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Fibre optic access to end-user — A guideline to building of FTTX fibre optic network

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National foreword

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English version

**Fibre optic access to end-user -
A guideline to building of FTTX fibre optic network**

Accès à l'utilisateur par fibres optiques -
Lignes directrices relatives à la
construction d'un réseau en fibres
optiques de type FttX

Lichtwellenleiterzugang zum Endkunden -
Leitfaden für die Erstellung von FTTx-
Lichtwellenleiternetzen

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

This document (CLC/TR 50510:2012) has been prepared by CLC/TC 86A, "Optical fibres and optical fibre cables".

This document supersedes CLC/TR 50510:2007.

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Executive summary

The abbreviation FTTx refers to grids using fibres in the terminal area, meaning beyond the last exchange Central Office. “x” thereby denotes different penetration levels, for instance:

- FTTC = Fibre to the Curb, meaning to the street (to the last cabinet);
- FTTB = Fibre to the Building, meaning to the building, normally into the basement;
- FTTH = Fibre to the Home, meaning into the residential area.

Most FTTx networks are designed without any active equipment in the external network and are therefore classified as passive optical networks. The only active equipment is at the central office and the customer premises. FTTH - PON networks can be designed around different architectures.

The purpose of this Technical Report is to be a first guideline for those considering to install a high bandwidth (high bit-rate) FTTx-network. After studying the Technical Report operators, communities, energy companies, installers and others will understand the necessary steps to take to plan and install FTTx-networks with high quality and cost effectiveness, and to secure a uniform structure and a high quality level on such networks.

The main part of this Technical Report describes the FTTx-networks, but Clause 2 also contains more general information to give an understanding as to how these networks fit into the planning of other network infrastructures.

FTTx has for many years been regarded as the most future-proof technique for transmission of broadband multi-media applications. The building of FTTx-networks has previously been prevented by high costs. New investigations show, however, that the cost to install a new fibre based network (100 Mbit/s) is a little less than to install a new copper network. The FTTx-network is also the only structure, which with certainty can offer both the present and the future needs, which broadband access services require. At the same time the technique allows efficient operating maintenance and cost savings.

The networks to be presented are usually called FTTx, but with the strategy described here fibre networks can reach any point in the network. The end-user can be separate homes, houses, office environments, optoelectrical transitions in equipment for alarms, surveillance, monitoring devices etc.

The Technical Report also describes recommendations and gives basic requirements to be fulfilled by an optical fibre installation in an FTTx-network to satisfy present and future requirements on capacity, transmission distance and network quality. As a target, the minimum capacity is set to 1 Gbit/s (1 000 Mbit/s) up to 10 km distance. Relevant types of single-mode optical fibres are specified in EN 60793-2-50. However, in the industry single-mode optical fibre is typically described by the relevant ITU-T recommendations. The physical network should have an expected lifetime of at least 25 years.

The recommendations are written for a general audience, but in particular for people involved in private and public enterprises, people responsible for broadband decisions, planning, training and installations.

The Technical Report is divided into eight clauses:

- Clause 1 introduces the term “broadband” and its background.
- Clause 2 introduces the telecommunications infrastructures and provides an overview of the basic structure for the FTTx network.
- Clause 3 describes system implementations for FTTx including requirements on products and installation techniques.
- Clause 4 provides guidance on how to create a network and gives an overview of applicable network topologies.
- Clause 5 provides basic information in relation to various installation practises and the planning relevant to those practises.

- Clause 6 addresses installation of the FTTx network.
- Clause 7 addresses the testing, documentation and maintenance of the installed network.
- Clause 8 addresses the overall quality.

A number of annexes are included to give deeper knowledge in certain areas. They are broad examples and can be used to give a better view on the principles for installation of FTTx-networks with cables, microduct optical fibre cables, microducts and blown fibre units. To some extent these annexes are company specific, which the reader should be aware of. Annex A (reference [1]) gives a comprehensive list of standards. References [2], [3], [5] and [6] give a good overview of the present status in ITU-T, IEC and the general CENELEC view.

Some of the requirements put forward in this Technical Report are unique for an FTTx-network and should not be used in a general sense for optical networks.

1 Introduction to Broadband

Communication today is digital and therefore sound, pictures, voice, data carried by networks are data expressed in terms of bit, bytes and their multiples (kilo (k), mega (M), giga (G), tera (T)). A bit (binary digit) is the smallest digital unit and has only two values: 0 or 1. A byte includes 8 bits and defines the size of a data file. Transmission capacity of networks and terminals is not expressed by using bytes, but using bit per second (Bit/s). When a data file is transferred in a network two supplementary bits are necessary. It means that 10 bits are required for 1 byte.

