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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.

Source

ITU-T Recommendation G.983.4 was prepared by ITU-T Study Group 15 (2001-2004) and approved under the WTSA Resolution 1 procedure on 29 November 2001.

FOREWORD

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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.

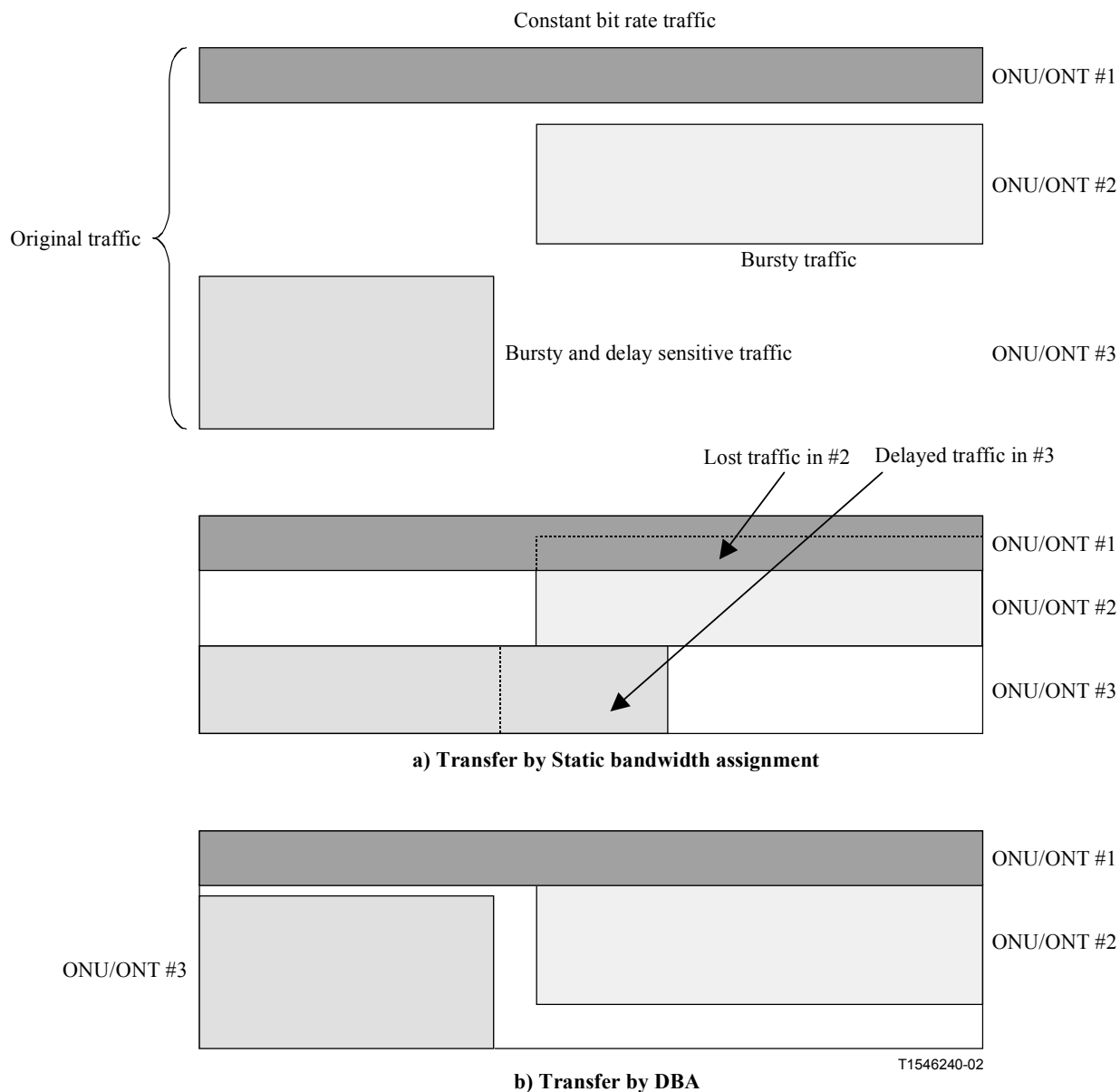


Figure 1/G.983.4 – Comparison between the current mechanism and DBA

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.

