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

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

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Optical access networks to support services up to the ISDN primary rate or equivalent bit rates

ITU-T Recommendation G.982

(Previously CCITT Recommendation)

ITU-T G-SERIES RECOMMENDATIONS

TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

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ITU-T RECOMMENDATION G.982

OPTICAL ACCESS NETWORKS TO SUPPORT SERVICES UP TO THE ISDN PRIMARY RATE OR EQUIVALENT BIT RATES

Summary

This Recommendation deals with the characteristics of an Optical Access Network (OAN) with the capability of transporting interactive services over the Optical Distribution Network (ODN) based on point-to-multipoint configuration using passive optical branching components.

The Recommendation considers an OAN for both business and residential customer service requirements based on 64 kbit/s bearer capabilities up to and including ISDN primary rate services.

Source

ITU-T Recommendation G.982 was prepared by ITU-T Study Group 15 (1993-1996) and was approved under the WTSC Resolution No. 1 procedure on the 8th of November 1996.

FOREWORD

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The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 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, the ITU had/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.

CONTENTS

Recommendation G.982

OPTICAL ACCESS NETWORKS TO SUPPORT SERVICES UP TO THE ISDN PRIMARY RATE OR EQUIVALENT BIT RATES

(Geneva, 1996)

1 Scope

This Recommendation is intended to describe flexible access networks using optical fibre technology. The intention is to provide for the services of today and also the basis for the future service requirements.

This Recommendation describes the characteristics of an Optical Access Network (OAN) with the capability of transporting interactive services based on 64 kbit/s bearer capabilities between the user-network interface and the network-network interface. The Recommendation considers an OAN for both business and residential customer service requirements up to and including ISDN primary rate services carried over a passive split optical network. Distributive services (e.g. cable TV) are not considered in this Recommendation.

The OAN described in this Recommendation should enable the network operator to provide a flexible upgrade to meet future customer requirements, in particular in the area of the Optical Distribution Network (ODN). The ODN considered is based on the point-to-multipoint tree and branch option.

This Recommendation is based on the Time Division Multiple Access (TDMA) protocol; however, other protocols are not precluded. Systems using both one and two fibres are described. Although examples are quoted, it is not the intention of this Recommendation to preclude further innovation.

The use of optical amplifiers is not excluded within the scope of this Recommendation.

2 References

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

[1] ITU-T Recommendation G.652 (1993), *Characteristics of a single-mode optical fibre cable*.

[2] ITU-T Recommendation G.803 (1993), *Architecture of transport networks based on the Synchronous Digital Hierarchy (SDH).*

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

[4] ITU-T Recommendation G.955 (1996), *Digital line systems based on the 1544 kbit/s and the 2048 kbit/s hierarchy on optical fibre cables*.

[5] ITU-T Recommendation G.957 (1995), *Optical interfaces for equipments and systems relating to the synchronous digital hierarchy*.

[6] ITU-T Recommendation G.964 (1994), *V-interfaces at the digital Local Exchange (LE) – V5.1-interface (based on 2048 kbit/s) for the support of Access Network (AN).*

[7] ITU-T Recommendation G.671 (1996), *Transmission characteristics of passive optical components*.

[8] ITU-T Recommendation M.3010 (1996), *Principles for a telecommunication management network.*

[9] ITU-T Recommendation G.653 (1997), *Characteristics of a dispersion-shifted single-mode optical fibre cable*.

[10] ITU-T Recommendation G.662 (1995), *Generic characteristics of optical fibre amplifier devices and sub-systems.*

3 Abbreviations

This Recommendation uses the following abbreviations:

AF	Adaptation Function
AU	Adaptation Unit
FTTB	Fibre-To-The-Building
FTTC	Fibre-To-The-Curb
FTTH	Fibre-To-The-Home
FTTO	Fibre-To-The-Office
ISDN	Integrated Services Digital Network
MCS	Monte Carlo Simulation
OA	Optical Amplifier
OAM	Operation, Administration and Maintenance
OAN	Optical Access Network
ODN	Optical Distribution Network
OLT	Optical Line Terminal
ONU	Optical Network Unit
OS	Operation System
OTDR	Optical Time Domain Reflectometer
SCM	Sub-Carrier Multiplexing
SCMA	Sub-Carrier Multiple Access
SDH	Synchronous Digital Hierarchy
SDM	Space Division Multiplexing
SNI	Service Node Interface
SPF	Service Port Function
TCM	Time Compression Multiplexing
TDMA	Time Division Multiple Access

TU	Tributary Unit
UNI	User Network Interface
UPF	User Port Function
WDM	Wavelength Division Multiplexing

4 Definitions

This Recommendation defines the following terms:

4.1 passive optical access link: The whole of transmission means between a given network interface (V) and a single user interface (T). The concept of passive optical access link is used in order to allow a functional and procedural description and a definition of the network requirements. The user side and the network side of the access link are not identical and, therefore, the access link is not symmetrical.

4.2 adaptation unit (AU): An AU provides adaptation functions between the Optical Network Unit (ONU) and the user side.

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

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

4.5 differential fibre distance: The difference of distance between the nearest and furthest ONU from the OLT.

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

4.7 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.

4.8 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.

4.9 ODN: An ODN provides the optical transmission means from the OLT towards the users, and vice versa. It utilizes passive optical components.

4.10 OLT: An OLT provides the network-side interface of the OAN, and is connected to one or more ODNs.

4.11 ONU: An ONU provides (directly or remotely) the user-side interface of the OAN, and is connected to the ODN.

4.12 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.

4.13 space division multiplexing: Bidirectional multiplexing using different fibres for upstream and downstream signals.

4.14 sub-carrier multiplexing: Multiplexing multiple electrical frequencies onto a single fibre at a single wavelength to provide an individual frequency to each multipoint-to-point path.

4.15 sub-carrier multiple access: Transmission technique involving the multiplexing of many frequencies onto the same carrier payload.

4.16 simplex working: Communication which uses a different fibre for each direction of transmission.

4.17 time compression multiplexing: Bidirectional multiplexing using different time slots for upstream and downstream signals.

4.18 time division multiplexing: Multiplexing information onto fixed time ranges.

4.19 time division multiple access: Transmission technique involving the multiplexing of many time slots onto the same time payload.

4.20 wavelength division multiplexing: Bidirectional multiplexing using different optical wavelength for upstream and downstream signals.

4.21 tributary unit: Contains one or more service port functions.