A subscriber who wants to download or upload a large file must wait for data transfer to be accomplished. This time depends on the file size; say 100 MB, and transmission speed. In most networks, like VDSL or cable, transmission speeds are asymmetrical, with download (data transfer towards the user) being faster than upload (data transfer from the user), e.g. 100 Mbit/s and 4 Mbit/s, respectively commonly offered using DOCSIS 3.0 technology. At these speeds, it takes just 8 s to download a 100 MB file, but as much as 200 s (3 min 20 s) to upload it. In ADSL networks, typical download and upload speeds are 15 Mbit/s and 1 Mbit/s, corresponding file transfer times being 53 s and 800 s (13 min 20 s) respectively.

Actual transmission speed in many networks is lower than advertised and vary with traffic load due to oversubscription of shared system capacity. This problem does not exist in point-to-point (P2P) fibre networks without capacity sharing, where 1 Gbit/s symmetrical transmission speed is currently possible.

While users of passively split FTTx network do share common capacity, it is large, for example 2,5 Gbit/s in a GPON system, so fast and reasonably symmetrical service can be offered, like 100/50 Mbit/s or 100/25 Mbit/s.

The following table gives examples of transmission times for downloading a 6,25 GB file with high quality DVD movie.

Transmission speed	Download time	Access technology
0,128 Mbit/s	5 days, 8 h	Dial-up
10 Mbit/s	8 h	VDSL
100 Mbit/s	48 min	DOCSIS 3.0, GPON, EPON
1 000 Mbit/s	50 s	P2P fibre access

We do not know all future applications, however existing technologies of today, such as video on demand and the exchange of medical data e.g. for Ambient Assisted Living (AAL), offer an outlook on the future usage of broadband networks.

For the purpose of this document the following classifications will be used:

- low bit rate transmission: up to 1 Mbit/s
- medium bit rate transmission: 1 up to 10 Mbit/s
- high bit rate transmission: 10 up to 100 Mbit/s
- Very high bit rate transmission: 1 Gbit/s and more.

2 Network Structure and Nodes

2.1 General

This clause provides an overview of the FTTx networks and provides a foundation for any terminology and references made from subsequent clauses in this Technical Report.

2.2 Network Layers

2.2.1 Overview

For a level-designed view on the components in the build-up of the infrastructure, see Figure 1.

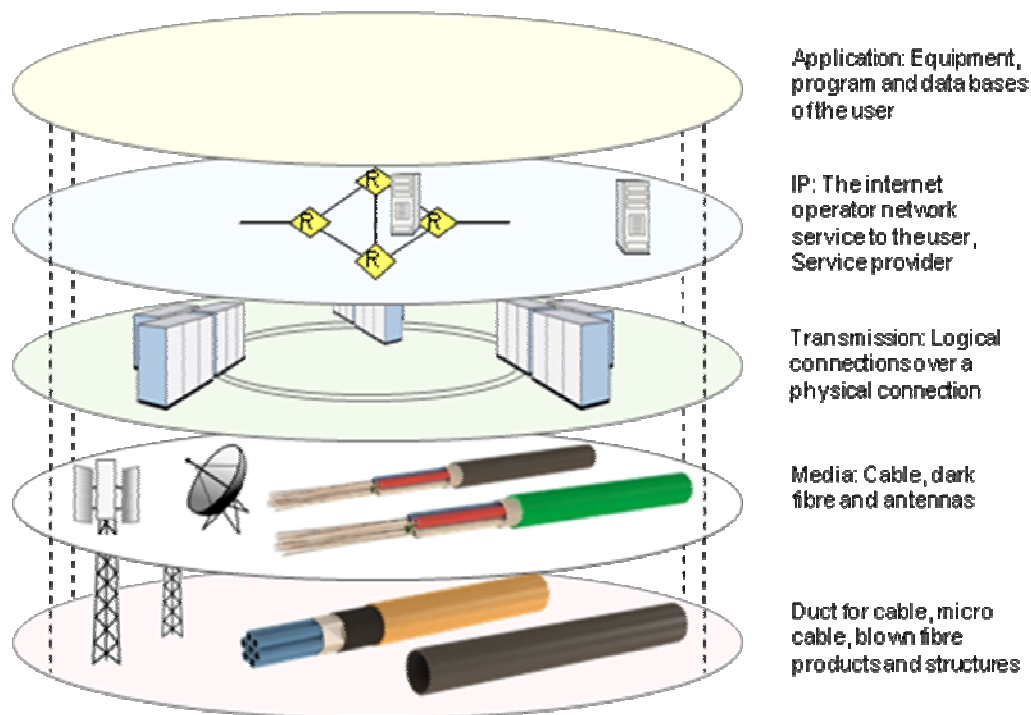


Figure 1 – Network layers

From the bottom up, Figure 1 shows the following network layers:

- Physical routing: Duct for cables, for microduct optical fibre cables, and for microduct fibre unit cables (blown fibre products) and for structures for antennas
- Passive transmission and interconnecting media: optical fibre cable, connectors, antennas, boxes, closures and their physical interconnections
- Active transmission systems: Logical connections over a physical connection
- IP: The internet operator network service to the user
- Application: Equipment, program and data bases of the user

Designing the infrastructure in layers makes it possible for different ownership of individual layers. This creates possibilities for open networks and competition, but also presents risks regarding responsibilities and long-term interaction.

2.2.2 Physical routing

The lowest layer in the physical network is the physical routing. It consists of ducts in standard dimensions, antenna structures, network components and microducts among others. Also existing infrastructure tubing such as sewer-, gas-, and drinking water tubes may be used. The physical routing should have an expected lifetime of 25 years.

This Technical Report describes the physical routing as applied to FTTx infrastructures. Most of the cost for a broadband network is in the planning and installation of the routing layer. It is therefore important to be accurate in planning, installation and documentation, and that the material of the parts used is of high quality. Applying an advanced Network Software Suite for the design, deployment and registration of the passive network, as readily available today, is essential to optimize the network design and to reduce costs. Normally the network owner owns this level.

2.2.3 Passive transmission media

This layer contains optical fibres (cable, microcable, indoor- and outdoor-cable, blown fibre units etc.), interconnecting devices (connectors, splices, closures etc.), copper cables (not treated here) and antennas for wireless access (FWA, WLAN, 2G, 3G, 4G, LMDS, LTE) as well not treated here.

This Technical Report describes the passive transmission media as applied to FTTx infrastructures.

The installation of single-mode optical fibres within FTTx-networks provides the longest operational lifetime due to its transmission performance. Cables containing those optical fibres are expected to have design lifetimes consistent with those of the physical routing components of 2.2.2.

Cables should be installed in ducts to minimise costs where network growth requires additional cables to be installed and when cables need to be repaired or replaced.

The network owner typically owns the cables and the optical fibres.

2.2.4 Transmission-, IP- and application layer

The transmission-, IP- and application layer will not be described in this Technical Report.

2.2.5 Ownership, operating and maintenance

When all parts in the infrastructure fulfil specified quality requirements regarding transmission and installation, different ownerships could be possible. Ownership and operation could be split by different governmental or community companies, jointly owned companies between different communities, energy companies, building enterprises. Housing co-operatives, house-owner associations, private persons and landowners may also own the local network closest to the end-users.

Considering operation and maintenance the network level owners have to specify acceptable downtimes.

2.3 Network topology – Terminology

2.3.1 Overview on Infrastructure

To get an overall picture of optical fibre networks it is necessary to explain some of the terminology and concepts used.

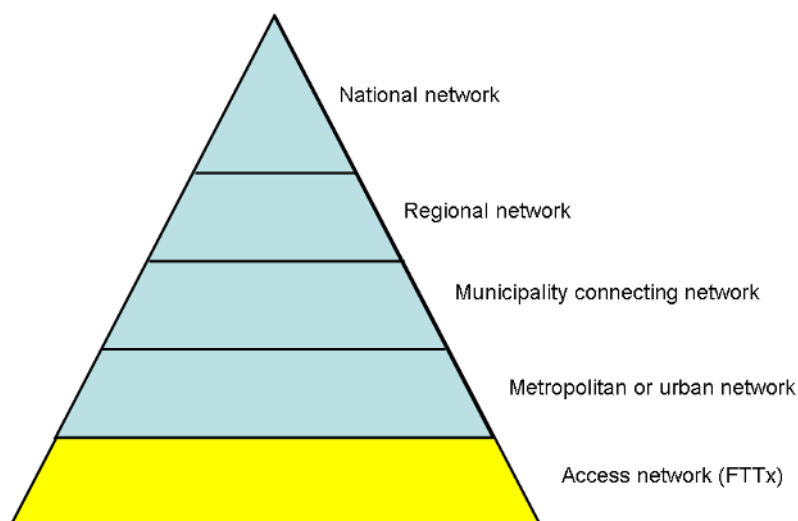


Figure 2 – The network is hierarchically built up

The traffic volumes and requirements for capacity, functionality and availability increase with the network level. Therefore the strategic significance and requirements for protection and security also increase in the higher network levels. All IP-traffic can be distributed, which means that this hierarchy may be flattened in a few years. The present network is a combination of a traditional telephone- and a future IP-network, which can be described as in Figures 2 to 7. This means that the information can find the best route when alternative routes are available.