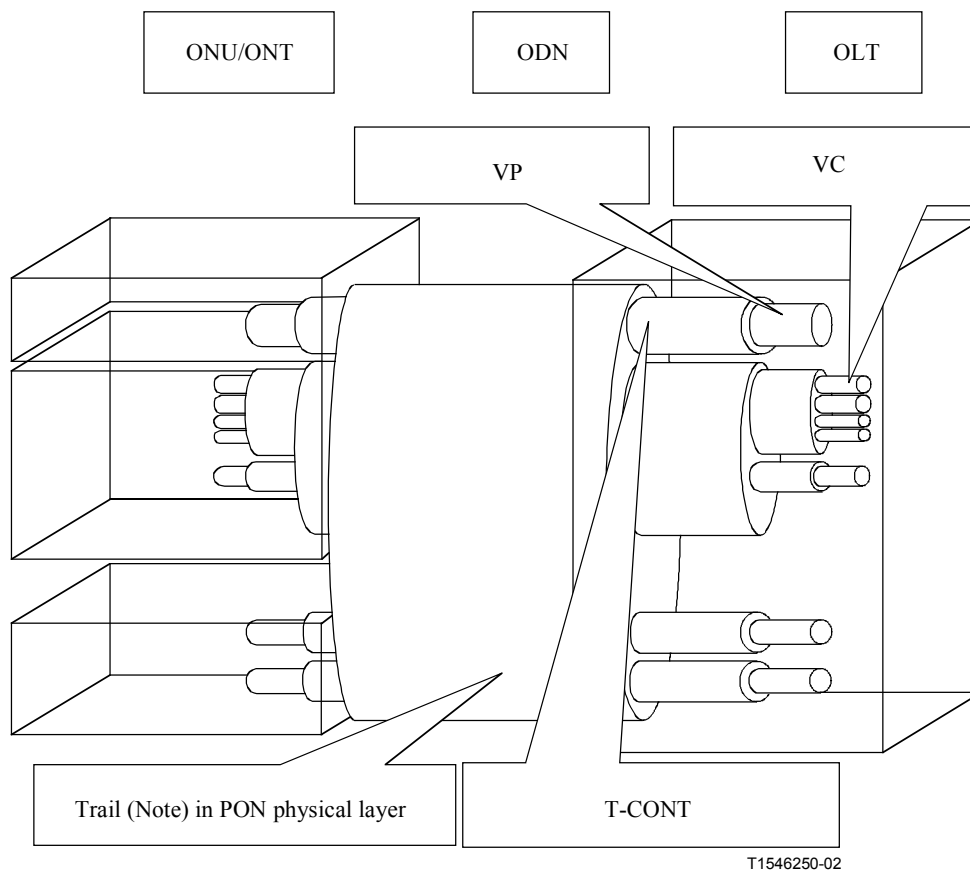
Performance benchmarks are addressed for:

- 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.

