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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 enhanced survivability

ITU-T Recommendation G.983.5

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ITU-T Recommendation G.983.5

A broadband optical access system with enhanced survivability

Summary

This Recommendation describes flexible access networks using optical fibre technology based on ITU-T Rec. G.983.1. Specifically, it describes the functions that extend ITU-T Rec. G.983.1 to enable survivability-protection enhancements for the delivery of highly reliable services. It describes B-PON survivability architectures, protection performance criteria, and protection-switching criteria and protocols.

Source

ITU-T Recommendation G.983.5 was prepared by ITU-T Study Group 15 (2001-2004) and approved under the WTSA Resolution 1 procedure on 6 January 2002.

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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ITU-T Recommendation G.983.5

A broadband optical access system with enhanced survivability

1 Scope

This Recommendation describes the extended functions for B-PON systems defined in ITU-T Rec. G.983.1 to enable protection functions. It is based on Appendix IV/G.983.1. In particular, it focuses on the protection-configuration types B and C described in that appendix.

This Recommendation discusses a number of protection feature and function choices and provides the necessary specifications in the PON layer to implement these choices. These include guidelines on performance objectives (for example, switching and detection time), application functionality (for example, revertive mode, non-revertive mode, extra traffic support, automatic switching, and forced switching), switching criteria and switching protocols (1+1, 1:1, 1:N, bidirectional and unidirectional mechanisms).

This Recommendation considers protection enhancements for the delivery of highly reliable services for a variety of B-PON network scenarios, including Fibre to the Cabinet (FTTCab) and Fibre to the Office (FTTO).

2 References

The following ITU-T Recommendations and other references contain provisions, which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; 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.841 (1998), *Types and characteristics of SDH network protection architectures*.
- [5] ITU-T Recommendation G.902 (1995), *Framework recommendation on functional access networks (AN) – Architecture and functions, access types, management and service node aspects*.
- [6] ITU-T Recommendation G.957 (1999), *Optical interfaces for equipment and systems relating to the synchronous digital hierarchy*.
- [7] ITU-T Recommendation G.958 (1994), *Digital line systems based on the synchronous digital hierarchy for use on optical fibre cables*.
- [8] ITU-T Recommendation G.982 (1996), *Optical access networks to support services up to the ISDN primary rates or equivalent bit rates*.
- [9] ITU-T G.983.1 (1998), *Broadband optical access systems based on Passive Optical Networks (PON)*.

- [10] ITU-T G.983.2 (2000), *The ONT management and control interface specification for ATM PON.*
- [11] ITU-T I.321 (1991), *B-ISDN protocol reference model and its application.*
- [12] ITU-T I.326 (1995), *Functional architecture of transport networks based on ATM.*
- [13] ITU-T I.356 (2000), *B-ISDN ATM layer cell transfer performance.*
- [14] ITU-T I.361 (1999), *B-ISDN ATM layer specification.*
- [15] ITU-T I.432.1 (1999), *B-ISDN user-network interface – Physical layer specification: General characteristics.*
- [16] ITU-T I.610 (1999), *B-ISDN operation and maintenance principles and functions.*
- [17] ITU-T I.732 (2000), *Functional characteristics of ATM equipment.*

3 Abbreviations

This Recommendation uses the following abbreviations:

AF	Adaptation Function
APS	Automatic Protection Switching
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
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
FTTO	Fibre to the Office
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
MSP	Multiplex Section Protection
NT	Network Termination
OAM	Operation, 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
SD	Signal Degrade
SDH	Synchronous Digital Hierarchy
SF	Signal Fail
SN	Serial Number
SNI	Service Node Interface
SPC	Service Port Function
TC	Transmission Convergence
TDMA	Time Division Multiple Access
UI	Unit Interval
UNI	User Network Interface
UPC	Usage Parameter Control
UPF	User Port Function
VC	Virtual Channel
VoD	Video on Demand
VP	Virtual Path
VPI	Virtual Path Identifier
WDM	Wavelength Division Multiplexing

4 Definitions

This Recommendation defines the following terms:

4.1 1:1 protection: A system of 1:1 protection configuration carries traffic in the working equipment while the protection equipment stands by without serving any traffic. The 1:1 protection configuration is a special case of the more general 1:N protection where the protection equipment is shared among N sets of working equipment.