4.22 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 protocol.

5 Configuration of an OAN

5.1 Reference configuration

Figure 1 shows the functionality of an OAN; it is service and application independent and includes a Q3 reference interface. Possible applications of an OAN include: Fibre-To-The-Curb (FTTC), Fibre-To-The-Office (FTTO), Fibre-To-The-Building (FTTB) and Fibre-To-The-Home (FTTH).

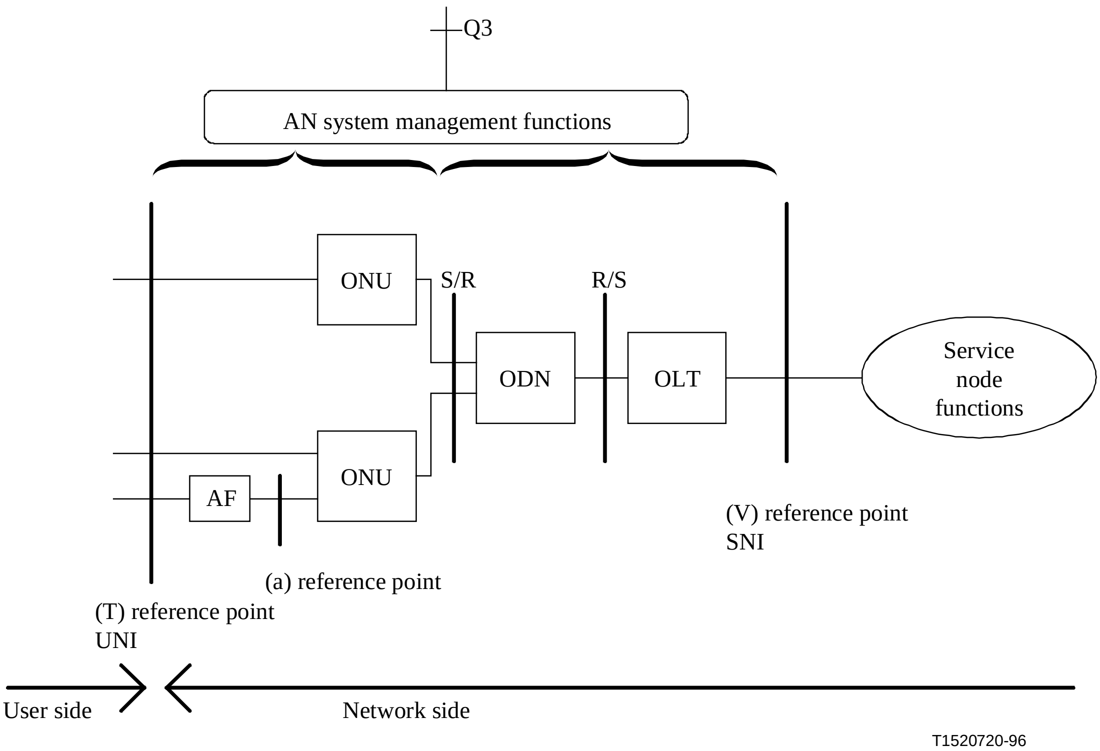


Figure 1/G.982 – Example reference configuration for an OAN

5.2 Functional architecture

An example functional architecture of the OAN in accordance with the principles of Recommendation G.803 is shown in Figure 2. The example is from Recommendation G.902 and refers to the functional requirements of the 64 kbit/s circuit mode oriented service node interface (V5.1 interface) defined in Recommendation G.964 for the case of 2 Mbit/s hierarchy, and a passive optical network.