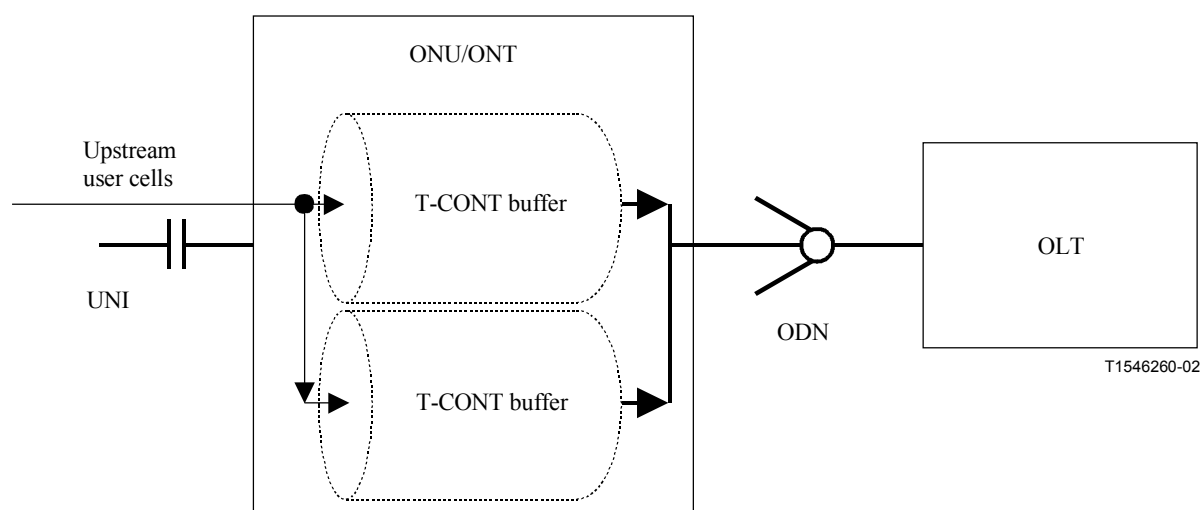


Figure 3/G.983.4 – Configurations of T-CONT buffers in one ONU/ONT

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.

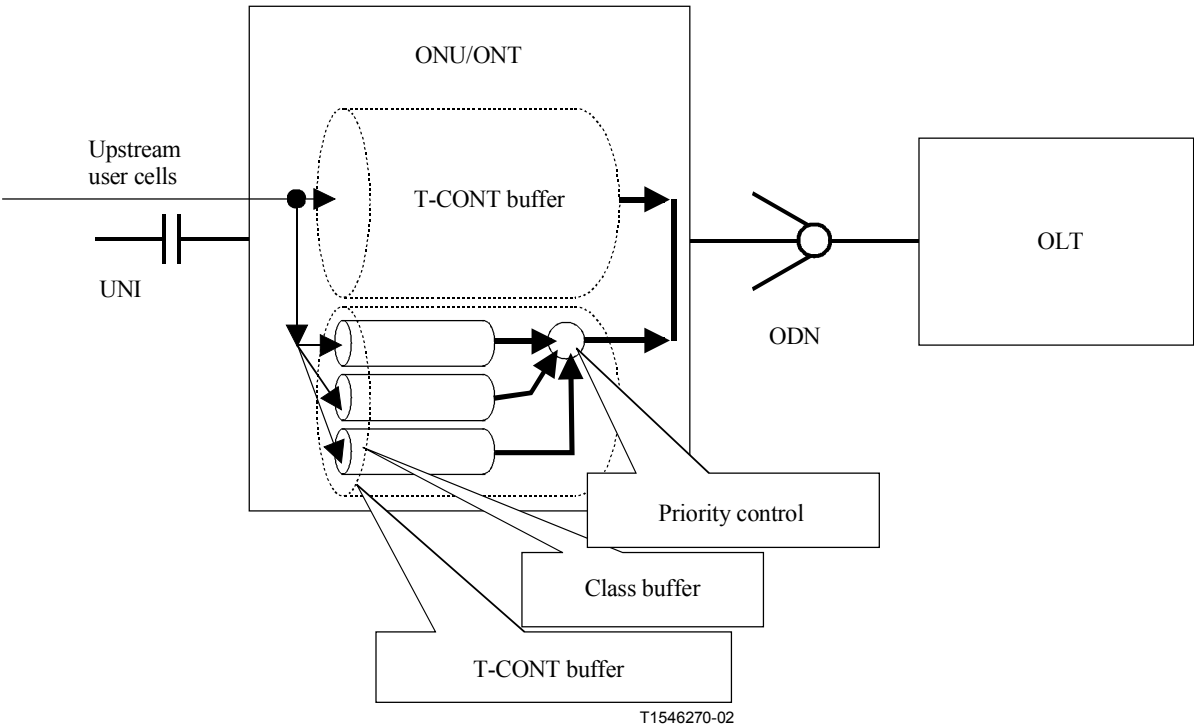


Figure 4/G.983.4 – An example of internal mechanisms in a T-CONT buffer

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.

