot grant, this implies that the new minislot must exist in another divided slot. This is not as restrictive as it sounds, because to achieve optimal packing of the variable sized minislots into the divided slots it will be necessary to move all the minislots contained in one divided slot to a new divided slot.

The configuration of the T-CONT reports within the minislots is mediated by the Additional_grant_allocation message. The fields in this message specify the current divided slot grant and offset to be used in reporting the T-CONT status. Note that this message can be sent in 3 cases:

Case 1: This is a new grant allocation.

Case 2: This is an existing grant deallocation.

Case 3: This is an existing grant, being reconfigured to report in a different minislot.

The first and second cases are clear, as they are the simple activate-deactivate pair, much like the use of the Grant_allocation message in ITU-T Rec. G.983.1. The third case is used to reconFigure an existing T-CONT report to a new minislot, offset combination. Thus, the behaviour of the ONU/ONT upon receiving an Additional_grant_allocation message containing a grant number that was previously allocated is as follows:

–   Do not modify any of the traffic-affecting properties of the T-CONT.

–   Change the minislot reporting association of that T-CONT to the newly specified one.

–   Fill the now unused field in the old minislot with the idle code (0xFF).

No particular timing relationship between the receipt of the message and the change is assumed. The OLT will be able to determine which of the two fields is active by looking for the idle code. Note that case 3 of the Additional_grant_allocation message can be applied to the grant that was provisioned using the Grant_allocation_message during the ranging procedure. In this way, that initial grant can be made into whatever type of T-CONT is needed for service.

An illustration of the divided slot configuration and reconfiguration at creation of T-CONTs is given in Figure 36. The presumed sequence of this process is that the ONU/ONT is initially configured with 3 T-CONTs and then requires a fourth T-CONT. Note that in this sequence, steps 1-4 are the initial configuration, and steps 5-9 are the reconfiguration actions. The figure shows the contents of two minislots in divided slots No. 23 and No. 24 in the middle and right columns, respectively.

NOTE – When the minislot is first created, the unused fields are filled with the idle code (0xFF).

Note that between steps 1 and 9, the minislot with offset zero in divided_slot No. 23 is well defined. Its beginning is at offset 0, and it has a total length of 7 bytes; therefore, its only CRC is found at offset = 6. This CRC is calculated by the ONU/ONT on whatever the minislot contains (idle codes or real reports). Hence, the OLT calculates the CRC on the received sequence, no matter what step the configuration process is in. The same applies to the other minislot contained in divided_slot No. 24 from step 5 onward. This ensures that the lower layer processing at the OLT always has integrity.

The approach being taken here is that the minislot transmission is exactly the right size for the number of T-CONTs being reported. This obviously requires a significant amount of messaging effort to maintain, and in many cases it will not reduce the bandwidth consumed by the minislots. A more efficient approach is to provision a modest but non-zero number of idle report fields for each ONU/ONT and utilize these as T-CONTs are provisioned and de-provisioned.

Also note that the interchange in Figure 36 only concerns one ONU/ONT's transmissions. So, while ONU/ONT 1 moves its minislot from divided slot No. 23 to No. 24, another ONU/ONT could perhaps move its minislot from yet another divided slot to divided slot No. 23. In this case, divided slot No. 23 would not be unscheduled (following step 10). By moving ONUs/ONTs back and forth between a given set of divided slot grants, much reconfiguration can be achieved without actually adding new divided slots or removing old ones. However, there is a limit to the reconfigurations possible in this piecewise reconfiguration, as gaps between odd-size minislots are bound to form. This problem is addressed by the process of divided slot configuration, described below.

ONU/ONT 1   DBA-OLT

1st T-CONT is created.

Step 1. Divided_grant_slot_configuration
(PON_ID=1, Activate DS_grant=23, Offset=0, Length=7)

Divided Slot #23

PL Overhead	Idle	Idle	Idle	CRC

Step 2. Additional_grant_allocation
(PON_ID=1, Activate grant=1, T-CONT ID=1, DS_grant=23, Report Type=0, Offset=0)

Divided Slot #23

PL Overhead	R1	Idle	Idle	CRC

2nd T-CONT is created.

Step 3. Additional_grant_allocation
(PON_ID=1, Activate grant=2, T-CONT ID=2, DS_grant=23, Report Type=0, Offset=1)

Divided Slot #23

PL Overhead	R1	R2	Idle	CRC

3rd T-CONT is created.