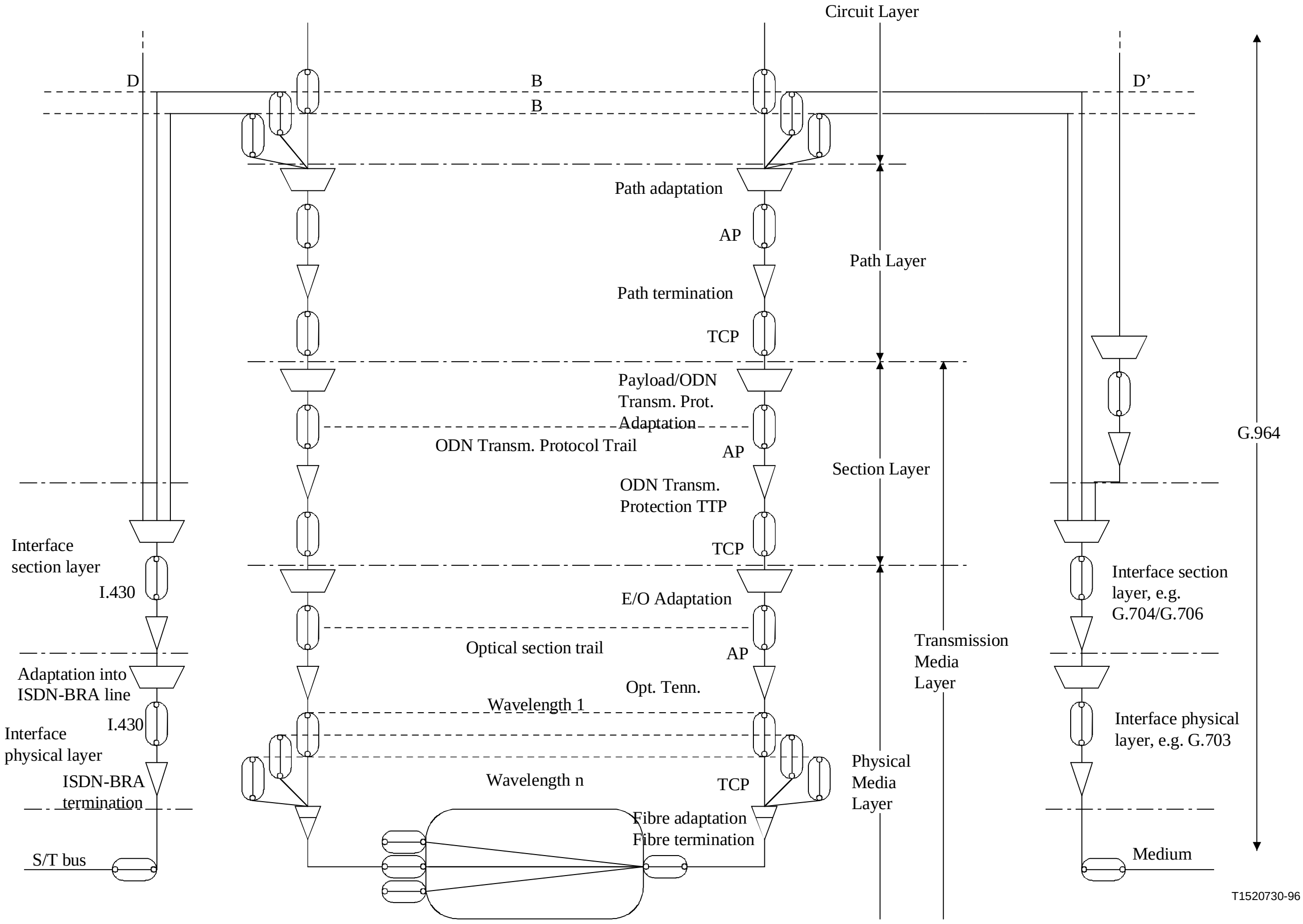


Figure 2/G.982 – Example architecture for the OAN (from Recommendation G.902)

6 Fibre type

Single-mode fibre should be used in accordance with Recommendation G.652.

7 Transmission methodology

The transmission method shall allow the OLT to ONU connection to be a point-to-multipoint ODN and a point-to-point ODN. Specific optimized point-to-point systems are outside the scope of this Recommendation.

The multiple access method may be based on a TDMA transmission method. Other transmission methods such as Sub-Carrier Multiple Access (SCMA) are not precluded. Bidirectional transmission schemes may be based on one of the following:

– Space Division Multiplexing (SDM) (2 fibres, simplex)

  The operating wavelength range shall be within the 1310 nm region.

– Time Compression Multiplexing (TCM) (1 fibre, half duplex)

  The operating wavelength range shall be within the 1310 nm region.

– Wavelength Division Multiplexing (WDM) (1 fibre, diplex)

  The operating wavelength range for upstream direction (ONU to OLT) shall be within the 1310 nm region.

  The operating wavelength range for downstream direction (OLT to ONU) may be within the 1310 nm region or 1550 nm region.

– Sub-Carrier Multiplexing (SCM) (1 fibre)

  The operating wavelength range shall be within the 1310 nm or 1550 nm regions.

NOTE – The use of the 1550 nm region for future services is for further study.

8 Wavelength allocation

The operating wavelengths used in the ODN shall be in the 1310 nm (2nd) window and the 1550 nm (3rd) window. A survey of some possibilities for wavelength allocation in case of interactive services is given in Appendix II.

NOTE – Transmission of testing and monitoring signals at other wavelengths may be used, but these are considered to be outside the scope of this Recommendation.

8.1 Wavelength range for the 1310 nm region

The operating wavelength range for the 1310 nm wavelength region shall be 1260-1360 nm.

NOTE – If OAs are used, a narrower wavelength range may be considered.

8.2 Wavelength range for the 1550 nm region

The operating wavelength range for the 1550 nm wavelength region shall be 1480-1580 nm.

NOTE – If OAs are used, a narrower wavelength range may be considered.

9 OAN system specification

9.1 OAN capacity and ONU classes

The recommended OAN and ONU capacities and classes are described in Table 1.

Table 1/G.982 – OAN capacity and ONU classes

Parameter	Type 1 (e.g. SDM and WDM)	Type 2 (e.g. TCM)
OAN capacity	At least four ODN interfaces with a total capacity of at least 800B. Each ODN interface at least 200B.	At least four ODN interfaces with a total capacity of at least 800B. Each ODN interface at least 100B.
ONU classes (Note)	Class 1: at least 2B Class 2: at least 32B Class 3: at least 64B	Class 1: at least 2B Class 2: at least 32B Class 3: at least 64B
NOTE – Three types of ONU may be applied according to the network topologies. For example, the Class 1, the Class 2 and the Class 3 ONU may be applied for FTTH, FTTC and FTTO/FTTB. The classes of ONU are defined by the maximum throughput required at the customer side of the ONU. This is defined in terms of the usable B-channels (where B is a 64 kbit/s bearer channel). Control and signalling channels are not generally included except where carried within the bearer channels (e.g. ISDN-PRA).		

9.2 Logical reach limitation

The logical reach in excess of 20 km is not within the scope of this Recommendation.

The recommended logical reach values are distinguished by system types and splitting ratios and are shown in Table 2.

Table 2/G.982 – Recommended logical reach limitations

Distance	OAN system type 1	OAN system type 2
20 km	A split ratio of at least 16 way shall be supported	A split ratio of at least 8 way shall be supported
10 km	A split ratio of at least 32 way shall be supported	A split ratio of at least 16 way shall be supported

All distances quoted in Table 2 refer to fibre kilometres.

Knowledge of the difference of differential fibre distance may be required for the system design. This does not limit future innovation but may provide flexibility in initial systems. The OAN system must be capable of operating over an ODN such that the differential fibre distance is anywhere between 0 km and at least 5 km.

NOTE – If the OAN system will not provide service to ONUs when the differential fibre distance is 4.5 km, then the system does not meet this Recommendation. However, if the OAN system will provide service to ONUs when the differential fibre distance is 5.1 km, 10 km or 20 km (i.e. greater than or equal to 5 km), then the system meets the Recommendation.

9.3 ONU functional specification

The ONU provides an optical interface towards the ODN and implements the interfaces at the customer side of the OAN. ONUs shall be located on the customer's premises (FTTH, FTTO, FTTB) or in the field (FTTC). The ONU provides the means necessary for delivering the different services that are to be handled by the system. The ONU functional block diagram is shown in Figure 3.