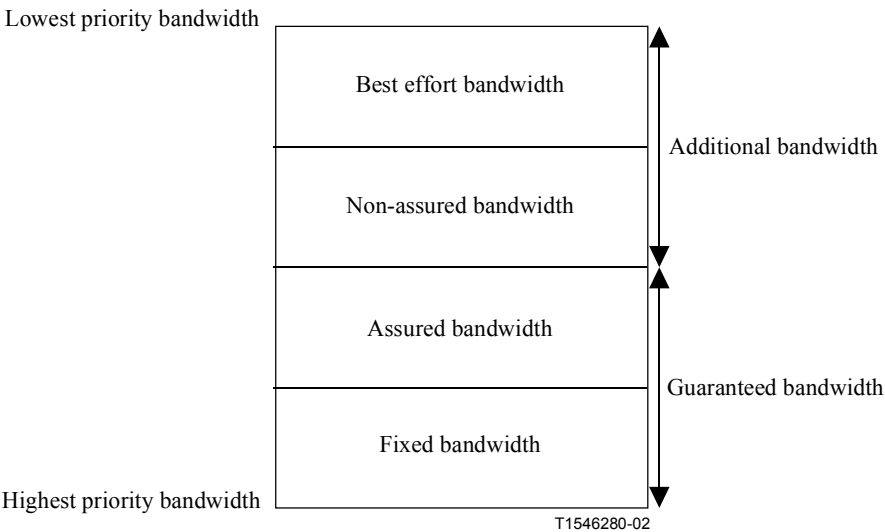


Figure 5/G.983.4 – Priority of bandwidth for grant allocation

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 most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published.

- [1] ITU-T 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 duplex 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.

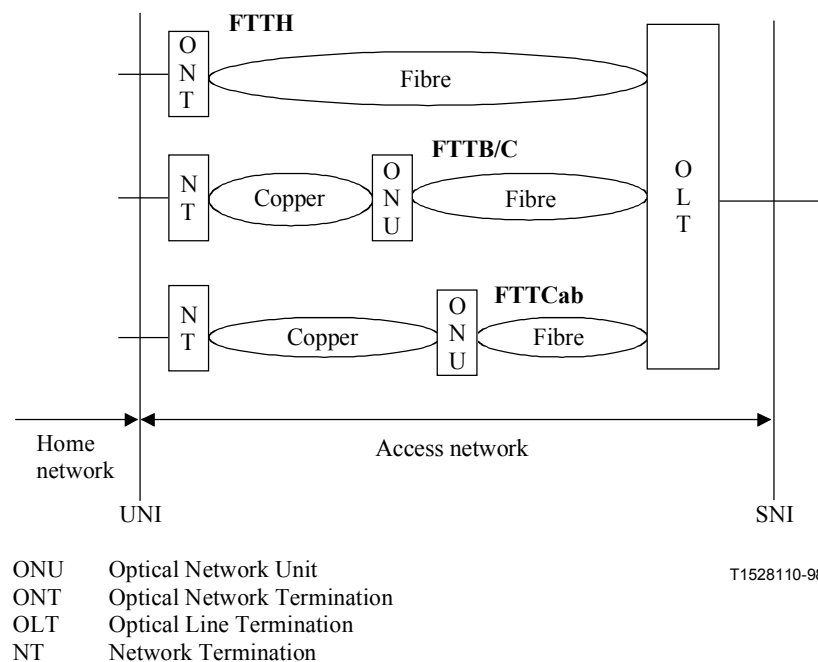


Figure 6/G.983.4 – Network architecture

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:

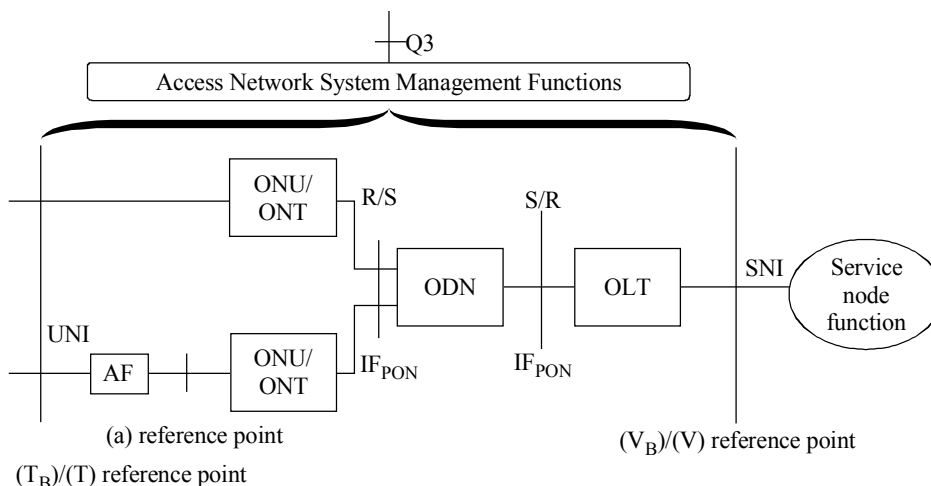
- A DBA-OLT shall dynamically and fairly allocate bandwidth on a PON that includes NSR-ONUs/ONTs from different vendors.
- A DBA-OLT shall dynamically and fairly allocate bandwidth on a PON that includes SR-ONUs/ONTs from different vendors as long as these SR-ONUs/ONTs conform to the status reporting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