4.2 1+1 protection: A system of 1+1 protection configuration carries identical traffic in both working and protection equipment.

4.3 X:N protection architecture: A system of X:N protection architecture offers X protection PONs for N working PONs, where some or all of the protected ONUs on the working PONs can be connected to any of the X protection PONs.

4.4 bidirectional protection: Upon detecting a failure of its working equipment, a system of bidirectional protection configuration requires acknowledgement from the far-end protection equipment before switching to the protection equipment.

4.5 unidirectional protection: A system of unidirectional protection configuration can switch to protection equipment once it detects failure in its working equipment.

4.6 churning: Churning is a function that can be applied to the downstream user data from an OLT to its ONUs. 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 B-PON system and can be activated for point-to-point downstream connections.

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

4.8 extra traffic: Lower priority traffic with respect to that being carried by the working entity. It is carried over the protection entity while the working entity is active. The extra traffic is not protected, i.e. when the protection entity is required to protect the traffic that is being carried over the working entity (due to a failure or forced/manual switch operation), the extra traffic is pre-empted.

4.9 grant: A grant is a short downstream message giving permission to a specific ONU to transmit an upstream cell. The OLT controls the distribution of grants to the ONUs and ensures good use of the upstream channel without data collisions.

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

4.11 non-revertive: A protection configuration is non-revertive if the system does not switch back.

4.12 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.

4.13 Optical Distribution Network (ODN): An ODN provides the optical transmission means from the OLT towards the users, and vice versa. It utilises passive optical components.

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

4.15 Optical Network Termination (ONT): An ONU used for FTTH and includes the User Port function.

4.16 Optical Network Unit (ONU): An ONU provides (directly or remotely) the user-side interface of the OAN, and is connected to the ODN. As far as the protection functions are concerned, ONU and ONT share the same functionality. Thus, only ONU is referenced in this Recommendation for the sake of clarity.

4.17 ranging: It is necessary to transmit an upstream cell without cell collision in this system. Ranging is a function to measure the logical distance between each ONU and OLT and decide the transmission timing when each ONU receives a grant.

4.18 revertive: A protection configuration is revertive if the system automatically switches back to the working equipment after it is repaired or recovered from a failure condition. Therefore, in a revertive protection configuration, the system has fixed working equipment. The protection equipment is used only when the working equipment is out of service.

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

4.20 Time Division Multiple Access (TDMA): Transmission technique involving the multiplexing of many time slots onto the same time payload.

4.21 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 access 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.

4.22 verification: It is possible for a malicious user to masquerade as another ONU and use the network if the user knows that the ONU is powered-off. Verification is a function to check whether the connected ONU is masqueraded by a malicious user.

4.23 Wavelength Division Multiplexing (WDM): Bidirectional multiplexing using different optical wavelength for up and downstream signals.

5 Architecture and requirements for a protected optical access network

5.1 Architecture and requirements

5.1.1 Service categories

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 narrow-band telephone services.
- Reliable services. The access network must be able to provide protection for user traffic that demands high levels of reliability against equipment or facility failures in the network.

5.1.2 Background and requirements

Network configuration is basically satisfied with the type B and type C configurations described in ITU-T Rec. G.983.1. The following items are required for the B-PON survivability architecture:

- Type B protection configuration. In this configuration type (shown in Figure 1), no equipment redundancy is provided in the ONUs. The protection-capable OLT performs switching if its working PON interface fails or its directly connected fibre breaks. G.983.1 compliant ONUs satisfy type B protection configuration without modification.