The highest level is the national network, see Figure 2 and the lowest (colour-marked) is the network for connecting end-users or subscribers and is focussed on in this Technical Report.

2.3.2 National network

The national network connects all regions in the country and is connected to international networks. This type of network has a very high security level. A national network has normally few owners.

2.3.3 Regional network

A regional network or a community-connecting network connects networks within a region. Networks within a region often consist of municipality-connecting networks from different communities. A regional network is then connected to the national network.

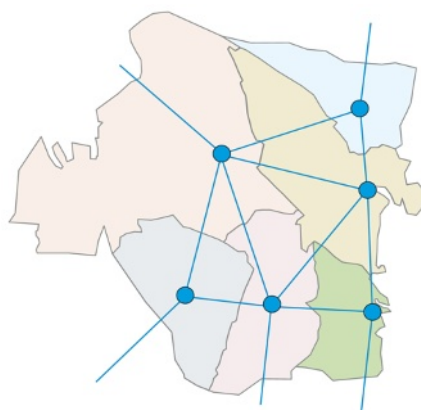


Figure 3 – A regional network, e.g. in a county

Some of the municipality-connecting networks can be connected to nearby regions (Figure 3).

2.3.4 Municipality connecting network

Municipality-connecting networks connect different municipalities (places) within a community. These networks are in turn connected upwards to regional networks or community-connecting networks and downwards to access networks. The connection is made through the community main node.

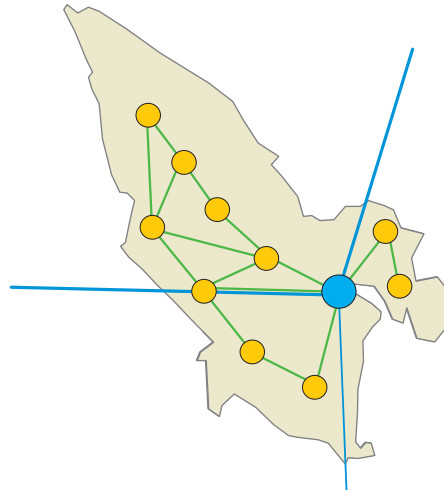


Figure 4 – The municipality-connecting network connects the larger places within a community

In each place there are one or more nodes, access nodes (possibly also distribution nodes), which connects the end-user – the subscriber (Figure 4).

2.3.5 Metropolitan or urban network

City (metropolitan) or urban networks are networks within a city or in a sparsely populated area. The function is to give a broadband infrastructure, which meets a long-term need using cost-effective solutions enabling the access networks to reach subscribers. This can be achieved by using existing or planned networks of different kinds. These networks are directly connected to the main node or to a distribution node (redundancy). Access nodes are connected along the ring structure (Figure 5).



Figure 5 – The metropolitan or urban network, the red lines, connects areas in a thinly populated area

2.3.6 Access network

The network levels described in 2.3.2 to 2.3.5 are normally installed on public land. In contrast, parts of the access network may be installed on private properties or land. Subscribers from houses, terraced houses, blocks of flats, companies, hospitals and authorities can be connected to the access network. Also masts for FWA (Fixed Wireless Access) or WLAN (Wireless LAN) and antennas for the mobile network can be connected. Furthermore equipment for security, surveillance, fire-alarms and control equipment can be connected.