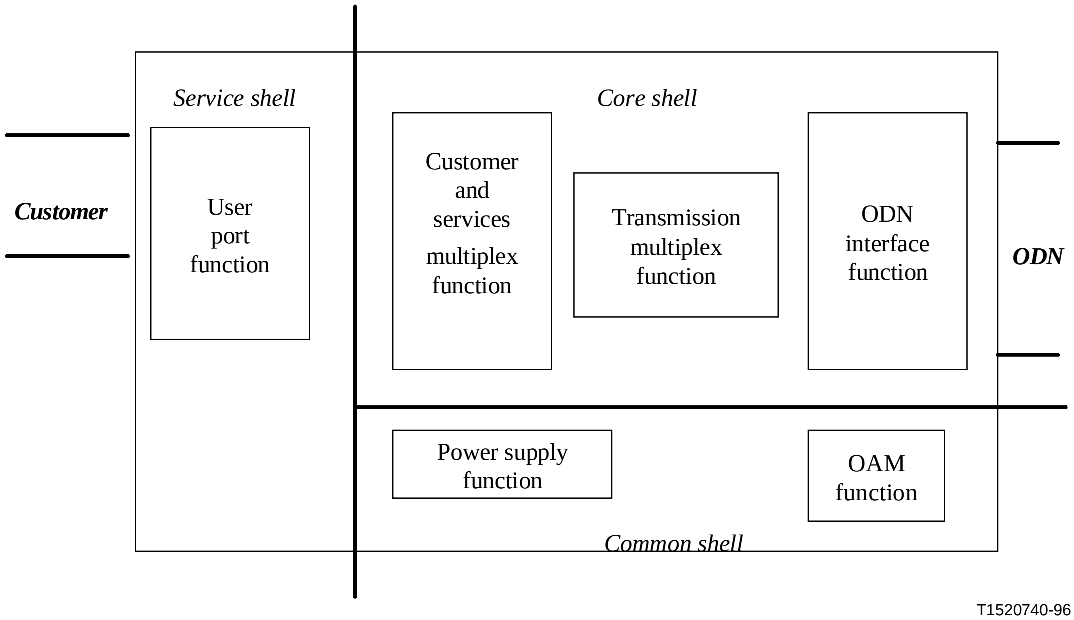


Figure 3/G.982 – ONU functional blocks

An ONU can be considered in three parts, defined as the core, service and common shells. Their functionalities are described in the following subsections.

9.3.1 ONU core shell

The ONU core shell includes:

i) customer and services multiplex function;

ii) transmission multiplex function;

iii) ODN interface function.

The transmission multiplex function provides the necessary functions for evaluation and allocation of the incoming and outgoing signals from and to the ODN interface function extracting and inputting the information relevant to this ONU. The customer and service multiplex function assembles/disassembles the information from/to the different subscribers and connects the individual service interface functions. The ODN interface function provides a set of optical physical interface functions terminating the relevant set of optical fibres of the ODN. It includes optical/electrical and electrical/optical conversion.

NOTE – More than one physical interface can exist if more than one fibre is used per ONU, for instance for simplex operation.

9.3.2 ONU service shell

The ONU service shell provides the user port functions.

The user port functions provide the customer service interfaces and their adaptation into 64 or n × 64 kbit/s. The function can be provided for a single customer or a group of customers. It also provides signalling conversion functions according to the physical interface (e.g. ringing, signalling, A/D and D/A conversions).

9.3.3 ONU common shell

The ONU common shell includes power supply and OAM functions.

The power supply function provides the powering to the ONU (e.g. AC to DC or DC to DC conversion). Power shall be provided locally (from mains) or remotely. The power supply may be shared by several ONUs. The ONU shall be capable of operating via a battery back-up source.

The OAM function provides the means to handle the operations administration and maintenance functionality to all blocks of the ONU (e.g. control of loopbacks in the different blocks).

9.4 OLT functional specification

The Optical Line Terminal (OLT) provides an optical interface towards the Optical Distribution Network (ODN) and provides at least one network interface on the network side of the OAN. The OLT can be co-located within a local exchange or at a remote location. It comprises the means necessary for delivering different services to the required ONUs. The OLT functional block diagram is shown in Figure 4.

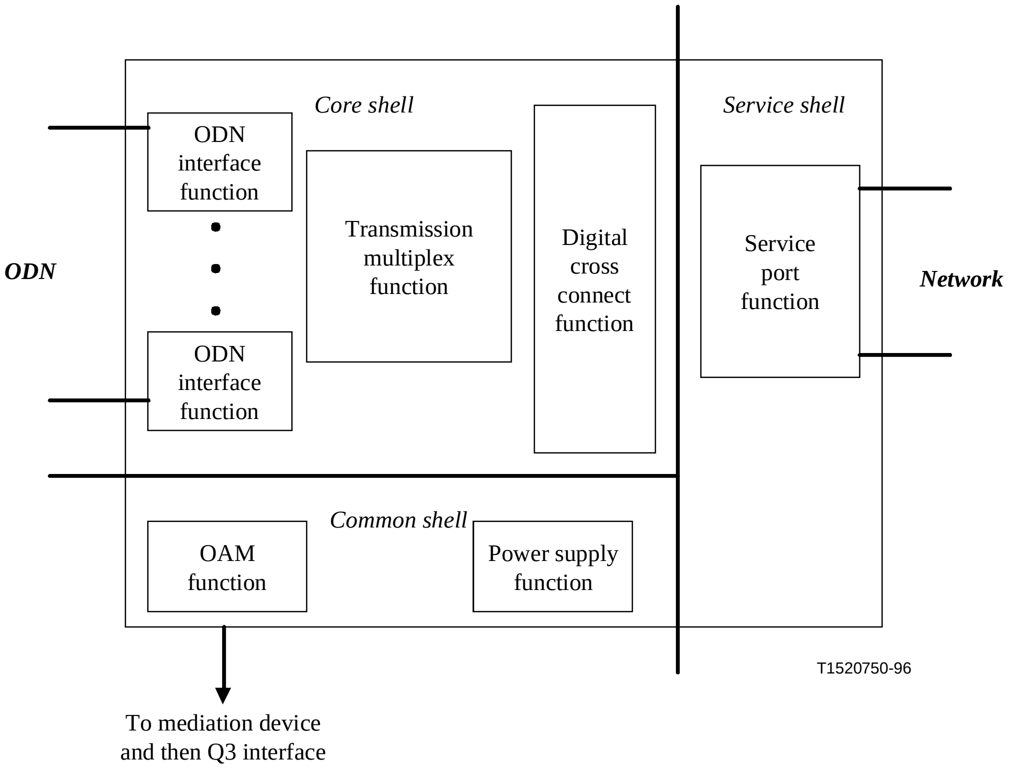


Figure 4/G.982 – OLT functional blocks

An OLT can be considered in three parts, defined as the core, service and common shells. Their functionalities are described in the following subclauses.

9.4.1 OLT core shell

The OLT core shell can include:

i) digital cross connect functions;

ii) transmission multiplex function;

iii) ODN interface function.