- Type C protection configuration. In this configuration type (shown in Figures 2 and 3), equipment redundancy is provided in both the OLT and ONUs. The protection-capable OLT performs switching if any PON interface in the OLT or ONUs fails or if any fibre in the ODN breaks. This Recommendation addresses the modifications to ITU-T Rec. G.983.1 necessary to support the type C protection configuration.
- Mixture of protected and unprotected ONUs in type C configuration. The protection functions shall allow a mixture of protected and unprotected ONUs. In certain fault scenarios, the unprotected ONUs may suffer service disruption while the protected ONUs are recovered.
- X:N variant of type C protection configuration. In this variant of configuration type C (shown in Figure 3), equipment redundancy is provided in the OLT (some or all of the Line Terminals (LTs)) and some or all ONUs. This variant allows protected ONUs to be connected to any of the protection LTs, independent of which working LT they belong to. This variant is optional.
- Extra traffic for type C configuration. Extra traffic should be able to be carried over the protection entities while the working entity is active. The extra traffic will not be protected. This option provides effective usage of bandwidth in the protection entities. It must be possible for an operator not to activate this extra traffic option.

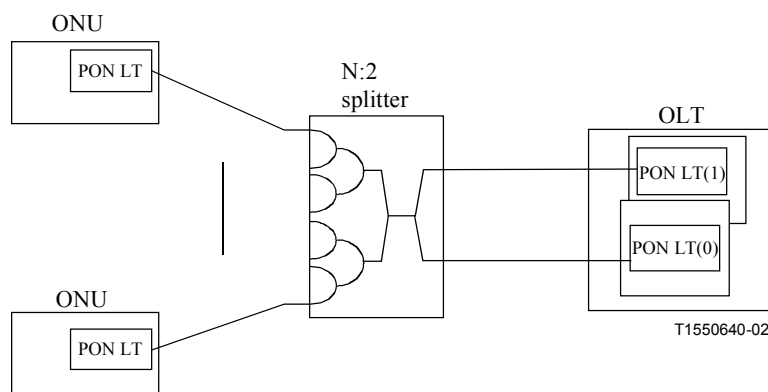


Figure 1/G.983.5 – Type B: OLT-only protected system

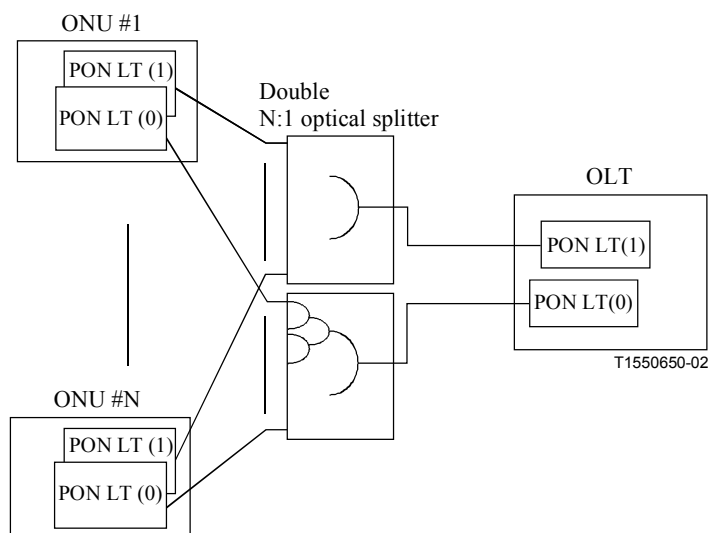


Figure 2/G.983.5 – Type C: Fully protected system, 1:1 and 1+1

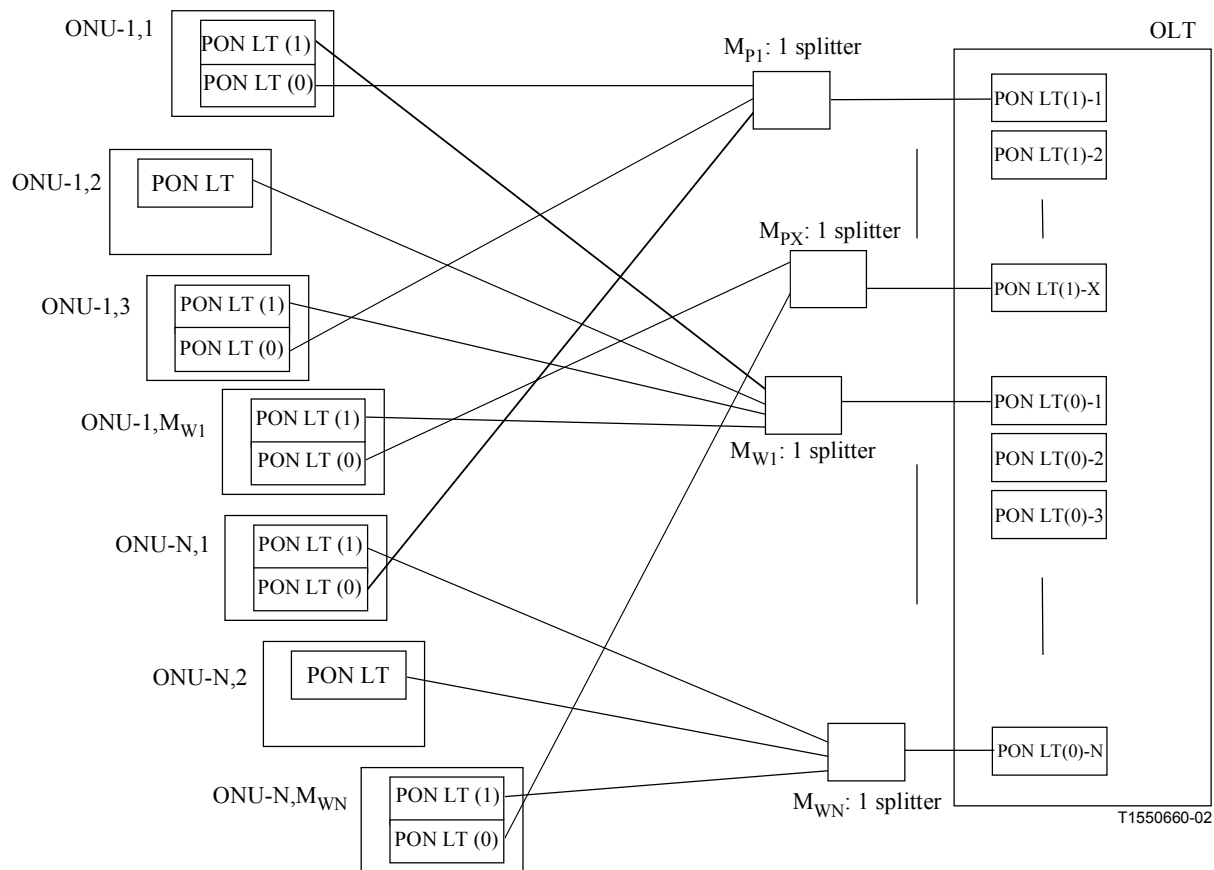


Figure 3/G.983.5 – Type C: X:N protection system

A redundant B-PON system shall satisfy the following requirements:

- It should be possible to have both the type B and type C protection configurations on the same OLT:
 - It should be possible to duplicate the OLT-PON-Interface and the fibres between the OLT and splitter and to duplicate the entire fibre path between the OLT and ONU for a set of ONUs.