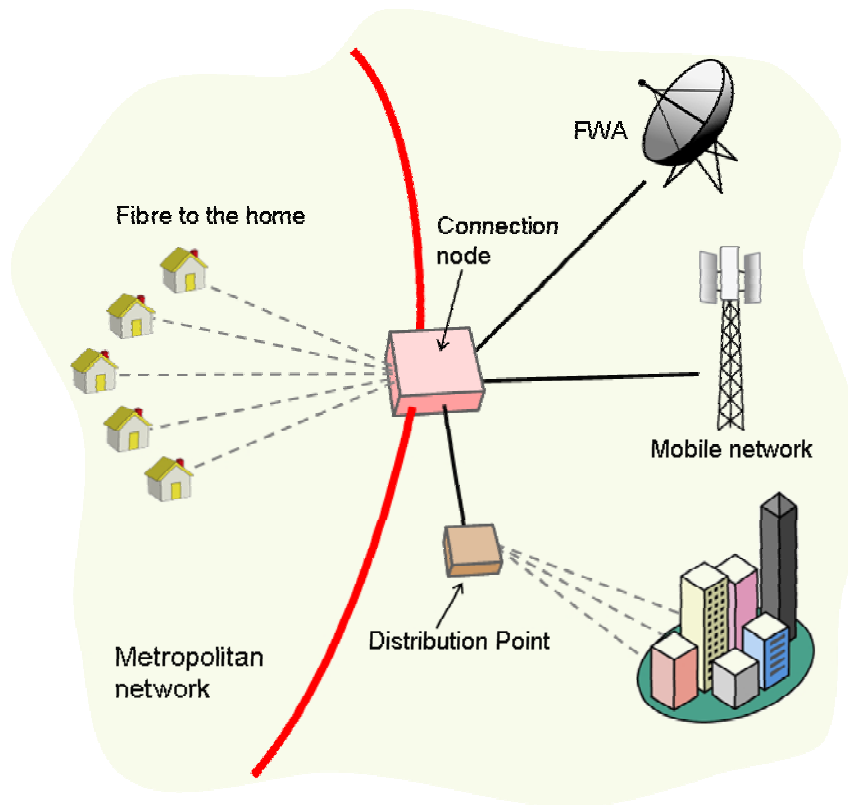


Figure 6 – The access network connects a large number of end-users

2.4 Nodes – Topology and Terminology

2.4.1 Overview

There are a number of junctions (also known as nodes) in a broadband network, where single traffic flows are mixed, multiplexed and de-multiplexed to create an efficient flow through the network. In the nodes the routing and switching of the data packages is performed. Joint traffic between different network owners or operators is also possible. The largest number of nodes will be used for the connection of the end-customers.

The nodes are spaces filled with transmission equipment, ODFs (Optical Distribution Frames), cross-connect devices, splice boxes, uninterruptible power supplies and equipment for climate control.

The design of the access node will be briefly described in the following but other types of nodes will not be discussed, except for a few comments.

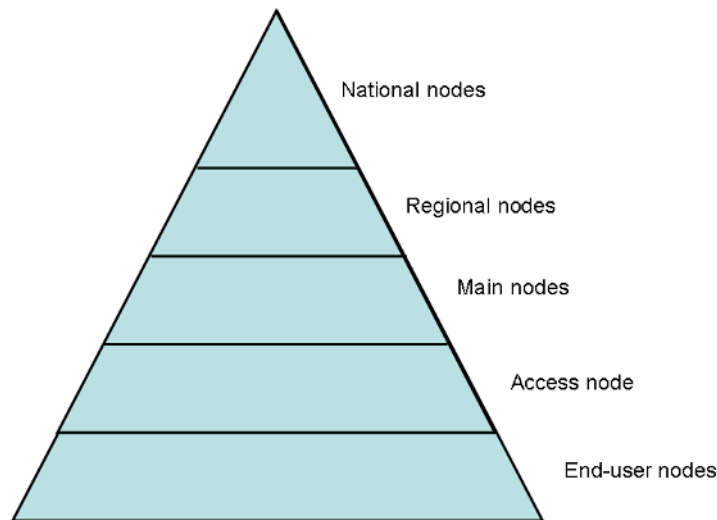


Figure 7 – Node hierarchy

2.4.2 National node

A national node is connected to several national and international networks and therefore have to have a high security level.

2.4.3 Regional node

A regional node is connected to a national network, regional and municipality network.

2.4.4 Main node

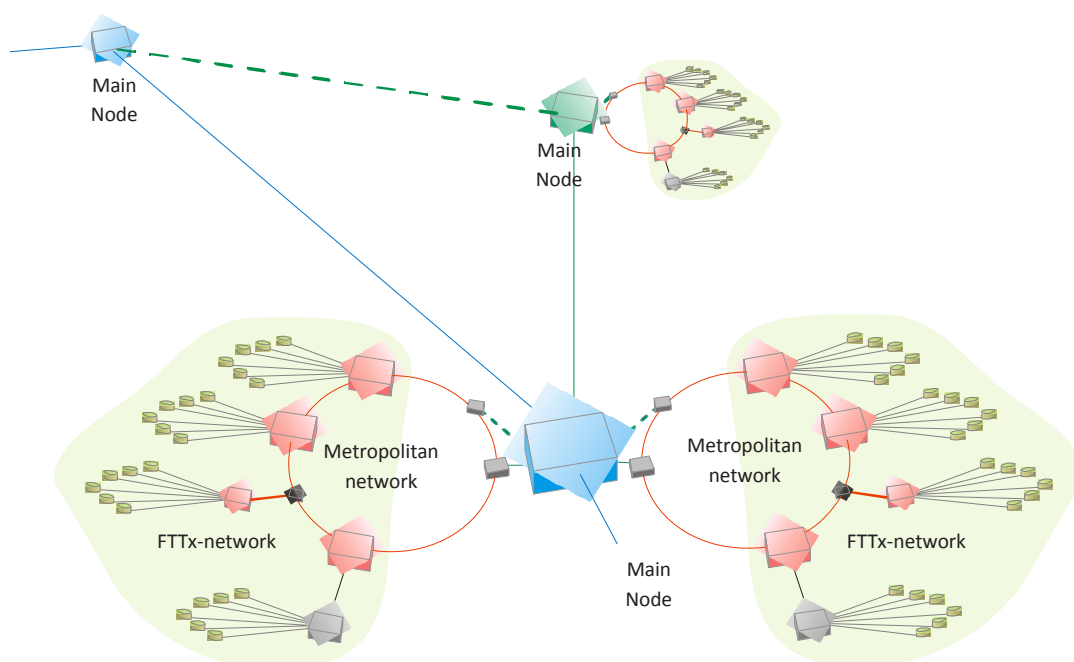
There are main nodes in a community which are connected to a regional network or a municipality-connecting network in the same community. Such a node should contain equipment and connections to the higher level network to provide redundancy.