The transmission multiplex function provides the necessary functions for transmitting or receiving service channels over the ODN. The digital cross connect function provides connectivity between the available bandwidth at the ODN side and the Network parts at the network side. The ODN interface function provides a set of physical optical interface functions terminating the relevant set(s) of optical fibres of the ODN(s). It includes optical/electrical and electrical/optical conversion. In order to enable implementation of protection switching between geographically redundant routes up to a flexibility point in the ODN where optical fibre splitting occurs, the OAN system should provide the possibility of optionally equipping the OLT with a duplicate ODN interface. This is in addition to the maximum number of ODNs that the OLT is designed for normal operation. Detailed characteristics of possible protection mechanisms are not considered in this Recommendation.

NOTE – More than one physical interface can exist if more than one fibre is used per ODN, for instance for simplex operation.

9.4.2 OLT service shell

The OLT service shell includes service port functions. Service ports shall carry at least ISDN primary rate and shall be configurable to one of a number of services, or capable of simultaneously supporting two or more different services. Any TU that provides two or more 2 Mbit/s ports shall be independently configurable on a per-port basis. For this type of multi-port TU, it shall be possible to configure each port to a different service. Each TU position in the OLT equipment shall be capable of accepting a TU of any type. The OLT shall be able to support any number of TUs up to the designed maximum number in any combination of service types.

9.4.3 OLT common shell

The OLT common shell can include power supply and OAM functions.

The power supply function converts an external power source to the required level. OAM function provides the means to handle the operation, administration and maintenance functionality to all blocks of the OLT. It also provides an interface function. For local control, an interface may be provided for testing purposes and Q3 interface for access networks towards the OS via a mediation function.

9.5 Operation, Administration and Maintenance (OAM) functionality

A framework has been used which consists of two axes along which the OAM functions can be classified. The first axis consists of the functional subsystem of the OAN to which the OAM function relates. The second axis is the OAM functional category.

The following functional subsystems fulfil the OAM requirements:

1) Equipment (Enclosure and power);
2) Transmission;
3) Optical Subsystem;
4) Service Subsystem.

OAM requirements by functional category can be defined by the five categories according to M.3010:

a) Configuration management;
b) Performance management;
c) Fault management;
d) Security management;
e) Accounting management: out of scope.

For passive optical access networks, these categories are described further in Appendix III.

10 UNI and SNI interfaces

The information required in this area is summarized in Recommendation G.902.

11 ODN functional requirements

In general, the Optical Distribution Network (ODN) provides the optical transmission medium for the physical connection of the ONUs to the OLTs.

Individual ODNs may be combined and extended through the use of optical amplifiers. Appendix I provides a possible use of optical amplifiers within ODNs.

11.1 Passive optical elements

The ODN consists of passive optical elements:

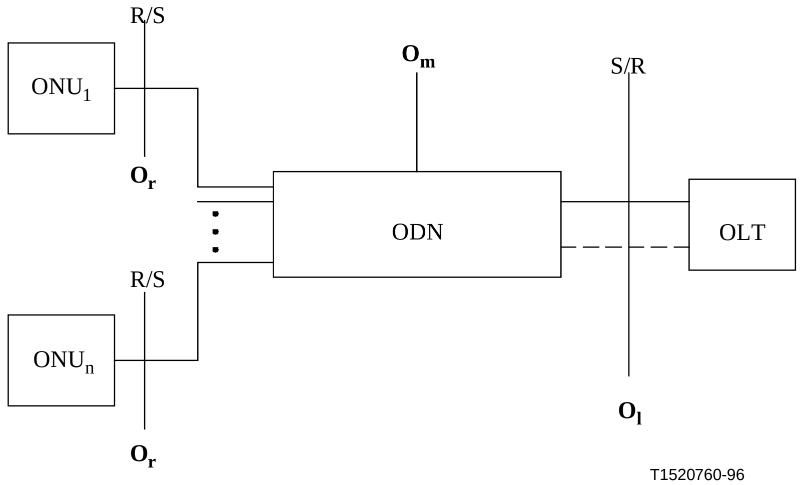
- single-mode optical fibres and cables;
- optical fibre ribbons and ribbon cables;
- optical connectors;
- passive branching components;
- passive optical attenuators;
- splices.

The specific information required to describe passive optical components is described in Recommendation G.671.

The specific information required to describe optical fibres and cable is described in Recommendation G.652.

11.2 ODN model

Figure 5 shows the generic physical configuration of an ODN.



R/S Reference point

O_r, O_1 and O_m Optical interfaces

Bold solid lines represent one or more fibres.
Dashed lines represent protection fibres.

Figure 5/G.982 – Generic physical configuration of the Optical Distribution Network

NOTE – In Figure 5, each line linking any two optical blocks may represent one or more fibres.

The ODN is defined between the reference points S and R. In analogy with the definitions provided in Recommendations G.955 and G.957, S and R are defined here, as follows:

– S: Point on the optical fibre just after the OLT[a]/ONU[b] optical connection point (i.e. optical connector or optical splice).

– R: Point on the optical fibre just before the ONU[a]/OLT[b] optical connection point (i.e. optical connector or optical splice).

NOTE – These optical connection points are not part of the ODN.

Definition [a] holds when considering optical signals travelling from the OLT(s) to the ONUs; definition [b] holds when considering optical signals travelling from the ONUs to the OLT(s).

Depending on the physical realization of the ODN, the points S and R at each end of the ODN may be located either on the same fibre (i.e. they coincide) or on separate fibres.

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

At the physical layer, the interfaces O_r and O_l may require more than one fibre, e.g. for separation of transmission directions or different types of signals (services). The interface O_m may be physically located at several points in the ODN, and may be implemented both with dedicated fibres and network fibres carrying traffic.

Specification of the optical interfaces defined above is for further study.

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 Recommendation G.652.

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/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.

11.2.1 ODN model loss calculations

Loss allowance for the optical power budget is defined as the loss, in dB, between reference points, S/R and R/S, of the ODN. This includes the loss due to fibre length and passive optical components (e.g. optical branching devices, splices and connectors). The loss allowance has the same value both in the downstream and upstream direction.

The following parameters are important for the overall system performance:

– maximum difference of loss between the optical paths of the ODN;

– maximum allowable path loss, defined as the difference between minimum transmitter output power and maximum receiver sensitivity, both under End Of Life conditions (including variations due to temperature, ageing, etc.);

– minimum allowable loss, defined as the difference between maximum transmitter output power and minimum receiver overload, both under End Of Life conditions.