 - The two configurations should be available on the same OLT, but not on the same ODN interface.
- It should be possible to have multi-vendor interoperability between OLT and ONU.
- In the type C configuration, it should be possible to have a mixture of protected and unprotected ONUs on one B-PON interface.
- The addition or removal of a protected ONU on a PON should not affect other ONUs on the same PON.
- It should be possible to have automatic switching, which would be triggered by a fault detection such as loss of signal, loss of cell delineation, signal degrade (e.g. BER becomes worse than the pre-determined threshold), etc.
- It should be possible to have forced switching, which would be activated by administrative events such as fiber rerouting, fiber replacement, etc.
- It is necessary to avoid unnecessary switching. Because unstable switching affects service quality, unnecessary protection switching and unnecessary revertive protection switching should not occur.
- It should be possible to realise switching without connection loss of the ATM connections.

- It should be possible for the operator to choose between a revertive and a non-revertive switching mode.
- The service halt time should be less than 50 ms if the extra traffic option is not used.
- The events or conditions that trigger automatic switching should be chosen among the G.983.1 OAM parameters.
- The chosen protocols and mechanisms must apply to the B-PON section layer.
- The type C configuration should be able to support extra traffic:
 - Extra traffic should be carried over the protection entities while the working entity is active and would not be protected. This capability will provide effective usage of bandwidth on the protection entities.
 - This requirement is applicable only for the type C configuration.
 - It must be possible for an operator not to activate the extra traffic option (e.g. to achieve a lower service interruption time).

