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Transmission and Multiplexing (TM); Optical Distribution Network (ODN) for Optical Access Network (OAN)

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New presentation - see History box

Contents

Foreword

This draft European Telecommunication Standard (ETS) has been produced by the Transmission and Multiplexing (TM) Technical Committee of the European Telecommunications Standards Institute (ETSI) and is now submitted for the Public Enquiry phase of the ETSI standards approval procedure.

Proposed transposition dates	
Date of latest announcement of this ETS (doa):	3 months after ETSI publication
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1 Scope

This draft European Telecommunication Standard (ETS) defines the Optical Distribution Network (ODN) which is that part of the Optical Access Network (OAN) between the Optical Network Unit (ONU) and the Optical Line Terminal (OLT).

This ETS primarily addresses the optical aspects related to the transmission of the interactive services in an OAN according to the functional requirements specified in ETS 300 463 [11].

Optical aspects related to the transmission of signals corresponding to distributive services, which may have impact on the definition of this type of ODN (e.g. the use of Optical Amplification) are also taken into account, even if further studies are required in some cases.

2 Normative references

This ETS incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed below. For dated references, subsequent amendments to or revisions of, these publications apply to this ETS only when incorporated by amendment or revision. For undated references the latest edition of the publication referred to applies.

[1] ETR 247 (1996): "Transmission and Multiplexing (TM); Technical report on statistical approach design".

[2] ETR 248 (1996): "Transmission and Multiplexing (TM); Use of single-mode fibres in the access network".

[3] ETR 126 (1994): "Transmission and Multiplexing (TM); Applications of optical fibre amplifiers in long distance and optical access networks".

[4] ETS 300 019-1 (1992): "Equipment Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment Part 1: Classification of environmental conditions".

[5] I-ETS 300 226 (1993): "Transmission and Multiplexing (TM); Single-mode optical fibre cables to be used in ducts and for directly buried applications".

[6] I-ETS 300 227 (1993): "Transmission and Multiplexing (TM); ITU-T Recommendation G.652-type single-mode optical fibre cable".

[7] I-ETS 300 228 (1993): "Transmission and Multiplexing (TM); ITU-T Recommendation G.653-type dispersion-shifted single-mode optical fibre cable".

[8] I-ETS 300 229 (1993): "Transmission and Multiplexing (TM); Single-mode optical fibre cables to be used for aerial application".

[9] ETS 300 232 (1993): "Transmission and Multiplexing (TM); Optical interfaces for equipments and systems relating to the Synchronous Digital Hierarchy".

[10] prI-ETS 300 671: "Transmission and Multiplexing (TM); Passive optical components; Fibre optical connectors for single-mode optical fibre communication systems; Common requirements and conformance testing".

[11] prETS 300 463: "Transmission and Multiplexing (TM); The requirements of optical access networks (OANs) to provide services based on 64 kbit/s bearer capabilities".

[12] EN 60825-1 (1993): "Safety of laser products - Part 1: Equipment classification, requirements and user's guide".

[13]	EN 60825-2, (1993): "Safety of laser products - Part 2: Safety of optical fibre communication systems".
[14]	ITU-T Recommendation G.662 (1995): "Generic characteristics of optical fibre amplifier devices and sub-systems".
[15]	ITU-T Recommendation G.955 (1994): "Digital line systems based on the 1 544 kbit/s and the 2 048 kbit/s hierarchy on optical fibre cables".

NOTE: Concerning references [5]-[8]. These I-ETSs are due to be withdrawn as CEN have now published a series of ENs which replace the I-ETSs, according to the CEN-CENELEC-ETSI co-operation agreement on optical fibre standardization.

3 Definitions and abbreviations

3.1 Definitions

For the purposes of this ETS, the following definitions apply:

diplex (working): The use of a different wavelength for each direction of transmission over a single fibre.

downstream: The transmission direction from OLT to ONUs.

duplex (working): The use of the same wavelength for both directions of transmission over a single fibre.

Optical Access Network (OAN): The set of access links sharing the same network side interfaces and supported by optical access transmission systems.

NOTE 1: An OAN may include a number of ODNs connected to the same OLT.

Optical Amplifier (OA): Optical amplification element without any signal processing.

Optical Branching Device (OBD): A passive component (sometimes referred to as splitter/coupler), which has h inputs and n outputs, where h = 1 to H and n = 2 to N; it performs optical power splitting/combining according to a fixed factor (balanced or unbalanced).

optical connector: A passive component allowing removable interconnection between fibres.

Optical Distribution Network (ODN): Provides the optical transmission medium from the OLT towards the ONUs and vice versa between the S/R and R/S reference points.

optical fibre: The medium for the transport of optical signals according to ETSI standards.

optical filter: A device for the selection of optical signals at specific wavelengths.

Optical Line Terminal (OLT): Provides the network-side interface of the OAN, and is connected to one or more ODNs.

Optical Network Unit (ONU): Provides (directly or remotely) the user-side interface of the OAN, and is connected to the ODN.

passive component: A device that does not require external power (e.g. fibre, optical branching device, connector, filter, etc.).

point-to-multipoint: A network configuration which has one input/output at one end with multiple inputs/outputs at the other end.

point-to-point: A network configuration which has one input/output at one end with one input/output at the other end.

reference point: A point at which optical interfaces are defined.

reflectance: The ratio of reflected power to incident power for given conditions of spectral composition, polarization and geometrical distribution.

NOTE 2: In optics, the reflectance is generally expressed as reflectance density or in percentage terms; in communication applications it is generally expressed as $10 \cdot \log(P_r / P_i)$ in dB, where P_r is the reflected power and P_i is the incident power.

simplex (working): The use of a different fibre for each direction of transmission.

splice: A passive component allowing permanent interconnection between fibres (usually fusion of fibre ends).

upstream: The transmission direction from ONUs to (OLT).

3.2 Abbreviations

For the purposes of this ETS, the following abbreviations apply:

CEN	Comité Européen de Normalization
EN	European Standard (CEN/CENELEC)
E/O	Electrical-to-Optical (conversion)
FDM	Frequency Division Multiplexing
O/E	Optical-to-Electrical (conversion)
OA	Optical Amplifier
OAN	Optical Access Network
OBD	Optical Branching Device
ODN	Optical Distribution Network
O_l	OLT/ODN Optical Interface (local exchange side)
OLT	Optical Line Terminal
ONU	Optical Network Unit
O_r	ONU/ODN Optical Interface (remote side)
OTDR	Optical Time Domain Reflectometer
Q_m	Optical Interface for Testing and Monitoring Equipment
R/S	Optical Receive/Send Reference Points
S/R	Optical Send/Receive Reference Points
SDM	Space Division Multiplexing
TCM	Time Compression Multiplexing
WDM	Wavelength Division Multiplexing

4 Definition of the ODN in an OAN

The ODN specified in this ETS has a passive distribution function. It shall be able to provide:

- future proof cable plant;
- easily maintainable network;
- longitudinal compatibility;
- reliable network structure;
- high transport capacity;
- a means to allow integration of interactive and distributive services;
- high availability.

For manufacturing purposes, this ETS shall allow for ODN elements which can be mass produced, give a cost effective solution and stimulate further development.