These maximum and minimum losses shall be defined over the required environmental and wavelength ranges and not just measured at a given wavelength, given time and at a given temperature.

These definitions are analogous to Recommendation G.957, where the attenuation ranges for SDH optical interfaces are specified.

Figure 6 gives a schematic representation of the downstream optical path between the OLT and a specific ONU.

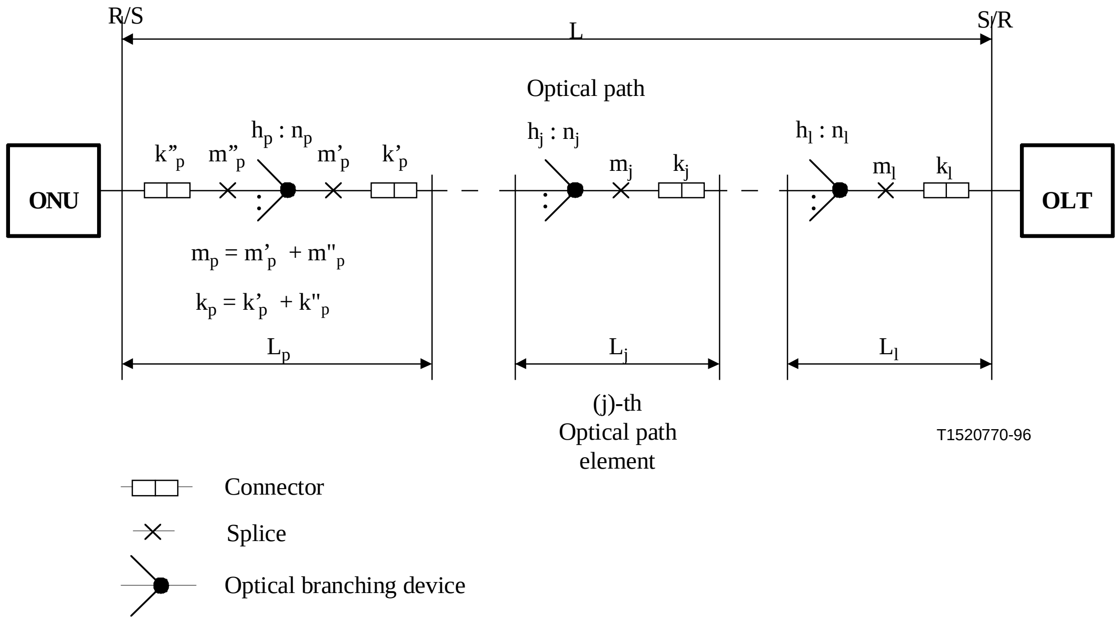


Figure 6/G.982 – Schematic representation of the optical path between the OLT and the ONU

The ODN is constituted by *P* splitting levels, even though 1 or 2 splitting levels are typically adopted. Within the ODN, several optical paths can be identified. Each optical path connects a specific ONU to the OLT. Optical path between the OLT and ONU, or more generally, between reference points S/R and R/S, is formed by a cascade of *P* optical path elements. The *P*-th splitting level is shown as a cascade of P optical path elements. The (*j*)-th optical path element begins at the output port of the (j–1)-th optical branching device and ends at the output port of the (*j*)-th optical branching device, with the following exceptions:

– $j = 1$, the optical path element begins at the S/R reference point and ends at the output port of the first optical branching device (or, for $P = j = 1$, at the R/S reference point).

– $j = P$, the optical path element begins at the output port of the (P–1)-th optical branching device (or, for $P = j = 1$, the S/R reference point) and ends at the R/S reference point, in order to take into account possible splices and connectors present at the output after the last optical branching device.

The (*j*)-th optical path element consists of optical fibre of length L_j and of the following passive optical components (the sequence of components in each path element is arbitrary):

– the (*j*)-th optical branching device with splitting ratio h_j:n_j ($h_j \geq 1$, $n_j \geq 1$);

– k_j connectors, with $k_j \geq 0$;

– m_j splices, with:

$$m_j = \overline{m}_{dj} L_j + \overline{m}_{rj} L_j + m_{aj}$$

where:

$\overline{m}_{dj}$ is the average number of planned splices per unit length of fibre in the first installation phase

$\overline{m}_{rj}$ is the average number of repair splices per unit length of fibre, foreseen in the operational phase

m_{aj} is the number of additional planned splices, not taken into account in the figure $\overline{m}_{dj} L_j$, in the first installation phase; m_{aj} takes into account the splices due to the installation of the optical branching device and the extra splices at the termination points of the ODN (e.g. at an optical distribution frame inside the central office, at the optical termination point at ONU side).

In conclusion, the whole optical path consists of optical fibre of length $L = \sum_{j=1}^{p} L_j$ and of the following passive optical components:

– P = number of optical branching devices, with splitting ratio h_j:n_j ($h_j \geq 1$, $n_j \geq 1$, $j = 1, ..., P$);

– $k = \sum_{j=1}^{p} k_j$ connectors;

– $m = \sum_{j=1}^{p} m_j$ splices.

The overall splitting ratio of the optical path is: $n = \prod_{j=1}^{p} n_j$.

NOTE – In the case of a point-to-point ODN configuration, there is no optical branching device along the optical path. Consequently, only one optical path element is considered, and the previous evaluations are valid simply excluding any reference to the optical branching device.

11.2.2 ODN model loss calculation technique

Appropriate optical loss ranges can be calculated for different optical paths using various calculation methods.

The optical loss of an optical path of an ODN is calculated by adding the losses of all optical components along the optical path. A statistical approach can be used in the summation in order to avoid over-specification of the ODN. The statistical distribution of the overall optical path loss can be obtained by combining the statistical distributions of losses of the various components of the optical path; this can be done using various statistical techniques, some being more accurate than others. These techniques are described in Appendix IV.

11.3 Classes for optical path loss

Recommended classes for optical path loss are shown in Table 3.

Table 3/G.982 – Classes for optical path loss

	Class A	**Class B**	**Class C**
Minimum loss	5 dB	10 dB	15 dB
Maximum loss	20 dB	25 dB	30 dB
NOTE – The requirements of a particular class may be more stringent for one system type than for another, e.g. the class C attenuation range is inherently more stringent for TCM systems due to the use of a 1:2 splitter/combiner at each side of the ODN, each having a loss of about 3 dB.			