5.2 Reference configuration

The reference configuration is the same as shown in Figure 2/G.983.1.

5.3 Functional blocks

Functional blocks are the same as described in 5.3/G.983.1.

5.4 ONU functional block

An example of a protected ONT (ONU with User Port Function) is shown in Figure 4. The ONT is active and decouples the access network delivery mechanism from the in-house distribution. The ONT core consists of redundant ODN interfaces, ODN interface switch, User Port, Transmission, Services and Customers Multiplexing (MUX)/demultiplexing functions and powering.

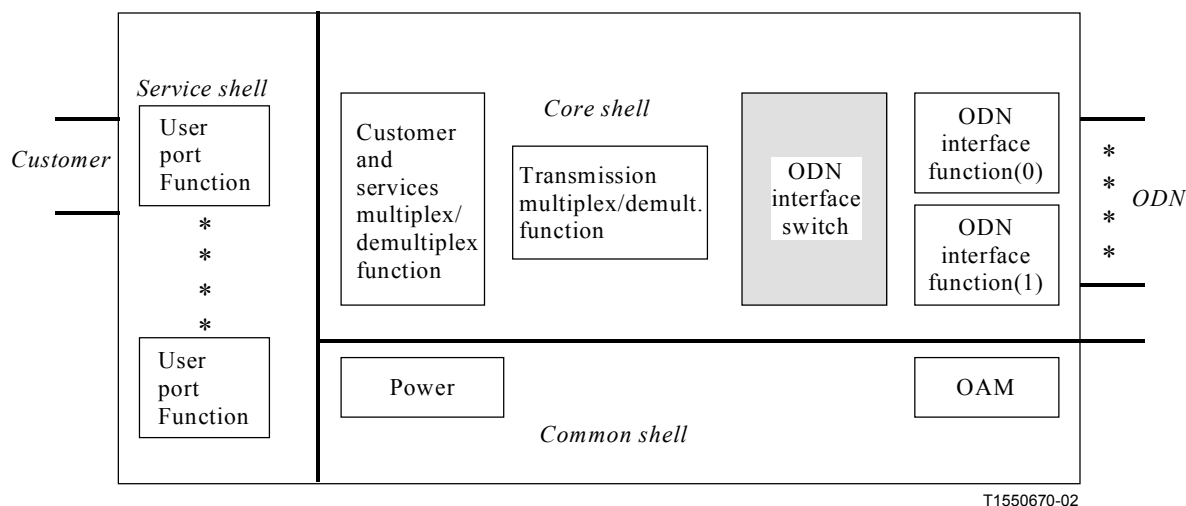


Figure 4/G.983.5 – ONU Functional Blocks

5.4.1 Optical Distribution Network (ODN) interface

The ODN interface handles the opto-electronic conversion process. The ODN interface extracts ATM cells from the downstream PON payload and inserts ATM cells into the upstream PON payload based on synchronisation acquired from the downstream frame timing. There are two ODN interfaces in a protected ONT/ONU.

5.4.2 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.

5.4.3 User Port

The User Port interfaces over the UNI to a user terminal. The User Port handles functions such as inserting ATM cells into the upstream payload and extracting ATM cells from the downstream payload.

5.4.4 ONU Powering

ONU powering may be implementation dependent.

5.4.5 ODN interface switch

The ODN interface switch selects the 'in-service' ODN interface.