In small places the end-user may be connected directly to a main node through the access network.

2.4.5 Access node

The access node is connecting the metropolitan network with the end-user via the access network.

It will be described more in detail later in the Technical Report.



NOTE The access network is here defined as FTTx

Figure 8 – A comprehensive picture over a community network

2.5 Examples of FTTx topologies

The following four pictures give some simple illustrations of to P2P and passive optical networks (PON). P2P is in general passive, where one fibre from central office is routed directly to the customer and does not use splitters. For PON (in general point to multi point) one fibre from the central office is shared among a number of customers (usually 32) by the use of one passive splitter located within the network. For example, in a “converged PON” a number of passive splitters are located together, whilst in a “distributed PON” each passive splitter is located separately within the network.

The pictures are examples from different countries in Europe. See also the Glossary. PON can also be explained as power splitting point-to-multipoint.

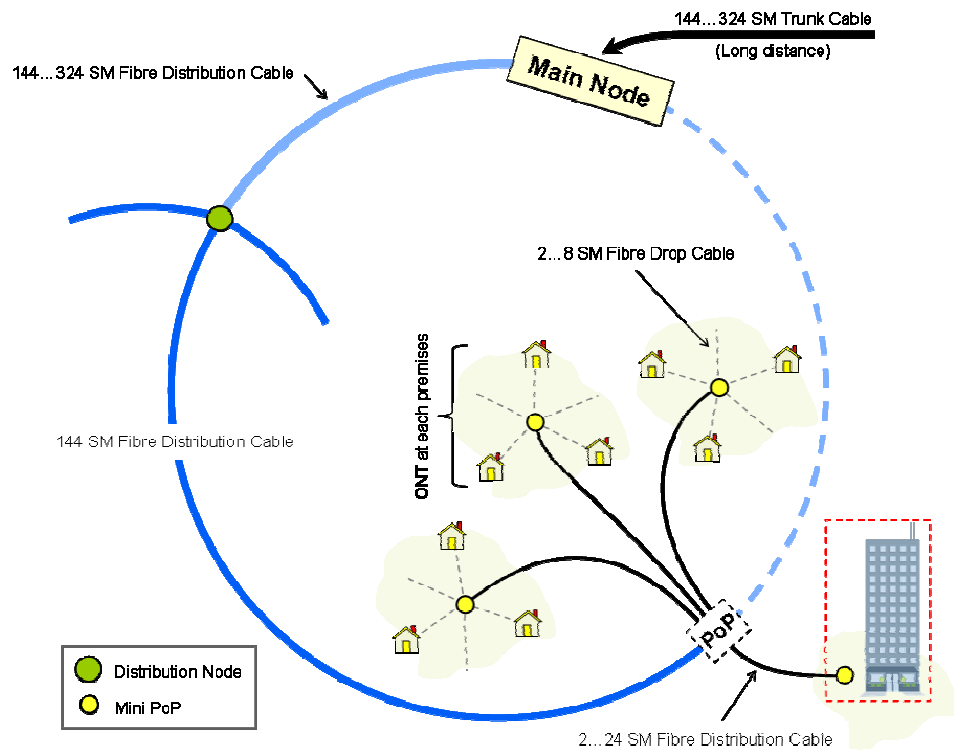


Figure 9 – Example for a Point-to-Point/Access Network

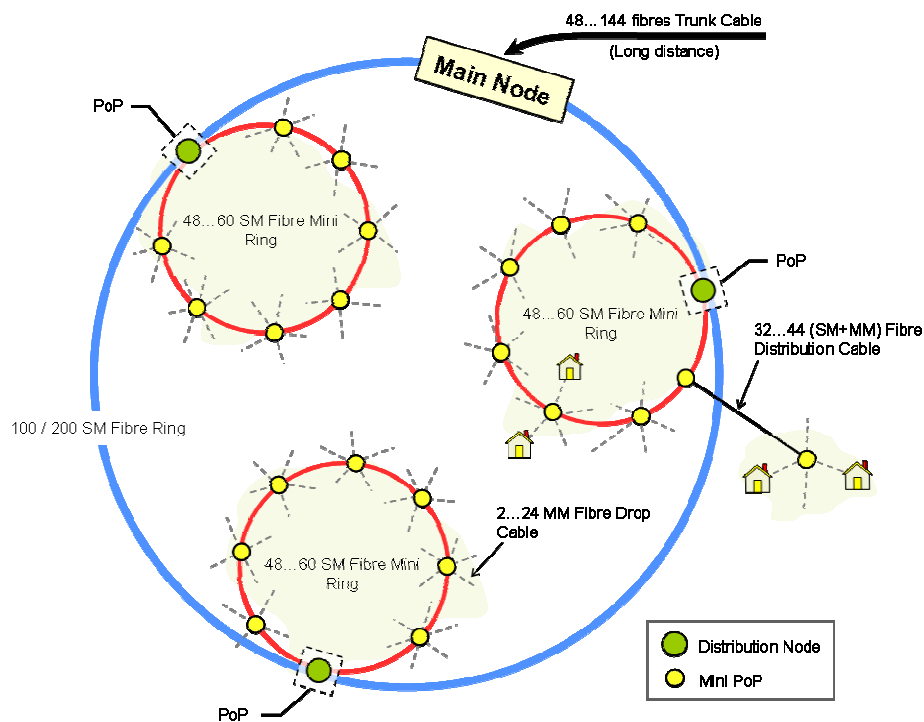