Step 4. Additional_grant_allocation
(PON_ID=1, Activate grant=3, T-CONT ID=3, DS_grant=23, Report Type=0, Offset=2)

Divided Slot #23

PL Overhead	R1	R2	R3	CRC

4th T-CONT is created.

ONU/ONT 1 is now configured with 3 data grants, being reported in Divided_slot #23.
A new service request requires one more data grant to be configured.

Step 5. Divided_slot_grant_configuration
(PON_ID=1, Activate DS_grant=24, Offset=0, Length=8)

Divided Slot #23

PL Overhead	R1	R2	R3	CRC

Divided Slot #24

PL Overhead	Idle	Idle	Idle	Idle	CRC

Step 6. Additional_grant_allocation
(PON_ID=1, Activate grant=1, T-CONT ID=1, DS_grant=24, Report Type=0, Offset=0)

Divided Slot #23

PL Overhead	Idle	R2	R3	CRC

Divided Slot #24

PL Overhead	R1	Idle	Idle	Idle	CRC

Step 7. Additional_grant_allocation
(PON_ID=1, Activate grant=2, T-CONT ID=2, DS_grant=24, Report Type=0, Offset=1)

Divided Slot #23

PL Overhead	Idle	Idle	R3	CRC

Divided Slot #24

PL Overhead	R1	R2	Idle	Idle	CRC

Step 8. Additional_grant_allocation
(PON_ID=1, Activate grant=1, T-CONT ID=3, DS_grant=24, Report Type=0, Offset=2)

Divided Slot #23

PL Overhead	Idle	Idle	Idle	CRC

Divided Slot #24

PL Overhead	R1	R2	R3	Idle	CRC

Step 9. Additional_grant_allocation
(PON_ID=1, Activate grant=4, T-CONT ID=4, DS_grant=24, Report Type=0, Offset=3)

Divided Slot #23

PL Overhead	Idle	Idle	Idle	CRC

Divided Slot #24

PL Overhead	R1	R2	R3	R4	CRC

Step 10. Divided_slot_grant_configuration
(PON_ID=1, Activate DS_grant=23, Offset=n/a, Length=n/a)

Divided Slot #24

PL Overhead	R1	R2	R3	R4	CRC

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Figure 36/G.983.4 - Creation procedure of T-CONTs and glitch-free minislot transmission for one ONU/ONT

8.6.3 Operations for deletion of T-CONTs

An illustration of the divided slot configuration and reconfiguration at deletion of a T-CONT is given in Figure 37. The presumed sequence of this process is that the ONU/ONT is initially configured with 4 T-CONTs and then no longer requires the 2nd and 4th T-CONTs. Note that in this sequence, steps 12-13 are the deletion actions, and steps 14-17 are the defragmentation action. The Figure shows the contents of two minislots in divided slots No. 23 and No. 24 in the middle and right columns, respectively.