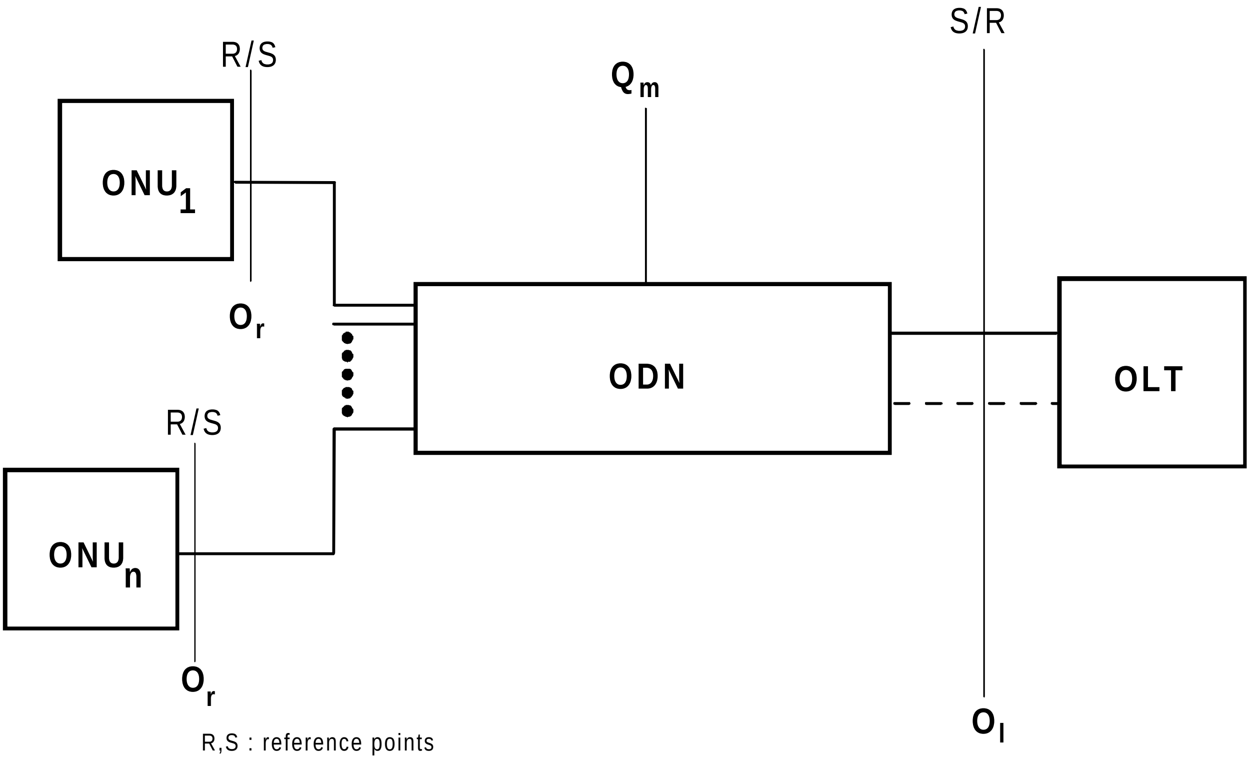
4.1 Introduction

In general, the ODN provides the optical transmission medium for the physical connection of the ONUs to the OLTs.

The ODN consists of passive optical components:

- single-mode fibres, in compliance with I-ETS 300 227 [6];
- single-mode optical fibre cables, in compliance with I-ETS 300 226 [5] and I-ETS 300 229 [8];
- optical fibre ribbons on ribbon cables, see annex F;
- optical connectors, in compliance with prI-ETS 300 671 [10];
- fibre optic branching devices, see annex F;
- fixed optical attenuators, see annex F;
- fusion splices, isee annex F.

NOTE: Passive components not included in the above list (e.g. optical filters, WDM devices) are for further study.



R,S : reference points

O_r, O_l, Q_m : optical interfaces

bold solid lines represent one or more fibres;

dashed lines represent protection fibres (see annex B)

NOTE: Each line linking any two optical blocks may represent one or more fibres in all subsequent figures.

Figure 1: Generic physical configuration of the ODN

The ODN is defined between the reference points S and R (see figure 1). In alignment with the definitions provided in ITU-T Recommendation G.955 [15] and ETS 300 232 [9], S and R shall be defined as follows:

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

b) **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 traveling from the OLT(s) to the ONUs; definition b) holds when considering optical signals traveling 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 path between one OLT and one or more ONUs. Each optical path is defined between reference points S and R in a specific wavelength window.

The following optical interfaces are defined in figure 1:

O_r: optical interface at the reference point R/S between the ONU and the ODN;
O_l: optical interface at the reference point S/R between the OLT and the ODN;
Q_m: optical interface between testing and monitoring equipment and the ODN.

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 signal (services). The interface Q_m may be physically located at several points in the ODN, and may be implemented both with dedicated fibres and with 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 the transmission of signals at any wavelength in the 1 310 nm and 1 550 nm regions;

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

- **fibre compatibility:** all optical components shall be compatible with single-mode fibre as specified in I-ETS 300 227 [6].

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

- **downstream:** direction for signals traveling from the OLT to the ONU(s);

- **upstream:** direction for signals traveling 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). Duplex working refers to the use of the same wavelengths for both directions of transmission over a single fibre; diplex working refers to the use of different wavelengths for each direction of transmission over a single fibre. Simplex working refers to the use of a different fibre for each direction of transmission.

The introduction of Optical Amplifiers (OAs) within the OAN is possible under the rules given in clause 8 of this ETS. In this case each OA shall not be considered as a part of the ODN. Instead separate ODNs will be considered, according to the rules also given in clause 8.

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.

4.2 Definition of ODN architectures

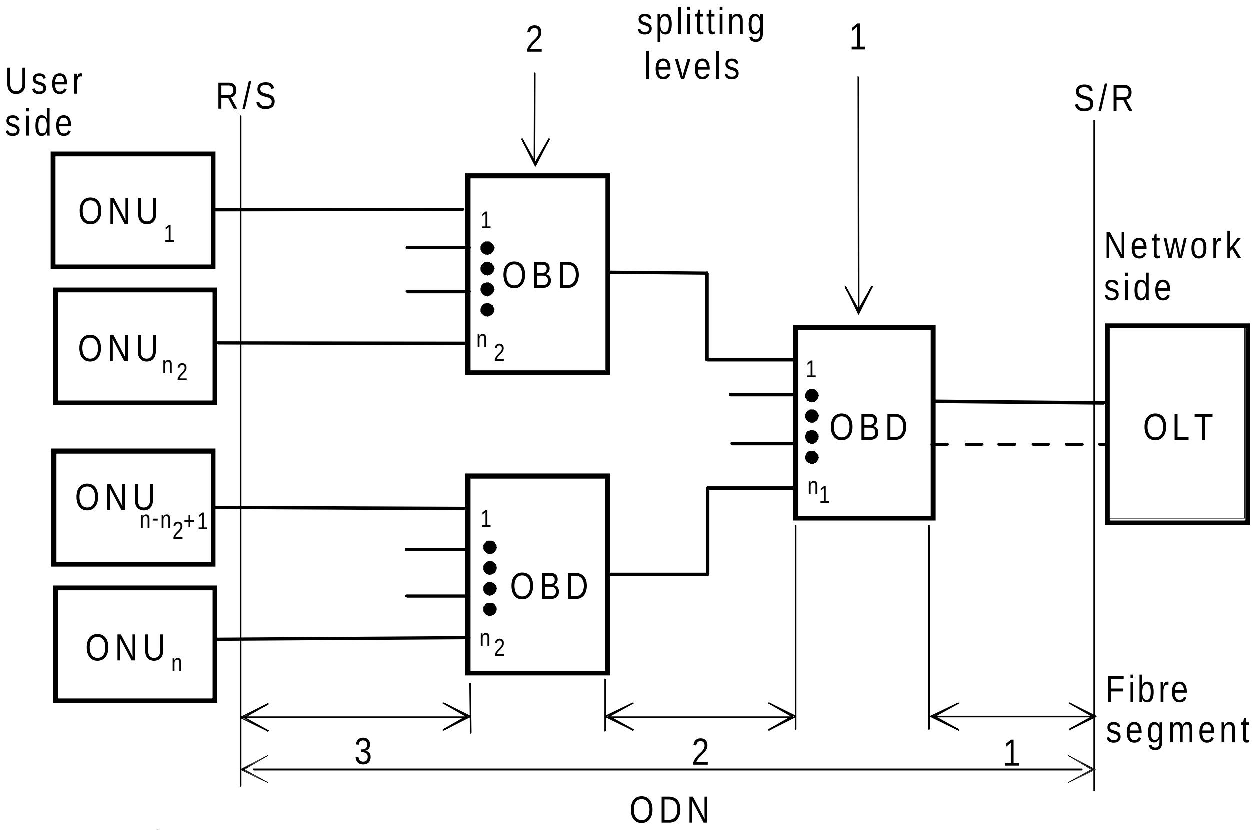
The physical connection of the OLT and ONUs to the ODN is made via one or two fibres, depending on the bi-directional transmission scheme adopted (duplex, diplex or simplex). Use of a greater number of fibres is allowed for upgrade or protection purposes.