Additional classes are for further study. For single-star architectures, the absence of optical branching devices may result in optical path losses of less than 5 dB.

11.4 Reflectance in ODNs

The reflectance of an ODN depends on the return loss characteristics of the individual components along the optical path and on any reflection points existing in the ODN.

In order to accommodate the different needs of all current and future applications in the OAN, all discrete reflectances between reference points S and R, including unused branches of branching devices, shall exhibit a reflectance better than –35 dB. A maximum discrete reflectance of –50 dB is recommended for fusion splices. This reflectance level shall not be exceeded during normal and maintenance modes. In case of maintenance mode, it shall be allowed to use an additional reflection control function.

NOTE – For emissions with a constant power level, the reflectance due to backscattering from single-mode fibre is lower than –33 dB after some kilometres length. For systems using bit rates higher than a few Mbit/s, the backscattered information in the fibre can be considered as information with constant power level, due to a phase cancellation effect.

11.5 Chromatic dispersion

The chromatic dispersion coefficients are specified in Recommendation G.652 for the 1310 nm and 1550 nm wavelength regions of standard single-mode fibre. For dispersion limitations of single-mode fibre systems, the maximum values of chromatic dispersion coefficients shall be used.

12 Maximum signal transfer delay

A maximum of 1.5 ms is recommended for the mean signal transfer delay between "V" and "T" for fibre-to-the-home applications.

A maximum of 1.5 ms is recommended for the mean signal transfer delay between "V" and "a" for other applications.

Optical transmission delay in fibre is approximately 5 ns/m.

13 Environmental conditions

The conditions of IEC 721-3-1 are recommended.

The conditions of IEC 801-2 and 801-3 for electromagnetic compatibility are recommended.

14 Safety

14.1 Electrical safety and protection

The electrical safety aspects for the ONU equipment is for further study.

14.2 Optical safety and protection

IEC 825-1 (1993) defines the following safety classes:

– Class 1, regarded as inherently safe;

– Class 3A, safe with viewing aids.

The conditions defined in these classes are recommended. The limits defined in IEC 825-2, for locations with unrestricted access, shall not be exceeded.

APPENDIX I

Optical amplifiers (OAs) for OANs

To increase the optical power budget, OAs can be used in OANs, both as line amplifiers and as booster amplifiers (also called post or power amplifiers) either as stand-alone devices or integrated subsystems. In principle, OAs can also be used as pre-amplifiers, either as stand-alone devices or integrated subsystems, before the ONU, even if economic considerations generally discourage such an approach. Figure I.1 shows examples of the insertion of OA devices in an OAN.

NOTE – The use of OAs is considered here only in the downstream direction. The use of OAs in both upstream and downstream directions is under study.

General information concerning OA applications are given in Recommendations G.662 and G.663.

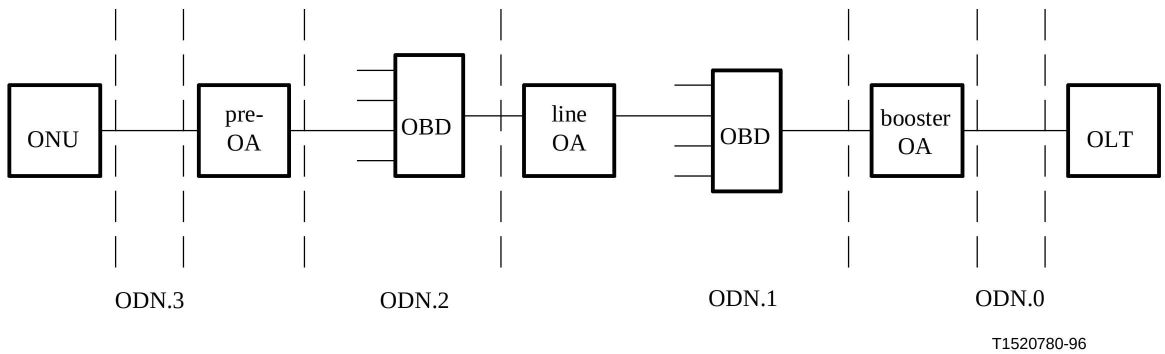


Figure I.1/G.982 – Example of insertion of OA devices in an OAN

The introduction of OAs within the OAN follows the rules given below:

– If an OA subsystem is used as a booster amplifier, it will be considered as a part of the OLT.

– If an OA subsystem is used as a pre-amplifier, it will be considered as a part of the ONU.

– If only one OA device (booster amplifier, pre-amplifier or line amplifier) is used, an ODN.0 will be considered between the OLT and the OA device and an ODN.1 will be considered between the OA device and the ONUs.

– More generally, if *n* OA devices (booster amplifiers, pre-amplifiers or line amplifiers) are cascaded along one path, an ODN.0 will be considered between the OLT and the first OA device, an ODN.i will be considered between the i-th OA device and the (*i*+1)-th OA device (for i = 1, 2, ..., *n*–1), and an ODN.n (ODN level n) will be considered between the last OA device along the path and the ONUs (see Figure I.1 for an example with *n* = 3).

Suitable R and S reference points will be introduced.

NOTE 1 – Specification of the additional R and S reference points and optical interfaces for OAs is for further study.

NOTE 2 – The use of OAs will influence the operating wavelength range of the OAN, as stated in clause 8.

NOTE 3 – The use of G.653 fibres is under study in conjunction with optical amplifiers.

APPENDIX II

Survey of possible wavelength allocation for interactive services

Table II.1 depicts a survey of some possibilities for the transmission of narrow-band interactive services.

Table II.1/G.982 – Transmission of narrow-band interactive services

Bidirectional transmission scheme	Number of fibres	Wavelength region	Transmission scheme implementation	Future implementations
Simplex	2	1310 nm upstream 1310 nm downstream	SDM	
Duplex	1	1310 nm upstream 1310 nm downstream	TCM	
Diplex	1	1310 nm upstream 1550 nm downstream	WDM	1310 + x nm upstream 1310 – x nm downstream

APPENDIX III

OAM functionality

The following text describes the details of OAM functional categories for passive optical networks.

III.1 Configuration management

Configuration management relates to the topology of the resources within the OAN and detailed structure of the system. Configuration management is responsible for the provision, modification and cessation of capabilities within the system.

The functions in configuration management include:

1) *Equipment*
   a) Support of simple and convenient working practices.
   b) Configuration of internal components.
   c) Configuration of duplicated components.