Note that between steps 12 and 16, the minislot with offset zero in divided_slot No. 24 is well defined. Its beginning is at offset 0, and it has a total length of 8 bytes; therefore, its only CRC is found at offset = 7. This CRC is calculated by the ONU/ONT on whatever the minislot contains (idle codes or real reports). Hence, the OLT calculates the CRC on the received sequence, no matter what step the configuration process is in. This ensures that the lower layer processing at the OLT always has integrity.
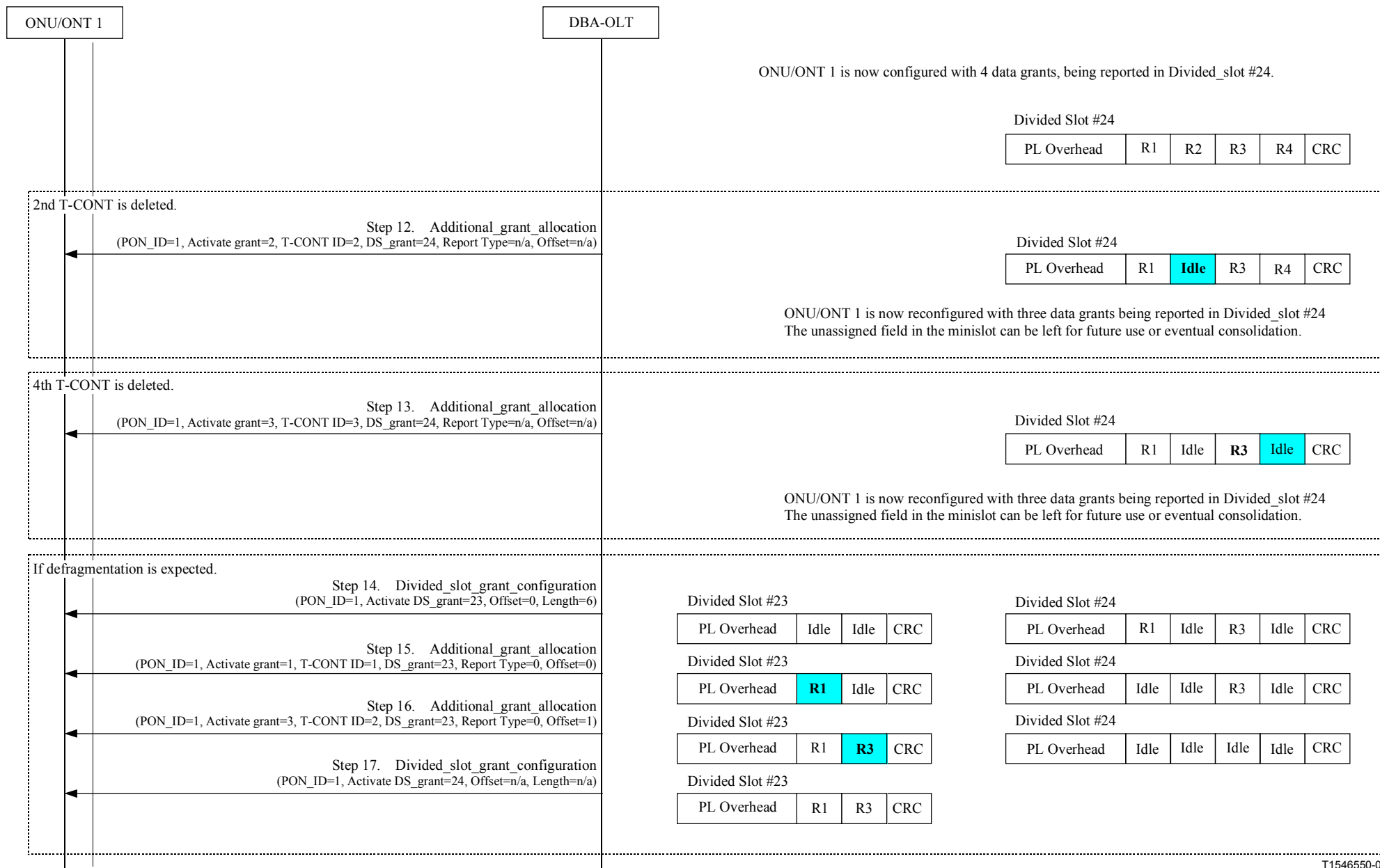
Figure 37/G.983.4 – Creation procedure of T-CONTs and glitch-free minislot transmission for one ONU/ONT

8.6.4 Impact by T-CONT status change

As described in 8.6.2 and 8.6.3 and to avoid glitches, the OLT should reconfigure minislots without interruption of the reporting service.

Figure 38 describes in general terms the process of divided slot consolidation, where several ONUs/ONTs' minislots are reconfigured in order to fit them into a small number of divided slots.