The configuration of the ODN shall be point-to-multipoint, where a number of ONUs are connected to the OLT via the ODN. Thus, sharing by ONUs of the optical medium and optoelectronic devices of the OLT is achieved.

Two basic point-to-multipoint architectures for the ODN can be defined: tree and bus.

An example of a tree architecture is shown in figure 2. It employs cascaded optical branching devices to split the downstream signal and to combine the upstream signals. The optical branching devices are generally of the 1:n type. To achieve enhanced network performance and reliability (e.g. input of additional signals, access points for testing and monitoring, network protection by means of path diversity, etc.) optical branching devices of the h:n type, where $1 < h \leq n$, may also be used. Typically, the optical branching devices used in the tree architecture are balanced devices, i.e. the optical loss from any input port to any output port is nominally the same for any choice of input and output ports. This requirement stems mainly from the need to have simple and general rules for power budget calculation and overall network design.

A description of a bus architecture with the use of unbalanced optical branching devices is given in annex A.



n = n1 x n2.

Dashed lines represent protection fibres.

Figure 2: An example of a tree architecture

In this ETS, the point-to-point configuration, where one ONU is connected to the OLT via the ODN, is considered as a specific point-to-multipoint implementation. In this case there are no optical branching devices in the ODN and a dedicated optical link, consisting of one or two fibres, connects each ONU to the OLT (see figure 3). This configuration is called single star architecture, which allows the maximum fibre length between the OLT and the ONU to be greater than that for a point-to-multipoint configuration.

NOTE: Several factors can be taken into account when choosing the ODN architecture, the main ones being: topological distribution of customers, distances between OLT and ONUs, optical paths for various services to be provided, available technology, optical power budget, wavelength allocation, upgrade requirements, reliability and availability, operation and maintenance, ONU powering, security, cable capacity.

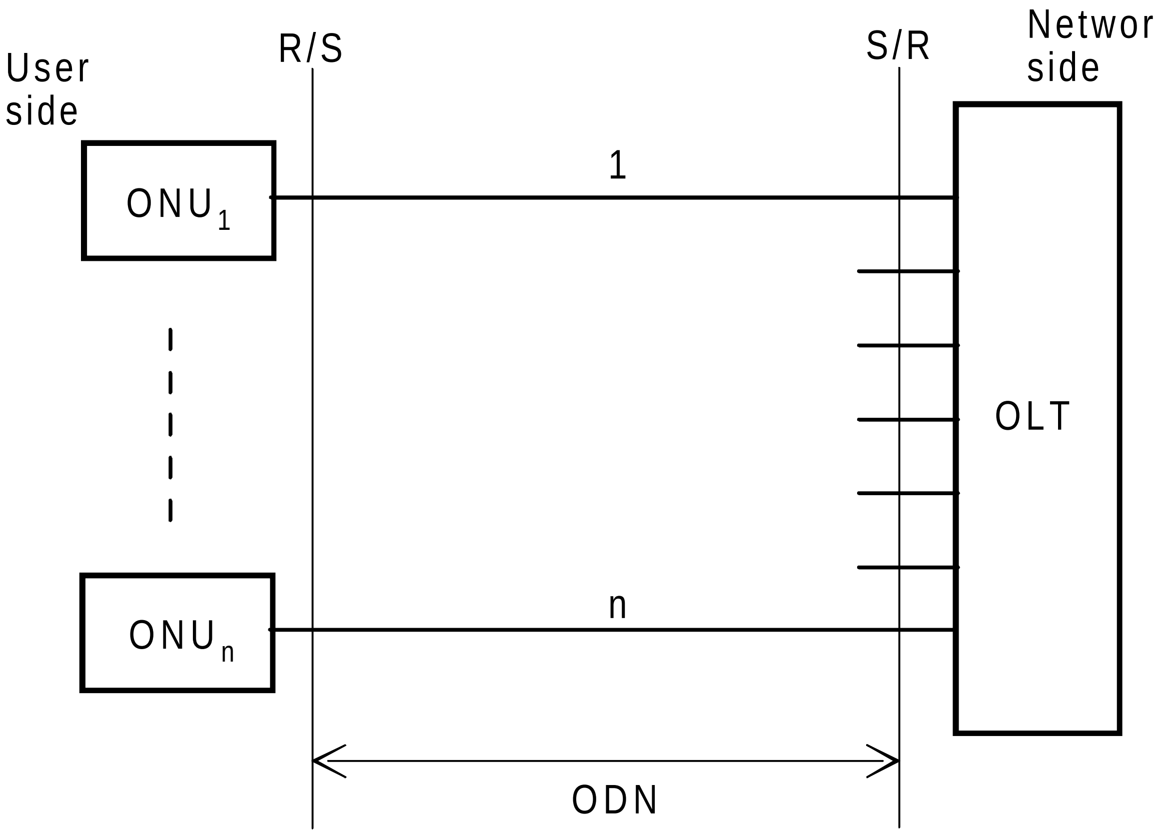


Figure 3: An example of a single star architecture

4.3 ODN functions

The following functions are identified for the ODN:

a) Direct optical connection:

- The ODN shall provide facilities for the direct exchange of optical signals between the OLT and the ONU. This function does not apply to the point-to-point ODN configuration, as this contains no optical branching devices.

b) Optical splitting/combining:

- Splitting is performed on the downstream signals and combining on the upstream signals, by means of optical branching devices.

c) Optical multi-wavelength transport capability:

- The ODN shall allow the simultaneous transmission on the same fibre of signals having different wavelengths, both in the downstream and upstream direction.

d) Optical monitoring attachments:

- The location of the access points for ODN optical testing and monitoring, and the measurements carried out in the ODN, shall not degrade the operation of the access link. Access points should be provided in the OAN. The access points may be located at the OLT, ONUs and intermediate places in the ODN. At the access points optical testing equipment such as OTDRs (Optical Time Domain Reflectometers) and optical power meters may be connected. Power measurements may be carried out at fibre terminations or along the fibre using appropriate measuring equipment.

e) Optical interfaces:

- The ODN shall provide physical interface functions for optical connection to the OLT and ONUs.

4.4 Protection configurations

Examples of protection configurations are given in annex B.

5 Wavelength ranges

The operating wavelengths used in the ODN shall be in the 1 310 nm (2nd) window and the 1 550 nm (3rd) window. A survey of some possibilities for wavelength allocation in case of interactive services is given in annex D.

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

5.1 Wavelength range for the 1 310 nm region

The operating wavelength range for the 1 310 nm wavelength region shall be 1 260 nm to 1 360 nm.

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

5.2 Wavelength range for the 1 550 nm region

The operating wavelength range for the 1 550 nm wavelength region shall be 1 480 nm to 1 580 nm.

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

6 Specification of the optical path

6.1 Definition of the optical path

The ODN is constituted by P splitting levels, even though one or two splitting levels are typically adopted.

Within the ODN, several optical paths can be identified. Each optical path connects a specific ONU to the OLT.

The 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.