2) *Transmission*
   a) Configuration of bandwidth allocation between the OLT and ONUs.
   b) Initialization of ONUs.
   c) Maintenance of an inventory and status of ONUs.
   d) Cross-connection at the OLT.
   e) Reconfiguration for loopback tests.

3) *Optical subsystem*
   a) Possible support of identification of OANs by clip-on optical power meters.
   b) Switching of OTDRs between OANs if required.

4) *Service subsystems*

a) Reconfiguration for line tests (Note 1).

b) Reconfiguration for loopback tests.

c) Configuration of indication of line cards in ONUs.

d) Upgrading of line cards in ONUs and of exchange interface at the OLT.

e) Reprovisioning through the use of spare line circuits in ONUs (Note 1).

NOTE 1 – The functions a) and e) are optional in the case of FTTH.

III.2 Performance management

Ongoing monitoring of the system may be required and include automatic routine testing of the system. Passive monitoring of the system acts to supplement alarms by providing status information and can also initiate alarms. Testing functions are used for detection of fault location and are included in fault management.

The functions in performance management include:

1) *Equipment*

a) Monitoring of condition of power supplier.

b) Environmental monitoring.

2) *Transmission*

a) Error monitoring.

b) Monitoring of ranging delays where applicable.

3) *Optical subsystem*

– Monitoring of OAN degradation.

4) *Service subsystems*

a) Monitoring of exchange interface at the OLT.

b) Monitoring of the lines at the ONUs.

III.3 Fault management

Alarms are raised to give notice of events which can jeopardize service. There are different degrees of priority and urgency of these alarms.

The most common response to an alarm is an attempt to locate the fault through testing functions. Alarms are incorporated into a strategy of scheduled preventative maintenance which reduces crisis management associated with high priority alarms.

Issues of the alarm priority and masking of alarms to prevent the swamping of the network management layer are relevant to all functional subsystems. Other functions for discussion for fault management include:

1) *Equipment*

a) Surveillance of fault location alarms of components.

b) Surveillance of power source failure.

c) Surveillance of environmental alarms at the ONUs if required.

2) *Transmission*

a) Surveillance of loss of communication with an ONU.

b) Surveillance of failure of transmission system at the OLT.

c) Surveillance of excessive errors.

d) Diagnostic testing of transmission section layer.

3) *Optical subsystem*

a) Fault and OAN degradation discovering by routine testing.

b) Detection of fault location on the OAN by testing.

4) *Service subsystems*

a) Surveillance of exchange interface alarms at the OLT.

b) Testing of the exchange interface at the OLT.

c) Testing of the line at the ONUs.

d) Loopback testing of service capability.

III.4 Security management

Security management relates to the integrity of the data in the system and fallback arrangements. This category also relates to who or what can access to the system and its resources. Functions in this category include:

1) *Equipment*

– Prevention of unauthorized access to the equipment.

2) *Transmission*

a) Detection of access to the system by unauthorized ONUs.

b) Security of transmission between the OLT and ONUs.

3) *Optical subsystem*

– Detection of unauthorized tapping of optical signals.

APPENDIX IV

Optical loss calculation techniques

IV.1 Gaussian statistical approach

The following example refers to a Gaussian statistical approach which, although simple. will introduce some errors.

The upper and lower limits of optical path losses are derived in this example, respectively, by subtracting from or adding to the mean value of the resulting distribution, a figure equal to three times the standard deviation. In the case in which a Gaussian distribution approximation for the losses of all components involved is used, the whole statistical distribution of overall path loss does not need to be calculated and the worst and best case losses for each optical path configuration shall be calculated directly as follows.

The statistical confidence of these upper and lower limits can be better than 99% using Gaussian distributions with three standard deviations.

Upper limit loss =

$$(mS_{\mu} + kC_{\mu} + LF_{\mu} + bB_{\mu} + M_{\mu}) + 3\sqrt{mS_{\sigma^2} + kC_{\sigma^2} + LF_{\sigma^2} + bB_{\sigma^2} + M_{\sigma^2}}$$

Lower limit loss =

$$(mS_{\mu} + kC_{\mu} + LF_{\mu} + bB_{\mu} + M_{\mu}) - 3\sqrt{mS_{\sigma^2} + kC_{\sigma^2} + LF_{\sigma^2} + bB_{\sigma^2} + M_{\sigma^2}}$$

with:

m	=	number of splices
k	=	number of connectors
L	=	fibre length (km)
b	=	number of optical branching devices
S_{μ}	=	mean splice loss (dB)
C_{μ}	=	mean connector loss (dB)
F_{μ}	=	mean fibre loss (dB/km)
B_{μ}	=	mean loss optical branching device (dB)
M_{μ}	=	mean loss miscellaneous device (dB)
S_{σ}	=	standard deviation splice loss (dB)
C_{σ}	=	standard deviation connector loss (dB)
F_{σ}	=	standard deviation fibre loss (dB/√km)
B_{σ}	=	standard deviation loss optical branching device (dB)
M_{σ}	=	standard deviation loss miscellaneous device (dB)

NOTE – The use of a Gaussian distribution for the component losses leads to differences which in general have only minor impact on the overall path loss calculation. However for some components, e.g. splices and connectors, the statistical distribution is not Gaussian and caution must be taken when using this analysis. It may be necessary with fused fibre optical branching devices to consider two discrete distributions: one for the higher loss path and one for the lower loss path.

IV.2 Monte Carlo statistical approach

An alternative statistical approach, Monte Carlo Simulation (MCS), to computing the loss of the ODN can be used. This approach requires that the distribution of at least some of the elements of the system be available. In the event that the distribution of a class of system elements is unavailable, one may assume either a Gaussian distribution or some fixed maximum value.

The MCS approach entails a computer simulation of randomly drawing each of the various system elements from its respective distribution. The total of all randomly drawn values produces one simulated system value. Repeated application of the procedure to several (hundreds) of systems will produce a distribution of system loss values that can be used as an indication of actual performance.

The following procedure describes a method to generate a random value from a histogram that represents a given distribution:

- Compute the cumulative integral of the histogram (called cdf).
- Normalize the integral by dividing by the sum (values of the cdf now fall between 0 and 1).
- Represent the cdf as a curve of probability versus loss value.
- Generate a uniform random variable between 0 and 1.
- Determine a random loss value by finding the inverse of the cdf at the generated value of probability.

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