Note that in the beginning case, two divided slots contain a number of poorly utilized and poorly spaced minislots. By a process of shifting each of these minislots into a more efficient version in a third minislot, all of the ONUs/ONTs can report in a single slot, and the two inefficient divided slots can be completely deconfigured and then taken out of the grant scheduler.
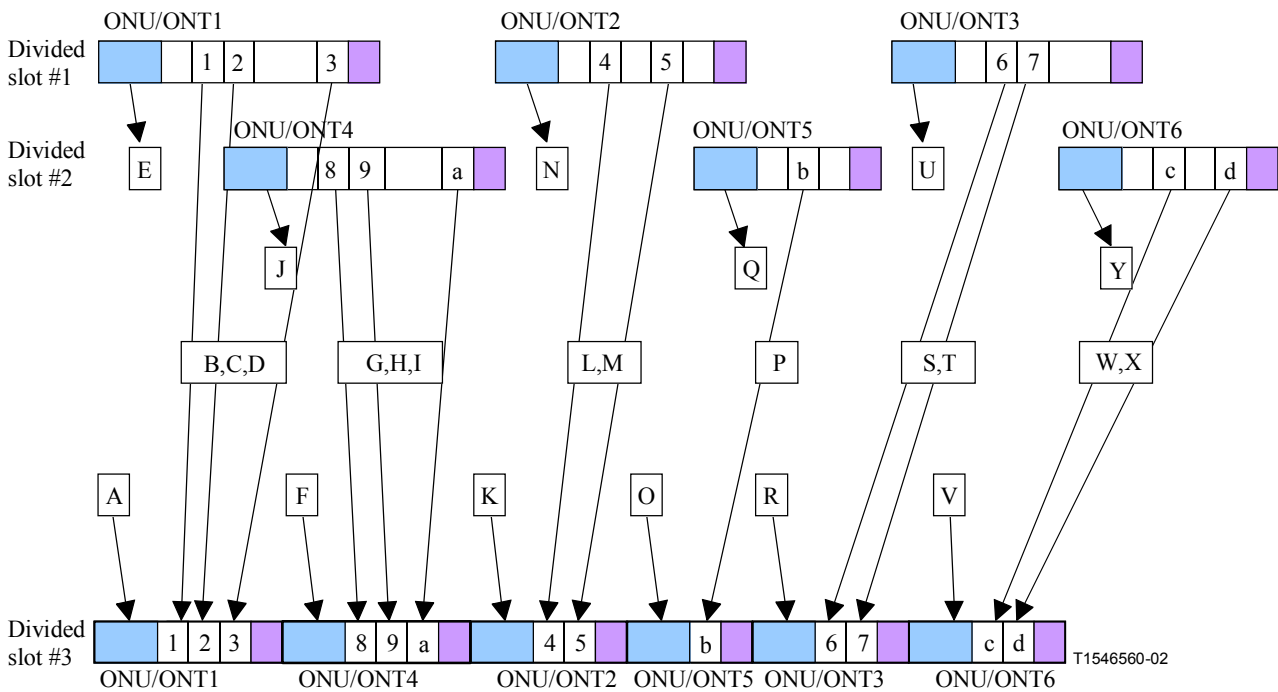

Figure 38/G.983.4 – An illustration of a bandwidth conserving reconfiguration of divided slots

List of the messages as indicated on the figure:

Divided_slot_configuration PONID=1, Activate DS_grant=3, Offset=0, Length=7

Additional_grant_allocation PONID=1, Activate grant=1, T-CONT_ID=1, DS_grant=3, Offset=0

Additional_grant_allocation PONID=1, Activate grant=2, T-CONT_ID=2, DS_grant=3, Offset=1

Additional_grant_allocation PONID=1, Activate grant=3, T-CONT_ID=3, DS_grant=3, Offset=2

Divided_slot_configuration PONID=1, Deactivate DS_grant=1, Offset=n/a, Length=n/a

Divided_slot_configuration PONID=4, Activate DS_grant=3, Offset=7, Length=7

Additional_grant_allocation PONID=4, Activate grant=8, T-CONT_ID=8, DS_grant=3, Offset=0

Additional_grant_allocation PONID=4, Activate grant=9, T-CONT_ID=9, DS_grant=3, Offset=1

Additional_grant_allocation PONID=4, Activate grant=a, T-CONT_ID=a, DS_grant=3, Offset=2

Divided_slot_configuration PONID=4, Deactivate DS_grant=2, Offset=n/a, Length=n/a

Divided_slot_configuration PONID=2, Activate DS_grant=3, Offset=14, Length=6

Additional_grant_allocation PONID=2, Activate grant=4, T-CONT_ID=4, DS_grant=3, Offset=0

Additional_grant_allocation PONID=2, Activate grant=5, T-CONT_ID=5, DS_grant=3, Offset=1

Divided_slot_configuration PONID=2, Deactivate DS_grant=1, Offset=n/a, Length=n/a

Divided_slot_configuration PONID=5, Activate DS_grant=3, Offset=20, Length=5

Additional_grant_allocation PONID=5, Activate grant=b, T-CONT_ID=b, DS_grant=3, Offset=0

Divided_slot_configuration PONID=5, Deactivate DS_grant=2, Offset=n/a, Length=n/a

Divided_slot_configuration PONID=3, Activate DS_grant=3, Offset=25, Length=6

Additional_grant_allocation PONID=3, Activate grant=6, T-CONT_ID=6, DS_grant=3, Offset=0

Additional_grant_allocation PONID=3, Activate grant=7, T-CONT_ID=7, DS_grant=3, Offset=1

Divided_slot_configuration PONID=3, Deactivate DS_grant=1, Offset=n/a, Length=n/a

Divided_slot_configuration PONID=6, Activate DS_grant=3, Offset=31, Length=6

Additional_grant_allocation PONID=6, Activate grant=c, T-CONT_ID=c, DS_grant=3, Offset=0

Additional_grant_allocation PONID=6, Activate grant=d, T-CONT_ID=d, DS_grant=3, Offset=1

Divided_slot_configuration PONID=6, Deactivate DS_grant=2, Offset=n/a, Length=n/a

Remove Divided slot grants No. 1 and No. 2 from scheduler.