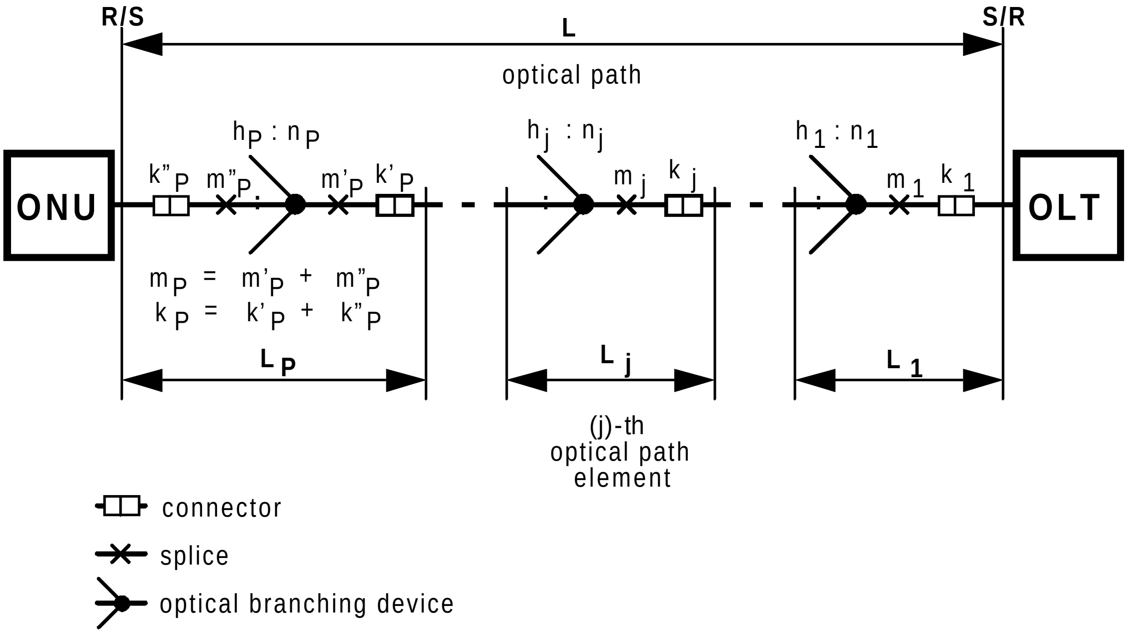


Figure 4: Schematic representation of the optical path between the OLT and the ONU

In figure 4, which gives a schematic representation of the downstream optical path between the OLT and a specific ONU, or more generally between reference points S/R and R/S, 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:

- for 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);

- for 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:

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

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 the 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 optical branching devices, with splitting ratio hj:nj (hj ≥ 1, nj ≥ 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.

6.2 Loss allowance

6.2.1 Loss definition

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 ETS 300 232 [9], where the attenuation ranges for SDH optical interfaces are specified.

6.2.2 Calculation methodology

Using the methodology of this subclause, appropriate optical loss ranges can be calculated for different optical paths.

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, based upon the following procedure, shall be used in the summation in order to avoid over specification of the ODN. The statistical distribution of the overall optical path loss shall be obtained by combining the statistical distributions of losses of the various components of the optical path.

> NOTE 1: The statistical distribution of the overall path loss is assumed to be Gaussian with very good approximation.

The best and worst case optical path losses shall be derived, 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:

- worst case loss =

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

- best case 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)·

The statistical parameters of the optical loss of the components along the optical path are given in the related ETSs as listed in subclause 4.1.

NOTE 2: 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 should 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.

An example of application of this calculation methodology for a typical ODN is given in annex C. The results of the loss calculations are presented in the form of a numerical table in which the worst case and best case losses are listed for each practical combination of the various parameters characterizing each optical path (e.g. fibre length, number and type of optical branching devices, number of splices and connectors).

6.2.3 Optical path loss classes

In order to limit the number of possible different system implementations, classes for optical path loss are specified below in table 1.

Table 1: 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

Classes B and C represent the requirements for the OAN system types 2 (e.g. TCM) and 1 (e.g. SDM, WDM), respectively, as defined in prETS 300 463 [11]. Different splitting ratios, distances and related path loss values between S/R and R/S have been taken into account using the example table in annex C. The specification of additional classes is for further study. For single star architectures, the absence of optical branching devices may result in optical path losses of less than 5 dB.

6.3 Passive optical components

6.3.1 Fibre

The attenuation shall be as specified in I-ETS 300 227 [6] for the 1 310 nm and 1 550 nm wavelength regions.

For optical fibre in cables the attenuation coefficients shall be as specified in I-ETS 300 226 [5] and I-ETS 300 229 [8], as required. This subject is also under further study (see annex F).

6.3.2 Optical branching devices

The characteristics of optical branching devices for double window use and splitting ratios h:n are currently under study (see annex F).

6.3.3 Splices

The specification of fusion splices is under study (see annex F).

6.3.4 Connectors

Connectors are specified in prI-ETS 300 671 [10].

6.3.5 Attenuators

The specification of fixed optical attenuators is under study (see annex F).

6.4 Reflectance (return loss)

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.

Optical components reflectance specifications to use are the following:

- for optical connectors:	prI-ETS 300 671 [10];
- for branching devices:	under study (see annex F);
- for fixed optical attenuators:	under study (see annex F);
- for fusion splices:	under study (see annex F);
- for open ended fibre:	14 dB (worst case).

The reflectance of an ODN can be calculated using the same methodology as outlined in subclause 6.2. An example of ODN reflectance calculation is given in annex E.

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 - 50 dB. 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 1: For emissions with a constant power level, the reflectance due to back-scattering from single mode fibre is lower than - 33 dB after some kilometers length.

NOTE 2: For systems using bit rates higher than a few Mbit/s, the back-scattered information in the fibre can be considered as information with constant power level, due to a phase cancellation effect. A provisional reflectance value of - 50 dB is retained.

6.5 Chromatic dispersion

The chromatic dispersion coefficients shall be as specified in I-ETS 300 227 [6] for the 1 310 nm and 1 550 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.

6.6 Optical delay

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

6.7 Polarization

For further study.

6.8 Environmental conditions

Various classes of environmental conditions are specified in ETS 300 019-1 [4]

7 Radiation safety requirements

In EN 60825-1 [12] the following safety classes are defined:

- class 1, regarded inherently safe;
- class 3A, safe without viewing aids.

The limits defined in EN 60825-2 [13] for locations with unrestricted access, shall not be exceeded.

8 Introduction of OAs in the OAN

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 5 shows examples of the insertion of OA devices in an OAN.

NOTE 1: 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 is given in ETR 126 and in ITU-T Recommendation G.662 [14].

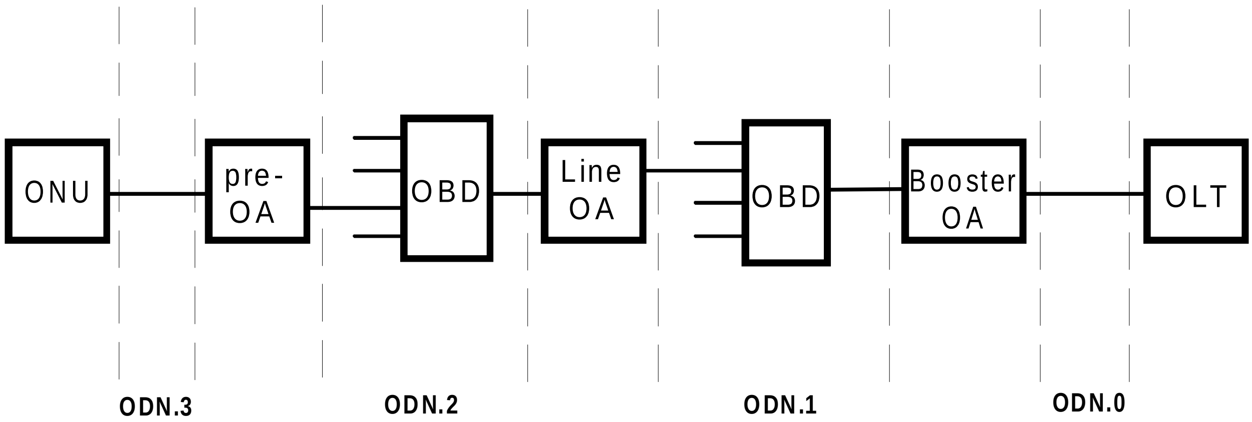


Figure 5: Example of insertion of OA devices in an OAN

The introduction of OAs within the OAN shall follow the rules given below:

- if an OA subsystem is used as a booster amplifier, it shall be considered as a part of the OLT;
- if an OA subsystem is used as a pre-amplifier, it shall 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 shall be considered between the OLT and the OA device and an ODN.1 shall 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 shall be considered between the OLT and the first OA device, an ODN.i shall 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) shall be considered between the last OA device along the path and the ONUs (see figure 5 for an example with n=3).