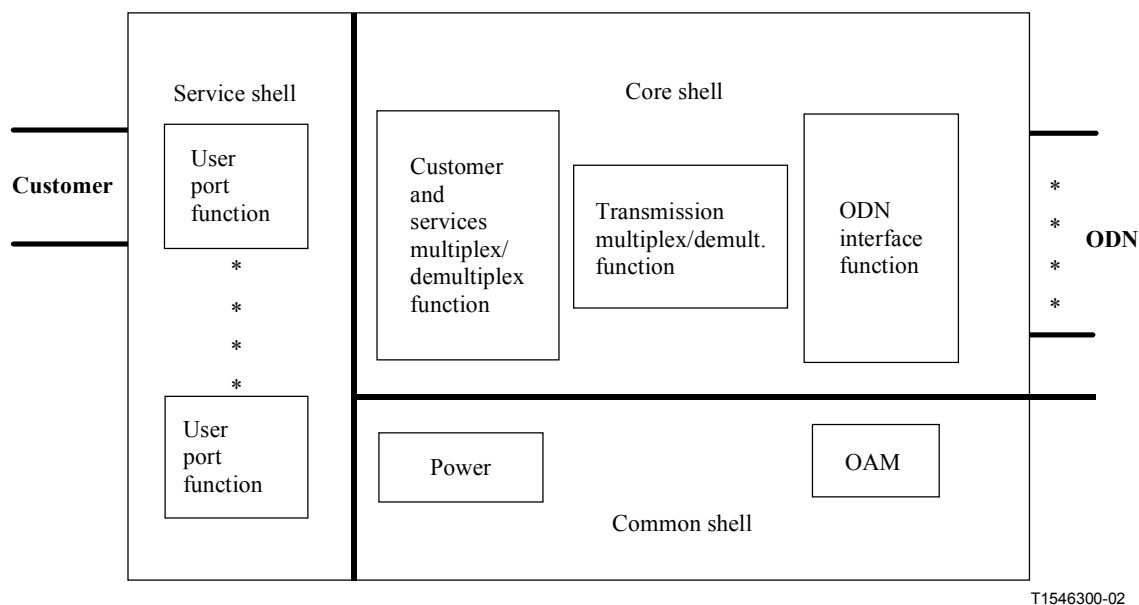


Figure 8/G.983.4 – Example of NSR-ONU/ONT functional blocks

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.