Note that this kind of full defragmentation of the divided slots is the fullest expression of the reconfiguration process. As mentioned previously, it is also possible to add and subtract individual minislots on an ONU/ONT by ONU/ONT basis, especially if the implementation chooses to configure minislots of a fixed size, since doing so avoids having unusable spaces in the divided slots.

Frequency of divided slot consolidation

The purpose of divided slot consolidation is the conservation of bandwidth. However, unless the consolidation results in a net reduction of the total number of divided slot grants in use, it will not result in any saved bandwidth. Hence, before any reconfiguration is attempted, it should be determined if one (or more) divided slots can be fully eliminated. If not, then reconfiguration can be delayed. This prevents needless message activity on the PON.

9 Operations Administration and Maintenance (OAM) functionality

The specific information is described in ITU-T Rec. G.983.1.

10 Performance

Performance of the ATM level specified in ITU-T Rec. I.356 should be guaranteed for any ATC/QoS. However, detailed performance in the network with DBA should be discussed as a future issue.

11 Environmental condition

The specific information is described in ITU-T Rec. G.983.1.

12 Safety

The specific information is described in ITU-T Rec. G.983.1.

Appendix I

Algorithm for DBA

This appendix presents some recommended algorithms for a DBA protocol, such as bandwidth assignment and grant allocation in the OLT. Currently, many algorithms have been evaluated. After completion of performance evaluation and comparison among these algorithms from several points of view, these algorithms are introduced in this appendix.

DBA algorithms are classified into several parts as follows.

I.1 Algorithms for detecting ONU/ONT status for SR-ONU/ONT

To detect congestion in the T-CONT, we can monitor the queue length at the ONU/ONT. Monitoring queue length means counting the number of waiting cells for transmission on the PON link. These processes are invoked in every T-CONT.

Procedures

Step 1: The ONU/ONT monitors the queue length in every T-CONT buffer.

Step 2: The ONU/ONT receives the divided slot grants from the OLT.

Step 3: The ONU/ONT sends the total queue length information for every T-CONT.

I.2 Algorithms for monitoring cell streams at OLT from NSR-ONUs/ONTs

We can detect congestion on the PON link by monitoring the number of receiving cells at the OLT. We present the procedures of this mechanism as one example.

Procedures

Step 1: Monitor the number of received cells at the OLT in the fixed interval.

Step 2: Calculate the utilization rate (= used BW/Current assigned BW) by using the results of real time monitoring in Step 1.

Step 3: Recognize congestion by comparison between the utilization rate and thresholds.

Notice

NOTE – In Step 1, we should study the definition of monitored cells, such as idle cell monitoring, user cell monitoring, or used cell monitoring.

I.3 Algorithms to update bandwidth

When we calculate the updated bandwidth at the OLT, we can divide these mechanisms into three types, such as memory-less, stepwise increase, and stepwise increase and decrease. We can summarize these types as follows.

1) *Memory-less*

When we detect congestion in a T-CONT, we allocate more resources to this group independent of previously allocated resources. We present the outline of this mechanism as follows and illustrate operations in Figure I.1.
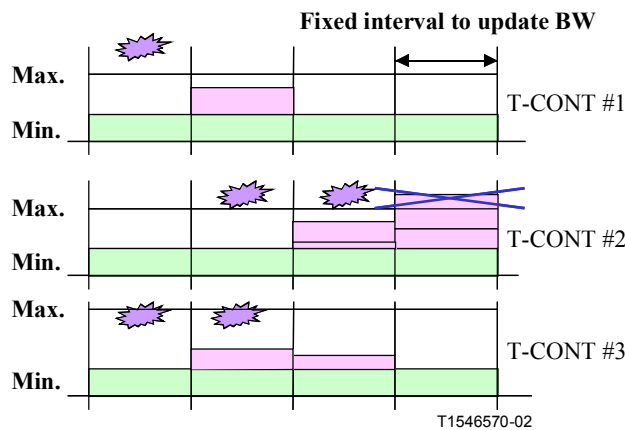
Figure I.1/G.983.4 – Operation in Memory-less bandwidth update