Suitable R and S reference points shall be introduced.

NOTE 2: Specification of the additional R and S reference points and optical interfaces for OAs is for further study.

NOTE 3: The use of OAs shall influence the operating wavelength range of the OAN, as stated in subclause 5.2 of this ETS.

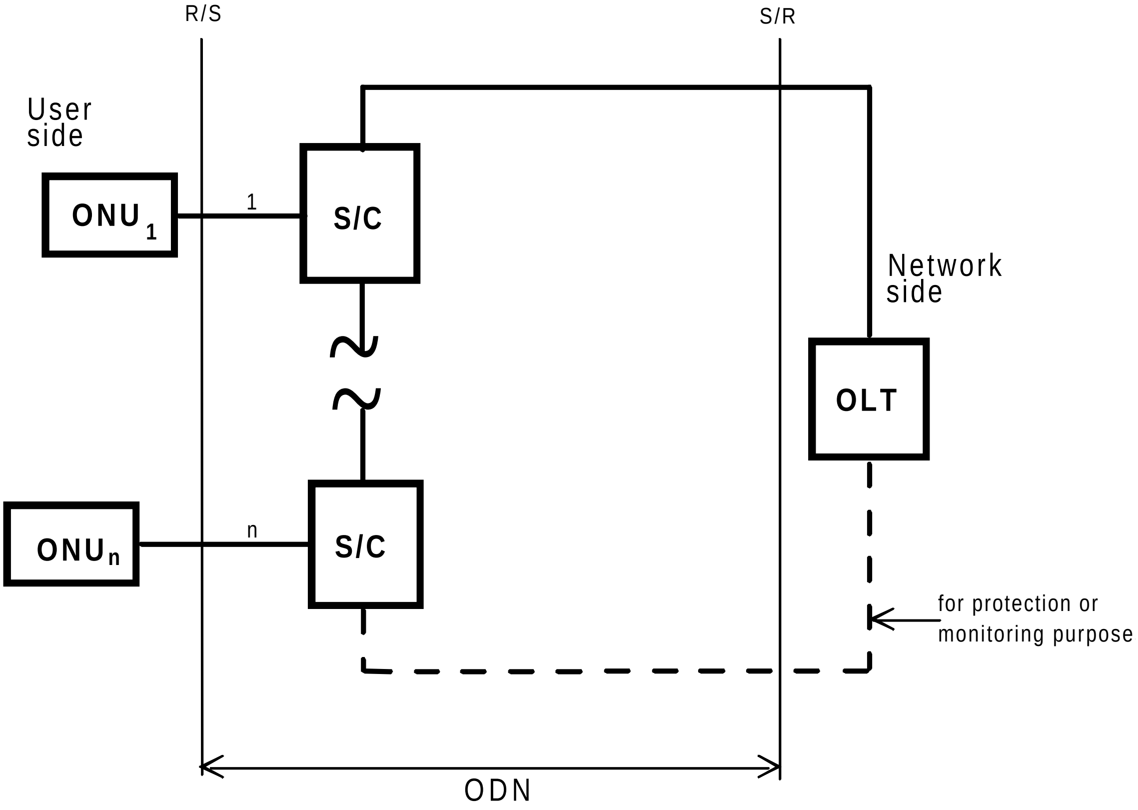
9 Influence of upgrade possibilities

This ETS considers the use of optical fibre covered by I-ETS 300 227 [6] only. Upgrades may be performed in the future by using different single-mode fibres (e. g. fibres covered by I-ETS 300 228 [7]).

Further upgrade possibilities are described in ETR 248 and prETS 300 463 [11], and are for further study.

Annex A (informative): The bus architecture

The bus architecture is shown below in figure A.1. The bus may end at the last ONU connected, or to be folded towards the OLT itself (e.g. for protection or monitoring purposes). Unbalanced optical branching devices are employed to pick up from the optical bus the signal transmitted by the OLT, and to insert into the bus the signal transmitted by each ONU. The unbalanced optical branching devices introduce a small loss on the bus, and hence, draw from the bus a small amount of power. The splitting ratio is determined by specific requirements, such as the maximum number of ONUs and the minimum optical power required at ONU input.



NOTE: In ETR 248, the ring topology has been considered as a possible choice for the passive ODN structure. It is believed, however, that the passive ring structure can be regarded as logically equivalent to one, or a combination of more than one, of the basic topologies which are dealt with in this document (e.g. the folded bus); therefore, the ring topology is not considered as an independent topology in this ETS.

Figure A.1: An example of a bus architecture

Annex B (informative): Protection configurations

Protection configurations can be implemented for any architecture, mainly based on:

- duplication;
- path diversity.

For the ODN itself, protection assumes that the optical path is doubled in some parts of the network (generally near the OLT).

The following methods are mainly used (each with two paths in parallel):

- the greatest degree of protection can be achieved by carrying each optical path on a separate fibre (one path per fibre), with each fibre in one cable, and to install each cable in a different physical way (different ducts);

- another method is to carry each optical path on a separate optical fibre (one path per fibre), and to install the fibres in the same cable (one duct).

Parameters can be identified to classify the performance of protection configurations, e.g:

- **degree of protection:** gives/defines the extent to which the protection is capable of preserving network operation in case of any fault. Evaluation of this parameter is based on one or more of the following quantities:

    - share of ONUs which remain operating in case of any fault;
    - minimum traffic capacity (at OLT) which is guaranteed in case of any fault;
    - quantity and quality of signals (services) which are guaranteed in case of any fault;
    - **degree of redundancy:** gives/defines the amount of supplementary equipment and/or fibre which is needed to achieve the required degree of protection;
    - **protection switching mode:** gives/defines how the protection equipment and/or fibres are activated in case of fault (automatically or manually).

Implementations are subject to several constraints, such as: the required degree of reliability, cost, layout of fibre ducts, etc..

Tree architecture - the protection configuration shown in figure 2 is based on duplication of some part of the OLT equipment, and path diversity up to the first splitting level in the ODN. Reliability of the OAN is enhanced by the fact that:

- in case of OLT failure, or in case of fibre failure in the first ODN fibre segment, the backup part of the OLT can be activated;

- in case of single fibre failure in the second ODN fibre segment, $1/n_1$ of the total number of fibre ends are cut off. This is the maximum number of ONUs (assuming fully populated fibre ends) that may share a serious service interruption because of any OLT or fibre failure in the ODN;

  without protection, an OLT or fibre failure in the first fibre segment could cut off all ONUs until repair.