5.5 OLT functional block

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

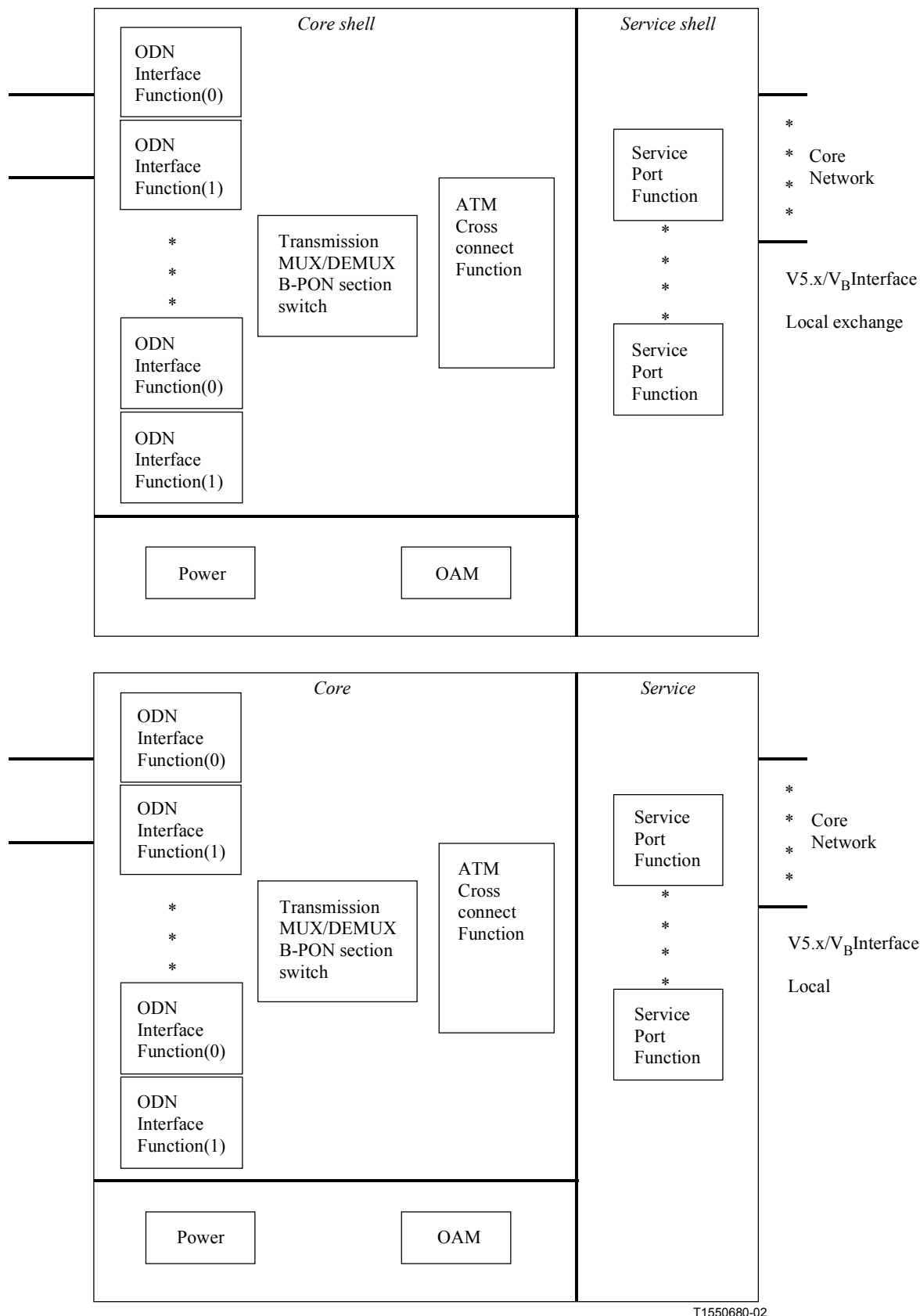


Figure 5/G.983.5 – OLT Functional Blocks

The OLT consists of three parts: the Service Port function, ODN interface and Transmission MUX/DEMUX/B-PON section switch for VP grooming (see Figure 5). (This combination is not intended to preclude the Virtual Channel (VC) layer function in the OLT. As discussed in ITU-T Rec. G.983.1, this function is for further study.)

1) *Service Port function*

Same as in item 1) of 5.5/G.983.1.

2) *The Transmission MUX/DEMUX/B-PON section switch*

This provides VP connections between the Service Port function and the ODN interface and different VPs are assigned to different services at the IF_{PON}. Various information flows such as the main data content, signalling, and OAM cells are exchanged by using VCs of the VP. The transmission MUX/DEMUX/B-PON section switch selects each B-PON section from the redundant ODN interfaces.