Notations

Max: maximum bandwidth for one B-PON physical interface

Max(i): maximum bandwidth for T-CONTi

Min(i): minimum bandwidth for T-CONTi

Old(i): allocated bandwidth for T-CONTi in the previous round

New(i): updated bandwidth for T-CONTi

SR(i): Shared bandwidth ratio for T-CONTi

C(i): Congestion status at T-CONTi

      C(i)=1 if congestion for T-CONTi

      C(i)=0 if non congestion for T-CONTi

Ad: Additional bandwidth for congested T-CONT

Procedures

```
If C(i)=0
     New(i)=Min(i)
If C(i)=1
     New(i)=SR(i)*(Max - sum(Min(j): for any j))+Min(i)
     If New(i)>Max(i)
        Ad=Ad+New(i)-Max(i)
        New(i)=Max(i)
```

For example, in these procedures, SR(i) can be specified as follows[1].

```
     SR(i)=Min(i)/sum(C(j)*Min(j): for any j)
```

---

[1] As the similar method, we present SR(i) as follows.

SR(i)=(Max(i)-Min(i))/sum(C(j)*(Max(j)-Min(j)): for any j)

Moreover, we should determine the procedure of how to share "Ad" to congested grant groups that can accept additional bandwidth after assignment of bandwidth. In short, we should specify the maximum number of retry calculations for each grant group until convergence of updated bandwidth.

2)   *Stepwise increase*

When we detect congestion in a T-CONT, we increase resources stepwise to this group based on previously allocated resources. We present the sample pseudo codes using the above notations and illustrate operations in Figure I.2.
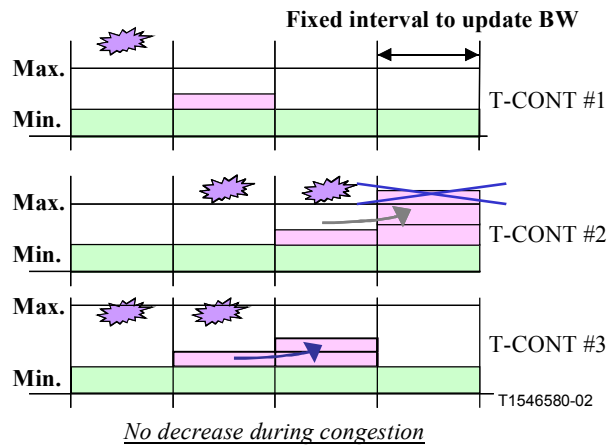

Figure I.2/G.983.4 – Operation in Stepwise increase bandwidth update

Procedures(1)

```
If C(i)=0
     New(i)=Min(i)
If C(i)=1
     New(i)=SR(i)*[Max – sum{(1-C(j))*Min(j): for any j}]+Old(i)
     If New(i)>Max(i)
        Ad=Ad+New(i)-Max(i)
        New(i)=Max(i)
```

For example, in these procedures, SR(i) can be specified as follows.

```
     SR(i)=Min(i)/sum(C(j)*Min(j): for any j)
```

Moreover, we can present another example of simplified procedures.

Procedures(2)

```
If C(i)=0
     New(i)=Min(i)
If C(i)=1
     New(i)=SR(i)*Old(i)+Old(i)
     If New(i)>Max(i)
        Ad=Ad+New(i)-Max(i)
        New(i)=Max(i)
     New(i)=min{New(i), New(i)/sum(New(j): for any j)*Max}
```

In this case, SR(i) can be a constant value, which is similar to the Rate Decrease Factor in ABR behaviour.

3) *Stepwise increase and decrease*

When we recognize update of congestion in a T-CONT, we increase and decrease resources stepwise to this group based on previously allocated resources and illustrate operations in Figure I.3.
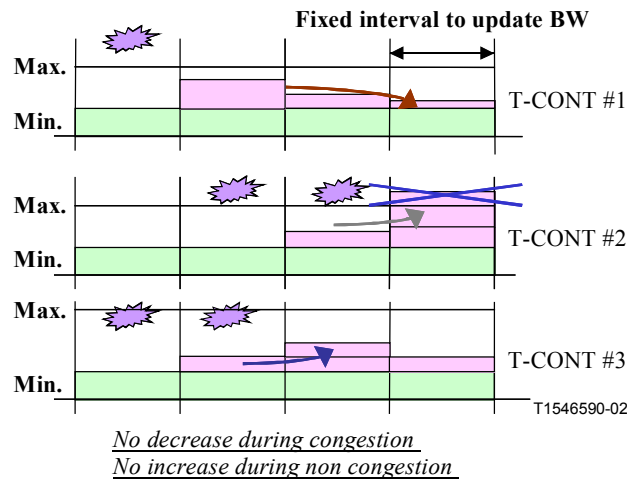