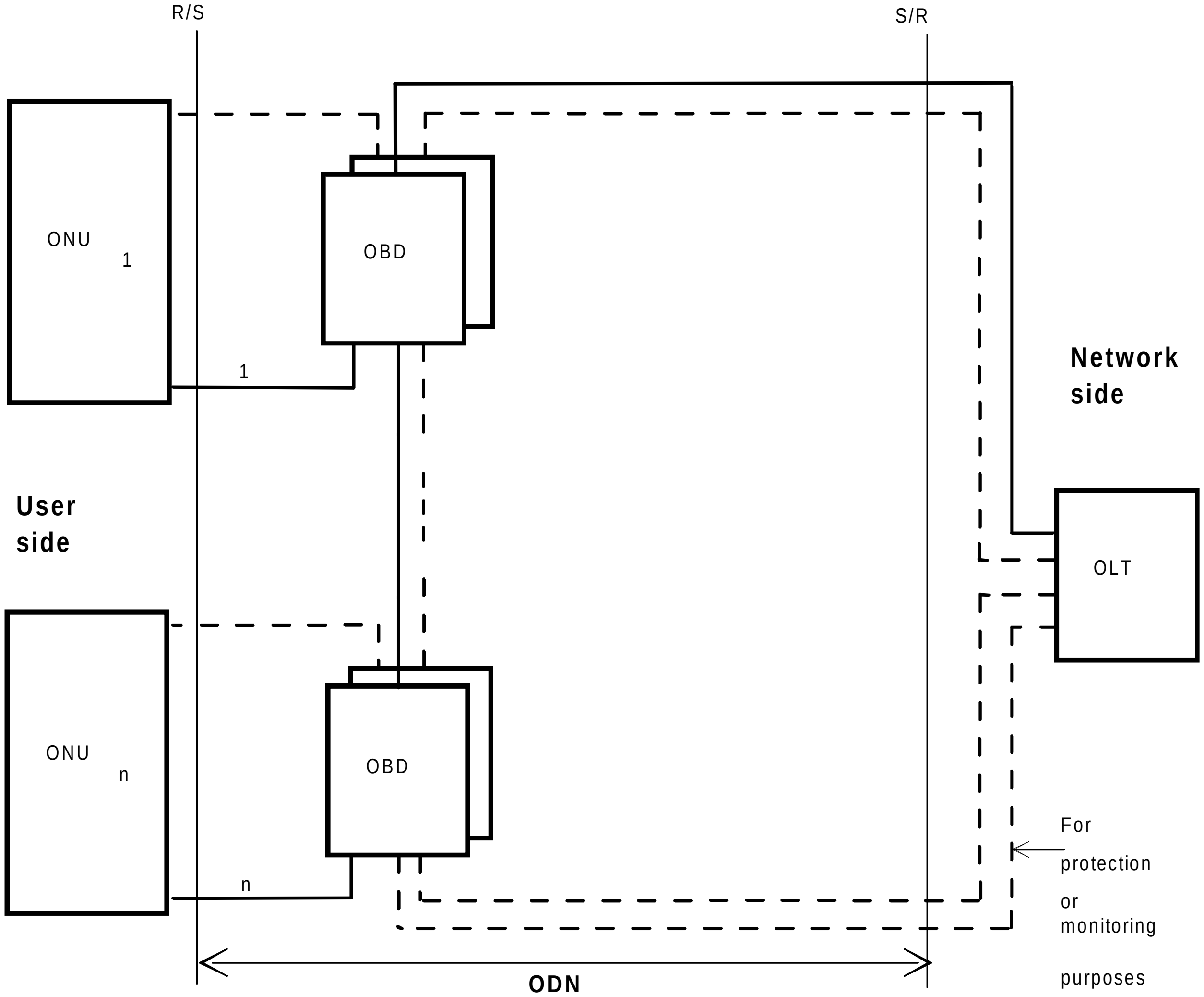


Figure B.1: An example of protection configuration for folded bus architecture

Bus architecture - the protection configuration shown in figure B.1 is based on duplication of some part of the OLT equipment and bus. In case of failure of the main equipment in the OLT, the backup equipment can be activated, restoring service to all ONUs. In case of bus failure, the backup part of the OLT can be activated, in addition to the main equipment (still operating), so that each ONU is connected to either the main or the backup equipment. OAN reliability is enhanced by the fact that both OLT and bus failures can be overcome without serious service interruption for any ONU.

Annex C (informative): Example of application of the calculation methodology

Table C.2c, below, gives examples of optical path loss values that can be calculated for different ODN configurations using the statistical approach described in subclause 6.2. Tables C.2a and C.2b give examples of optical path assumptions and statistical loss data for the passive optical components (optical branching devices, splices, etc.) respectively. The fibre loss values shown in table C.2b are specified for the 1 310 nm wavelength region. In the 1 550 nm wavelength window the resulting ODN optical path loss values will be lower, because of lower fibre loss values.

During normal use of such tables, it is expected that the statistical mean and standard deviation information of the passive optical components, i.e. table C.2b, will remain constant.

In order to model the numerous designs of an ODN, the assumptions in part a of the table can be altered. For example, table C.2a shows the ODN path loss that would result with the following assumptions:

- 0 wavelength division multiplexers (WDM);
- 2 connectors;
- 2 splices at the ends of each link;
- 2,0, 1,5 and 1,2 splices per km at distance ranges of 0 km to 5 km, 5 km to 20 km and > 20 km respectively;
- 0 dB allocation for additional plant margin;
- operation in the 1 310 nm wavelength region.

Table C.2c shows the resulting ODN optical path losses corresponding to the assumptions and passive optical component data entered in table C.2a and table C.2b. These ODN optical path losses represent the worst case loss and best case loss, in dB, for various ODN distance ranges (from 0,1 km to 30 km) and split ratios (1 to 64). In many situations the total splitting ratio is the result of a combination of two discrete optical branching devices. Such splitting is represented by a "composite optical branching device" (1:m) x (1:n), where the first optical branching device has a 1:m split, and the second optical branching device has a 1:n split.

Although the tables show the use of two optical branching devices to constitute the "(1:m) x (1:n) composite optical branching device" there is no restriction to the use of any number of optical branching devices.

In the definition of the three loss class ranges, given in subclause 6.2.3, the following system constraints have been taken into consideration:

- a maximum attenuation range of 15 dB;

- a power budget reduction of 5 dB for system type 2, compared to that for system type 1;

- equipment margins for ageing and temperature variations are outside reference points S and R, and are therefore not covered by the loss class ranges.

In table C.1 various distance ranges are shown for the three loss class ranges (defined in subclause 6.2.3), when using the assumptions in table C2. It should be evident that the distance/splitting ratio combinations, defined in prETS 300 463 [11] for systems type 1 and type 2, are feasible with sufficient margins for the network operator.

Table C.1: Distance ranges at various splitting ratios for the three loss classes A, B and C

Loss range	1:1	1:2	1:4	1:8	1:16	1:32	1:64
5 to 20 dB	10 to 30 km	3 to 28 km	0 to 20 km	0 to 13 km	0 to 6 km		
10 to 25 dB	20 to 30 km	13 to 30 km	7 to 30 km	2 to 23 km	0 to 16 km	0 to 7 km	
15 to 30 dB		23 to 30 km	18 to 30 km	12 to 30 km	6 to 26 km	0 to 17 km	0 to 8 km

Table C2: Example of ODN path loss calculations

Table C2a: ODN assumptions (input)

Assumptions:		
There are ≥	0	WDM(s)
There are ≥	2	connectors
There is a minimum of ≥	2	splices at ends of link
For distance up to 5 km ≥	2,0	splices per km
For distance between 5 and 20 km ≥	1,5	splices per km
For distance over 20 km ≥	1,2	splices per km
Plant Margin (Additional repair splices etc.)	0	dB

Table C2b: ODN passive optical components (input)