3) *ODN interface*

The PON Line Terminal (LT) handles the opto-electronic conversion process. The ODN interface handles such functions as inserting ATM cells into the downstream PON payload and extracting ATM cells from the upstream PON payload. The ODN interface is redundant.

5.6 Optical Distribution Network (ODN) functional block

The ODN functional block is the same as in 5.6/G.983.1.

5.6.1 Passive optical elements

Passive optical elements are the same as in 5.6.1/G.983.1.

5.6.2 Optical interfaces

In the context of the reference configuration, Figure 6 shows the generic physical configuration of an ODN.

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

- downstream direction for signals travelling from the OLT to the ONU(s);
- upstream direction for signals travelling from the ONU(s) to the OLT.

Transmission in downstream and upstream directions can take place on the same fibre and components (duplex/duplex 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 path between one OLT and one or more ONUs. Each optical path is defined between reference points in a specific wavelength window.

The following optical interfaces are defined in Figure 6:

O_{ru} , O_{rd} : optical interface at the reference point R/S between the ONU 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 will require at least two fibres for protected ONUs and OLTs, and may require more than two fibres, 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.

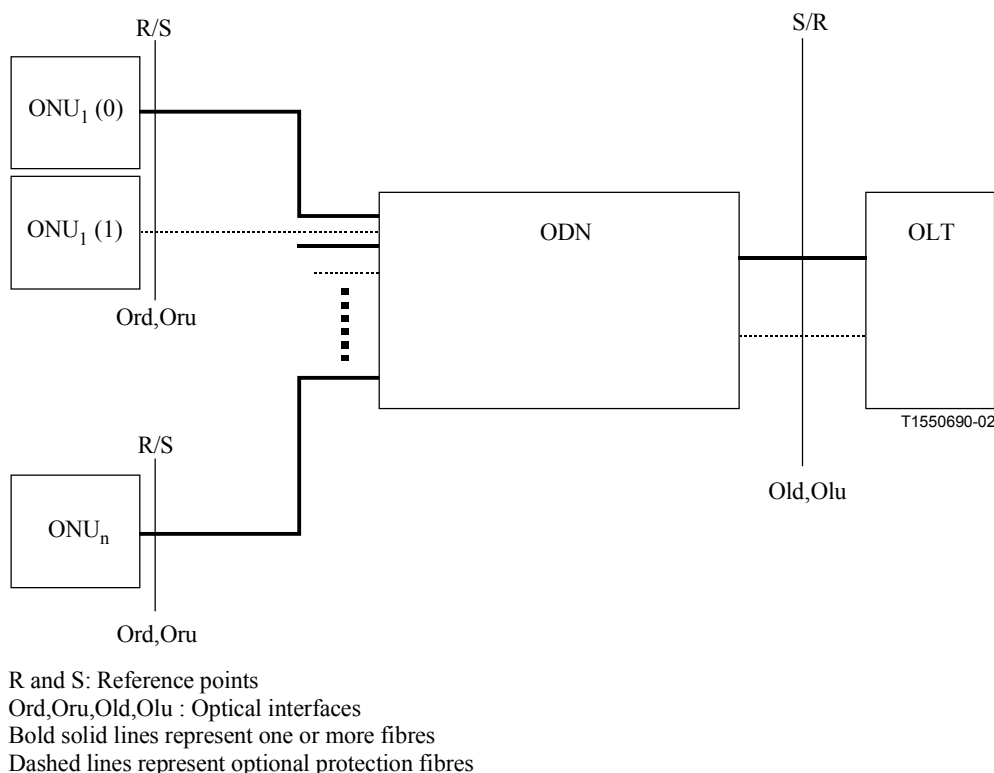


Figure 6/G.983.5 – Generic physical configuration of the Optical Distribution Network

The optical properties of the ODN shall enable the provision 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 which 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.

For the type B ODN configuration, the optical interface for the active/working OLT interface (O_{ld}) is the same as specified in ITU-T Rec. G.983.1. The O_{ld} interface for the inactive/stand-by OLT LT should not be "alight" (i.e. the laser diode should not be active) in order to prevent downstream interference.

For the type C ODN configuration, the optical interfaces at the OLT and ONU are the same as specified in ITU-T Rec. G.983.1.

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.