No decrease during congestion
No increase during non congestion

Figure I.3/G.983.4 – Operation in Stepwise increase and decrease bandwidth update

Procedures
```
If C(i)=0
    New(i)=Old(i)-SR(i)*Old(i)
    If New(i)<Min(i)
       Ad=Ad-(Min(i)-New(i))
       New(i)=Min(i)
If C(i)=1
    New(i)=Old(i)+SR(i)*Old(i)
    If New(i)>Max(i)
       Ad=Ad+New(i)-Max(i)
       New(i)=Max(i)
    New(i)=min{New(i), New(i)/sum(New(j): for any j)*Max}
```

For example, in these procedures, SR(i) can be a constant value to simplify these procedures. It looks like the Rate Increase or Decrease Factor in ABR behaviour.

I.4 Algorithms for grant assignment

Grants are assigned according to behaviours of each T-CONT type.

I.5 Control allowing for Upstream Congestion of the OLT NNI

For Further Study.

Appendix II

Options for minislot format and negotiating procedures

II.1   Extended T-CONT reporting options

It has been shown that to support T-CONTs that contain both CLP = 0 and CLP = 1 cells, it is necessary to report multiple cell counts to the OLT to ensure bandwidth fairness. Full reporting of each queue is impractical, as it would require excessive minislot fields. Therefore, a more compact notation is needed. This clause outlines the optional extended reporting options.

II.1.1   Report type field

The reporting type appears in Octet 41 of the Additional_grant_allocation message. The defined values for this field are:

Field = 0: Default: The report has one field, which contains the non-linear coding of the total number of cells in the T-CONT buffer. Each T-CONT buffer reporting uses 1 byte. Support of this type is mandatory.

Field = 1: Two byte: The report has two fields, the first contains the non-linear coding of the total numbers of cells in T-CONT buffer that have PCR tokens (1 byte), and the second field contains the non-linear coding of the total number of cells in T-CONT buffer that have SCR tokens (1 byte). This type of reporting uses 2 bytes in total. This is suitable for T-CONT type 3 and type 5 reporting

Field = 2: Four byte: The report has four fields. The first contains the non-linear coding of total number of T-CONT No. 2 class cells that have PCR tokens (assured BW) (1 byte). The second field contains the non-linear coding of the total number of T-CONT No. 3 class cells that have SCR tokens (assured BW) (1 byte). The third field contains the non-linear coding of the total number of T-CONT No. 3 class cells that have PCR tokens (non-assured BW) (1 byte). The fourth field contains the non-linear coding of the total number of T-CONT No. 4 class cells that have PCR tokens (best effort BW) (1 byte). This type of reporting uses 4 bytes in total. This is suitable for T-CONT type 5 reporting.

Note that all reporting methods use the same non-linear coding for each subfield.

II.1.2   Reporting capability

The reporting capability determined in the DBA OMCI handshaking exchange indicates the reporting capabilities of the ONU/ONT. The defined values of this capability code are:

Code = 0: Default one byte reporting only is supported;

Code = 1: One byte and two byte reporting supported;

Code = 2: One byte and four byte reporting supported;

Code = 3: One, two, and four byte reporting supported.

Note that these codes basically specify a bit field that indicates support for the two optional reporting formats recommended in this appendix, allowing any combination of support. Note that all possible combinations include the normative one byte reporting method, ensuring interoperability over all ONU/ONT types.

II.1.3   Usage of extended reporting types

The purpose of these extended reports is to give the OLT more information on the types of traffic waiting in the T-CONT buffer. Because the T-CONT buffer can contain multiple connections of multiple ATM service classes, a single cell count does not always give sufficient information on the traffic state of the T-CONT.

An example of the implementation of a T-CONT buffer that supports two-byte reporting is shown in Figure II.1. This shows a buffer that implements a weighted round robin type of scheduler, and each queue is policed using the standard dual-leaky bucket generic cell rate algorithm (GCRA). The derivation of the two cell counts to be sent in the two-byte report is shown to be the sum over all queues of the cells that have SCR tokens and PCR tokens, respectively. With these counts, the OLT DBA algorithm can send grants to those T-CONTs that have more SCR tokens first, ensuring fairness.