ENTER >>>	Mean	Standard deviation
1 : 1 splitter	0,00 dB	0,00 dB
1 : 4 splitter	6,70 dB	0,42 dB
1 : 6 splitter	8,70 dB	0,30 dB
1 : 8 splitter	9,80 dB	0,55 dB
1 : 16 splitter	13,10 dB	0,67 dB
1 : 32 splitter	17,00 dB	0,90 dB
1 : 64 splitter	20,80 dB	1,20 dB
ENTER >>>	Mean	Standard deviation
WDM	0,50 dB	0,10 dB
Connector	0,40 dB	0,10 dB
Splice	0,10 dB	0,05 dB

Table C.2c: ODN optical path loss (output)

Splitting ratio		Distance										
		0,1 km	1 km	2 km	3 km	4 km	5 km	10 km	15 km	20 km	25 km	30 km
1	(1:1) x (1:1) composite splitter	0,56 to 1,51	1,03 to 2,07	1,53 to 2,67	2,04 to 3,26	2,55 to 3,85	3,07 to 4,43	5,44 to 7,06	7,83 to 9,67	10,24 to 12,26	12,56 to 14,74	14,84 to 17,16
2	(1:1) x (1:2) composite splitter	3,86 to 5,41	4,34 to 5,96	4,86 to 6,54	5,38 to 7,12	5,90 to 7,70	6,43 to 8,27	8,83 to 10,87	11,24 to 13,46	13,66 to 16,04	16,00 to 18,50	18,29 to 20,91
4	(1:1) x (1:4) composite splitter	6,48 to 9,19	6,98 to 9,72	7,51 to 10,29	8,04 to 10,86	8,58 to 11,42	9,11 to 11,99	11,55 to 14,55	13,98 to 17,12	16,43 to 19,67	18,78 to 22,12	21,08 to 24,52
	(1:2) x (1:2) composite splitter	7,24 to 9,23	7,73 to 9,77	8,26 to 10,34	8,78 to 10,92	9,31 to 11,49	9,84 to 12,06	12,26 to 14,64	14,68 to 17,22	17,11 to 19,79	19,45 to 22,25	21,75 to 24,65
6	(1:1) x (1:6) composite splitter	8,81 to 10,86	9,30 to 11,40	9,83 to 11,97	10,35 to 12,55	10,88 to 13,12	11,41 to 13,69	13,83 to 16,27	16,26 to 18,84	18,69 to 21,41	21,03 to 23,87	23,32 to 26,28
8	(1:1) x (1:8) composite splitter	9,21 to 12,66	9,71 to 13,19	10,25 to 13,75	10,78 to 14,32	11,32 to 14,88	11,86 to 15,44	14,31 to 17,99	16,76 to 20,54	19,21 to 23,09	21,57 to 25,53	23,88 to 27,92
	(1:2) x (1:4) composite splitter	9,95 to 12,92	10,44 to 13,46	10,98 to 14,02	11,51 to 14,59	12,05 to 15,15	12,58 to 15,72	15,02 to 18,28	17,47 to 20,83	19,91 to 23,39	22,27 to 25,83	24,57 to 28,23
12	(1:2) x (1:6) composite splitter	12,23 to 14,64	12,73 to 15,17	13,26 to 15,74	13,79 to 16,31	14,32 to 16,88	14,85 to 17,45	17,28 to 20,02	19,72 to 22,58	22,15 to 25,15	24,50 to 27,60	26,80 to 30,00

(continued)

Table C.2c (concluded): Example of ODN path loss calculations

Splitting ratio		Distance										
		0,1 km	1 km	2 km	3 km	4 km	5 km	10 km	15 km	20 km	25 km	30 km
16	(1:1) x (1:16) composite splitter	12,16 to 16,31	12,67 to 16,83	13,21 to 17,39	13,74 to 17,96	14,28 to 18,52	14,82 to 19,08	17,28 to 21,62	19,74 to 24,16	22,19 to 26,71	24,56 to 29,14	26,87 to 31,53
	(1:2) x (1:8) composite splitter	12,70 to 16,37	13,21 to 16,89	13,74 to 17,46	14,28 to 18,02	14,82 to 18,58	15,35 to 19,15	17,81 to 21,69	20,26 to 24,24	22,71 to 26,79	25,07 to 29,23	27,39 to 31,61
	(1:4) x (1:4) composite splitter	12,78 to 16,49	13,28 to 17,02	13,82 to 17,58	14,36 to 18,14	14,89 to 18,71	15,43 to 19,27	17,88 to 21,82	20,33 to 24,37	22,79 to 26,91	25,15 to 29,35	27,46 to 31,74
24	(1:4) x (1:6) composite splitter	15,00 to 18,27	15,50 to 18,80	16,04 to 19,36	16,57 to 19,93	17,11 to 20,49	17,64 to 21,06	20,09 to 23,61	22,54 to 26,16	24,99 to 28,71	27,34 to 31,16	29,65 to 33,55
32	(1:1) x (1:32) composite splitter	15,39 to 20,88	15,90 to 21,40	16,44 to 21,96	16,98 to 22,52	17,52 to 23,08	18,06 to 23,64	20,53 to 26,17	22,99 to 28,71	25,46 to 31,24	27,83 to 33,67	30,16 to 36,04
	(1:2) x (1:16) composite splitter	15,67 to 20,00	16,18 to 20,52	16,72 to 21,08	17,26 to 21,64	17,79 to 22,21	18,33 to 22,77	20,79 to 25,31	23,25 to 27,85	25,71 to 30,39	28,08 to 32,82	30,39 to 35,21
	(1:4) x (1:8) composite splitter	15,59 to 19,88	16,10 to 20,40	16,64 to 20,96	17,18 to 21,52	17,71 to 22,09	18,25 to 22,65	20,71 to 25,19	23,17 to 27,73	25,63 to 30,27	27,99 to 32,71	30,31 to 35,09
36	(1:6) x (1:6) composite splitter	17,26 to 20,01	17,76 to 20,54	18,29 to 21,11	18,82 to 21,68	19,36 to 22,24	19,89 to 22,81	22,33 to 25,37	24,77 to 27,93	27,21 to 30,49	29,56 to 32,94	31,86 to 35,34
48	(1:6) x (1:8) composite splitter	17,78 to 21,69	18,29 to 22,21	18,83 to 22,77	19,36 to 23,34	19,90 to 23,90	20,44 to 24,46	22,89 to 27,01	25,35 to 29,55	27,80 to 32,10	30,17 to 34,53	32,48 to 36,92
64	(1:1) x (1:64) composite splitter	18,30 to 25,57	18,81 to 26,09	19,35 to 26,65	19,90 to 27,20	20,44 to 27,76	20,98 to 28,32	23,46 to 30,84	25,93 to 33,37	28,41 to 35,89	30,79 to 38,31	33,11 to 40,69
	(1:2) x (1:32) composite splitter	18,92 to 24,55	19,43 to 25,07	19,97 to 25,63	20,51 to 26,19	21,05 to 26,75	21,59 to 27,31	24,06 to 29,84	26,53 to 32,37	29,00 to 34,90	31,37 to 37,33	33,69 to 39,71
	(1:4) x (1:16) composite splitter	18,61 to 23,46	19,11 to 23,99	19,65 to 24,55	20,19 to 25,11	20,73 to 25,67	21,27 to 26,23	23,73 to 28,77	26,20 to 31,30	28,66 to 33,84	31,03 to 36,27	33,35 to 38,65
	(1:8) x (1:8) composite splitter	18,44 to 23,23	18,95 to 23,75	19,49 to 24,31	20,03 to 24,87	20,57 to 25,43	21,11 to 25,99	23,57 to 28,53	26,03 to 31,07	28,50 to 33,60	30,86 to 36,04	33,19 to 38,41

Annex D (informative): Survey of possible wavelength allocation for interactive services

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

Table D.1: Transmission of narrow-band interactive services

Bidirectional transmission scheme	Number of fibres	Wavelength region	Transmission scheme implementation	Future implementations
Simplex	2	1 310 nm upstream; 1 310 nm downstream	SDM	
Duplex	1	1 310 nm upstream; 1 310 nm downstream	FDM/TCM	
Diplex	1	1 310 nm upstream; 1 550 nm downstream	WDM	1 310 + nm upstream; 1 310 - nm downstream

Annex E (informative): ODN reflectance calculations

The ODN reflectance calculation methodology relies on the reflectance values of individual optical components, the mean loss and the standard deviation loss of ODN components. For the ODN reflectance, the reflectance contributions of all optical devices are added and their respective losses are taken into account.