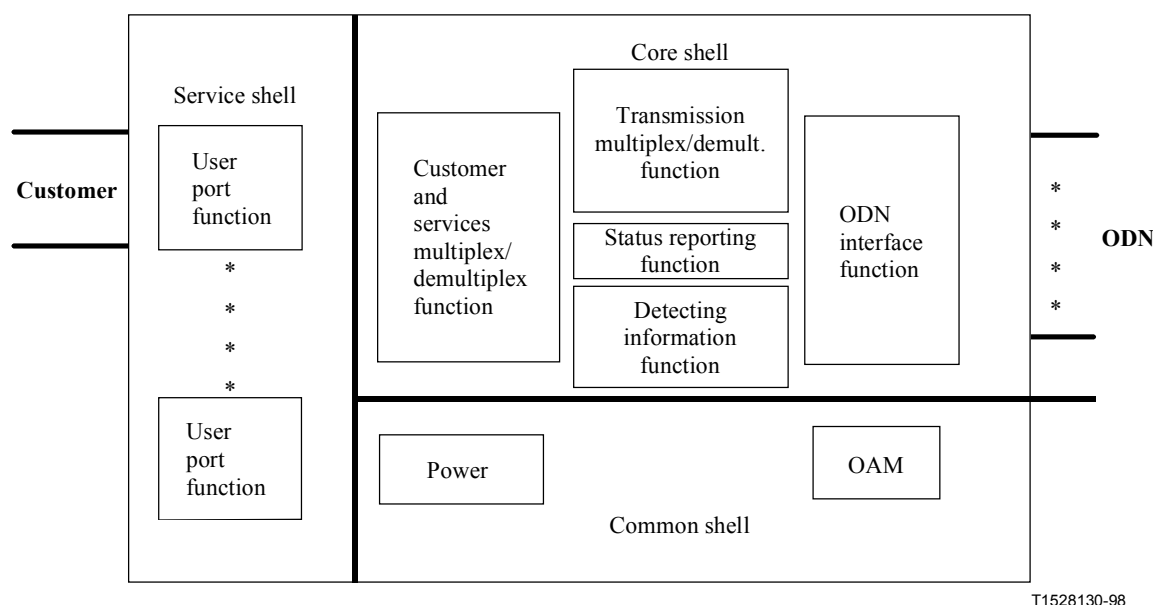


Figure 9/G.983.4 – Example of SR-ONU/ONT functional blocks

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.

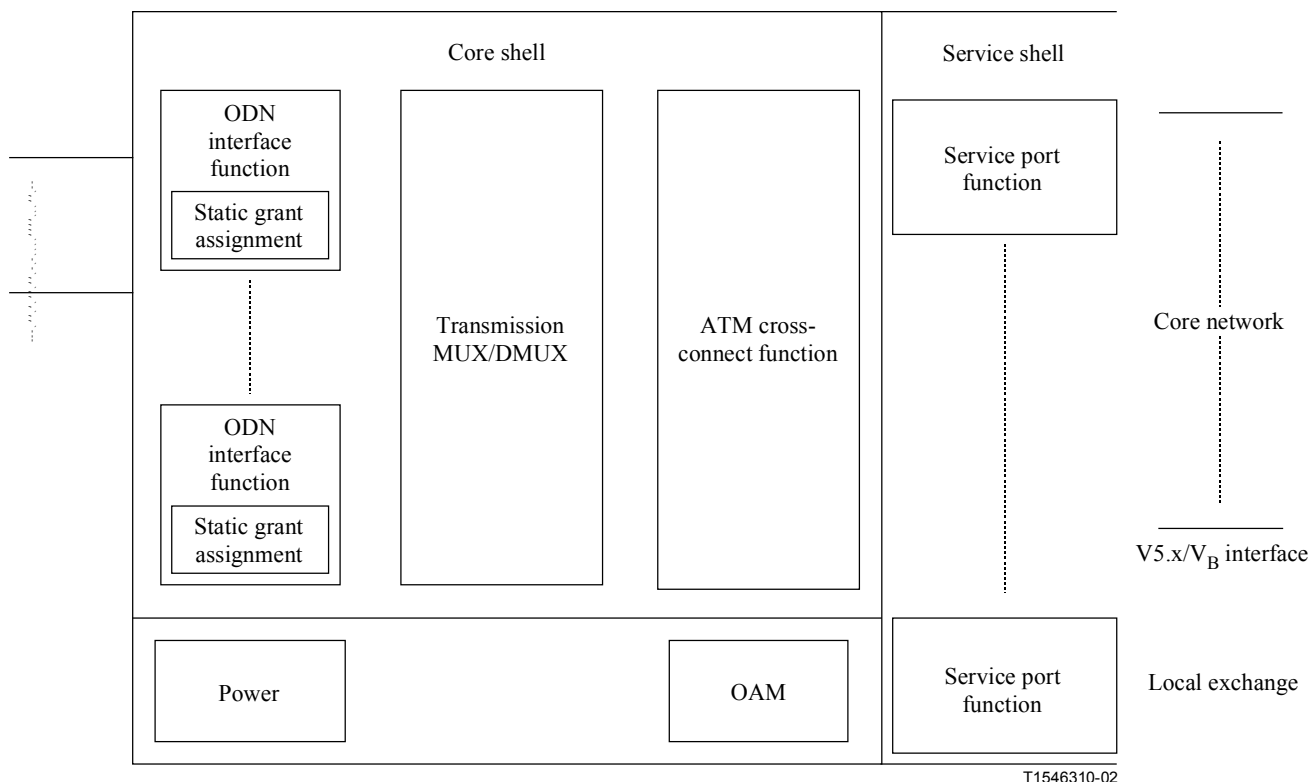


Figure 10/G.983.4 – Example of Non-DBA-OLT functional blocks

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.