A similar process would be done to compute the four counts required for the four-byte reporting method, with the sums being taken over the groups of connections as listed for that mode.
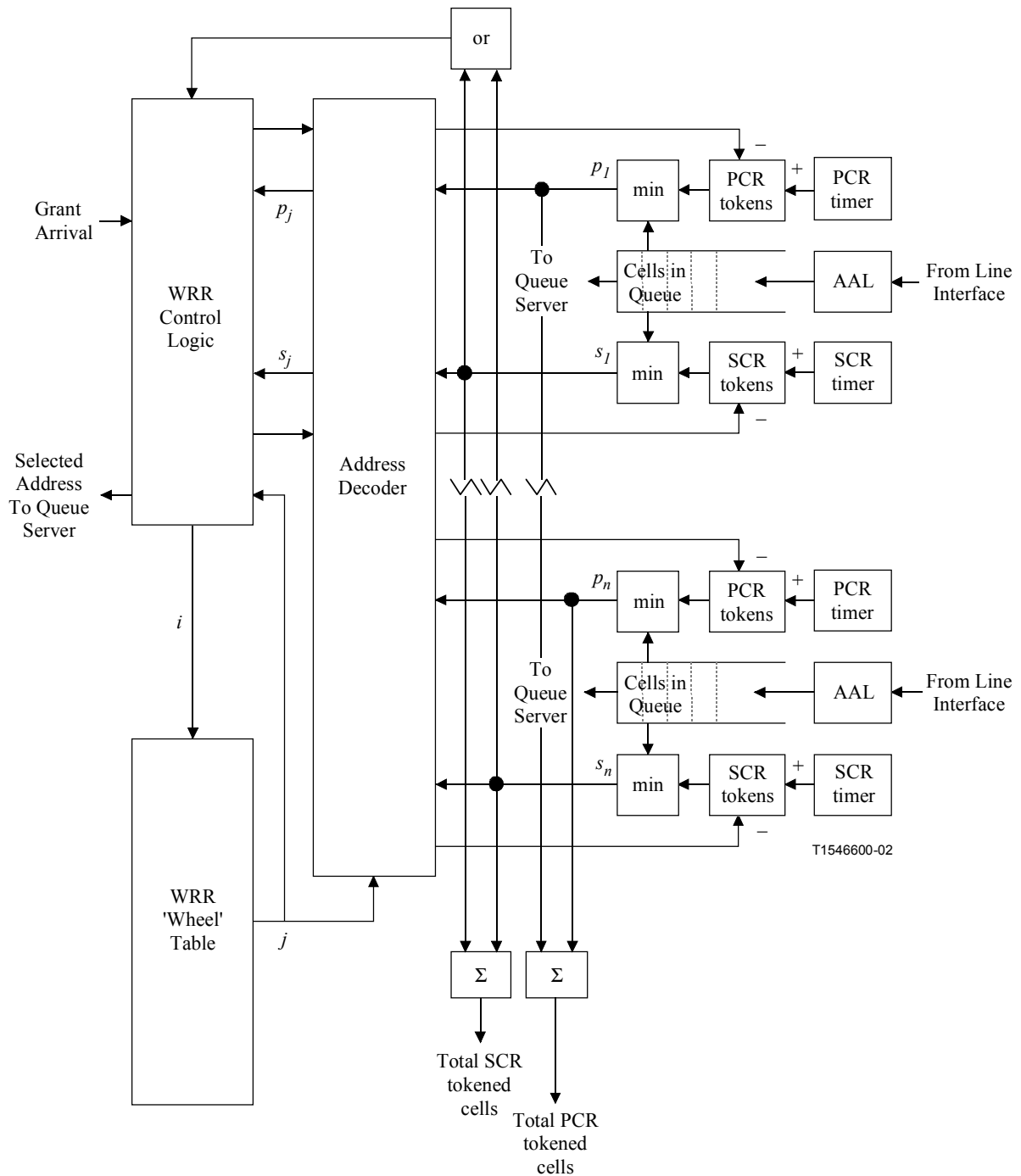
Figure II.1/G.983.4 – An implementation of a WRR dual-leaky bucket regulated scheduler

Note that the control logic is triggered by the arrival of a grant and then selects the next queue to be served based on: the weights configured in the 'wheel table', the availability of SCR and PCR tokens, and the presence of SCR tokenized cells in any queue. Also note that the occupancy of the multiple queues is summarized by calculating the total SCR and PCR tokenized cells.

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