The specifications of the reflectance of the optical components (e.g. connectors, receivers, laser modules) in the ONUs and the OLT is considered outside the scope of this ETS, but their reflections may limit the performance of an OAN system.

As for the calculation of ODN loss, values given for the best case and the worst case losses are equal to the mean value ± 3 σ assuming a gaussian distribution for all the components. For the optical component reflectance, only typical values are taken into account.

The calculations are based on the ODN structure given in figure E.1. Only one splitting level is considered, but with different OLT-ONU distances and splitting ratios, assuming a 0,2 km length for the final drop.

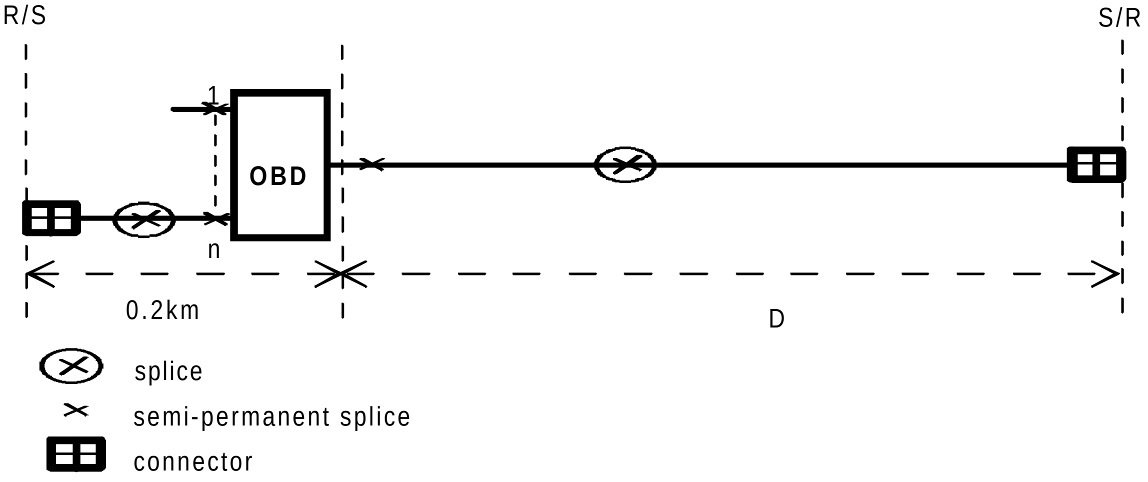


Figure E.1: An example of an ODN configuration for reflectance calculations

The characteristics of the ODN components are based on the ODN model described in this ETS:

Where:

- the wavelength is 1 310 nm;
- the length of the fibre is D, with D = 5, 10, 15 or 20 km;
- the number of connectors is k, with k = 2;
- the number of splices per km length is m', with:

    - m' = 2/km for up to 5 km;
    - m' = 1,5/km for more than 5 km and up to 20 km.

- 2 semi-permanent splices are assumed for the installation of the optical branching device;

- loss:

    - fusion splice: mean 0,1 dB, standard deviation 0,05 dB;
    - semi-permanent splice: mean 0,2 dB, standard deviation 0,07 dB;
    - connector: mean 0,4 dB, standard deviation 0,1 dB;
    - fibre: mean 0,35 dB/km, standard deviation 0,02 dB/$\sqrt{\text{km}}$;
    - 1:4 optical branching device: mean 7,05 dB, standard deviation 0,27 dB;
    - 1:8 optical branching device: mean 10,5 dB, standard deviation 0,33 dB;
    - 1:16 optical branching device: mean 13,5 dB, standard deviation 0,73 dB.

- return loss:
  - fusion splice: 60 dB;
  - semi-permanent splice: 55 dB;
  - connector: 50 dB;
  - optical branching device: 50 dB.

Tables E.1 and E.2 give ODN reflectance values for the worst and the best case ODN losses depending on the direction: OLT → ONU or ONU → OLT.

Table E.1: ODN reflectance values (OLT → ONU)

	Distance: OLT → ONU			
splitting ratio	**5 km**	**10 km**	**15 km**	**20 km**
1 → 4	- 47,53dB/- 47,96 dB	- 48,10dB/- 48,38 dB	- 48,25dB/- 48,47 dB	- 48,37dB/- 48,57 dB
1 → 8	- 47,65dB/- 48,02 dB	- 48,15dB/- 48,41 dB	- 48,27dB/- 48,48 dB	- 48,38dB/- 48,57 dB
1 → 16	- 47,71dB/- 48,05 dB	- 48,17dB/- 48,42 dB	- 48,28dB/- 48,49 dB	- 48,38dB/- 48,57 dB

Table E.2: ODN reflectance values (ONU → OLT)

	Distance: ONU → OLT			
splitting ratio	**5 km**	**10 km**	**15 km**	**20 km**
1 → 4	- 46,87dB/- 47,32 dB	- 46,90dB/- 47,32 dB	- 46,91dB/- 47,32 dB	- 46,92dB/- 47,32 dB
1 → 8	- 46,92dB/- 47,34 dB	- 46,92dB/- 47,34 dB	- 46,92dB/- 47,34 dB	- 46,92dB/- 47,34 dB
1 → 16	- 46,93dB/- 47,34 dB	- 46,93dB/- 47,34 dB	- 46,93dB/- 47,34 dB	- 46,93dB/- 47,34 dB

From these tables, it can be demonstrated that the ODN reflectance is practically independent of the splitting ratio and the distance, but mainly depends on the return loss characteristics of the first components of the ODN, as it is shown on table E.3 for different return loss values of the connectors.

Table E.3: ODN reflectance values according to the connector reflectance

Connector reflectance	**- 50 dB**	**- 45 dB**	**- 40 dB**	**- 35 dB**	**- 30 dB**
OLT → ONU 5 km 1 → 16	- 47,71/- 48,05 dB	- 44,11/- 44,28 dB	- 39,67/- 39,75 dB	- 34,86/- 34,91 dB	- 29,93/- 29,96 dB

An important point for the ODN reflectance is the impact of unused branches of the branching devices. As an example, a reflectance value of - 14 dB is assumed for an open ended branch. ODN reflectance values are reported in table E.4 for different distances. It is clear that the impact of the reflectance of an unused branch on the system performance can be very significant.

Table E.4: Impact of one unused branch on the ODN reflectance values

Distance OLT → ONU	**5 km**	**10 km**	**15 km**	**20 km**
1 → 4 1 open branch	- 27,24/- 30,74 dB	- 31,68/- 35,11 dB	- 35,44/- 38,91 dB	- 39,91/- 42,79 dB

Annex F (informative): Bibliography

The ETSI Transmission and Multiplexing (TM) Technical Committee is working on the following work items which are currently expected to be published during 1997. The results are intended to be of relevance to clauses 6.3 and 6.4 of this ETS.

- DI/TM-01030: "Transmission and Multiplexing (TM); Fibre optic branching devices"; (Draft I-ETS).

- DI/TM-01031: "Transmission and Multiplexing (TM); Fixed optical attenuators"; (Draft I-ETS).

- DI/TM-01032: "Transmission and Multiplexing (TM); Fusion splices"; (Draft I-ETS).

- MI/TM-01023 (1991): "Transmission and Multiplexing (TM); Optical fibre ribbons and ribbon cables, general study and liaison".

History

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