Figure 10 – Example of a Metro/Access Network

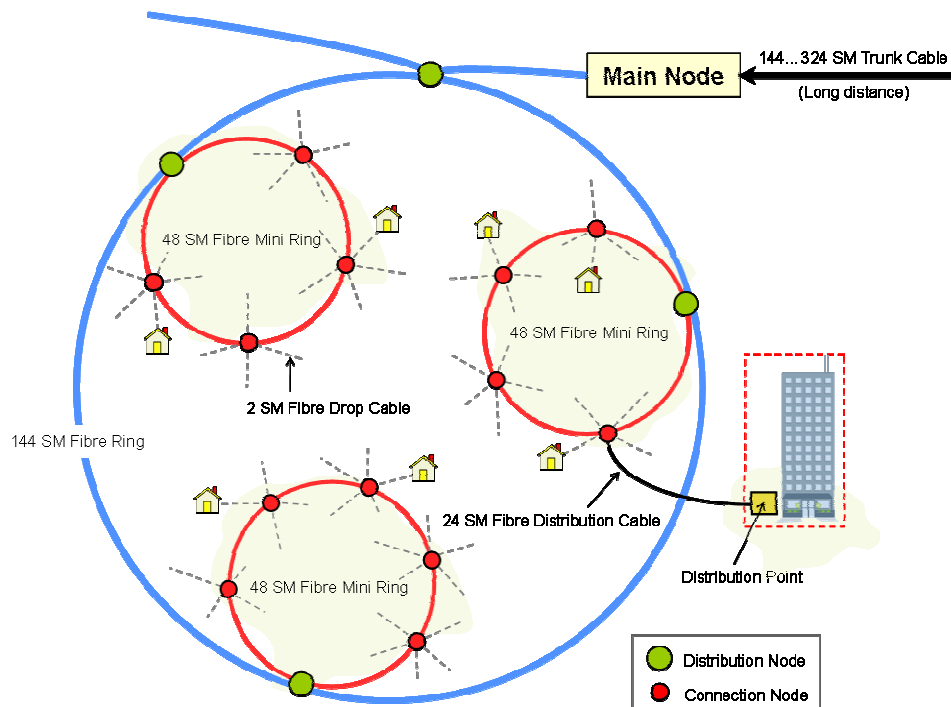


Figure 11 – Second example of a Metro/Access Network

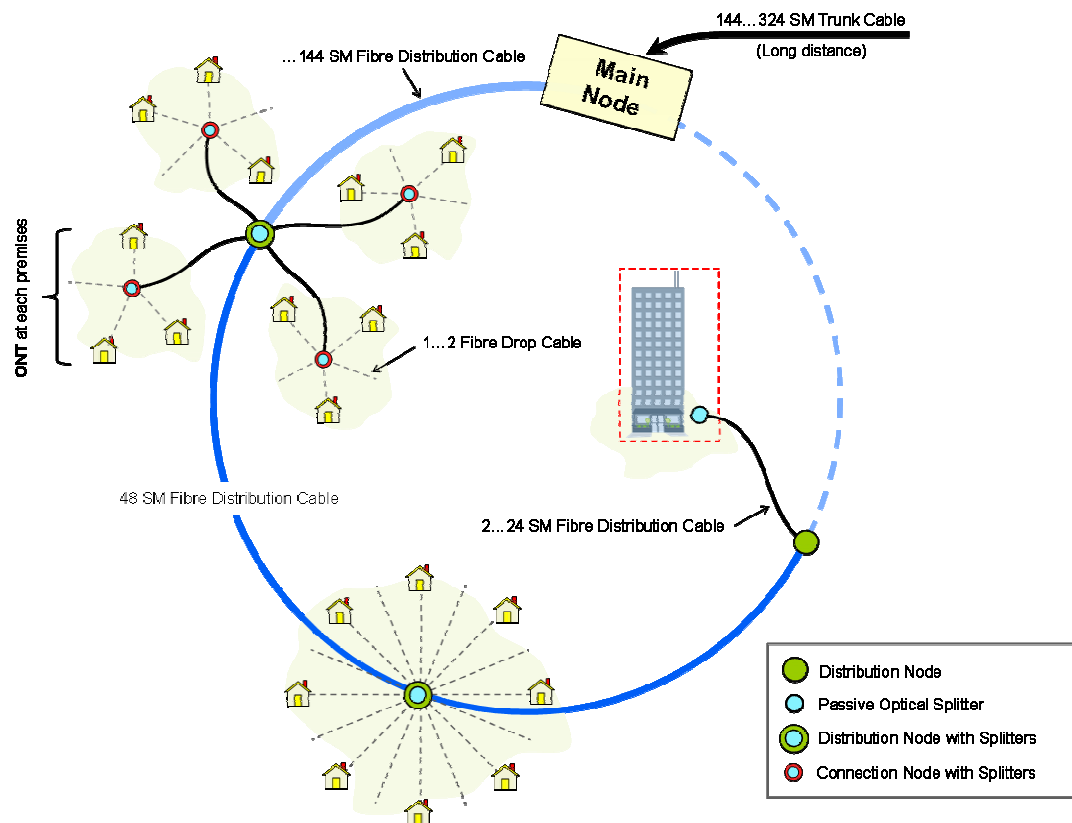


Figure 12 – Example for a Passive Optical Network (PON)

2.6 FTTx in the access network

2.6.1 Overview

The network, which connects each end-user to the access node, is called the access network. The network is normally part of the real property. The access network may consist of a network inside a house and/or a network between several buildings. It can therefore include an area with block of flats, houses, industrial areas, schools, hospitals or offices.

The access network is the most complex network within the fibre optic IT-infrastructure. Each access network is unique and requires special planning to be optimised in all aspects. The reader is assured that there are a number of solutions, which can be used as a base, see Annexes D and E.

2.6.2 FTTx in access networks

FTTx is often called the fibre access network. Here it is defined as the connection from a USER NODE in e.g. a private home to an ACCESS NODE. It is therefore the part of the IT-structure, where there is not a general redundancy requirement the fibres and can be connected like a star from the access node to the user, see Figure 6.

Note that in many areas with privately owned access networks the active equipment is placed close to the building in a house property node. This network will therefore be rather short in distance. A number of property nodes are then concentrated to an access node. This structure implies in many cases lower costs. Even working and maintenance expenses will increase for an area with active equipment in several nodes.

3 FTTx passive network products and system implementations

3.1 General

This clause provides information on optical fibres, connectors, splices, link designs and optical power budgets. Although optical fibre cables look similar to copper cables on the outside there are many differences in relation to design and handling. This clause discusses optical fibre cable technology and various installation techniques.

3.2 Optical fibres

3.2.1 Triple play and general about new fibres

In telecommunications, triple play service is a marketing term for the provisioning of two bandwidth-intensive services, high speed internet access and television, and a less bandwidth-demanding (but more latency-sensitive) service, telephone, over a single broadband connection.

Typical transmission wavelengths used for downstream are 1490 nm and 1550 nm and for upstream 1310 nm. Therefore it is important to understand what kind of problems may occur depending on wavelength. Is it a microbend or macrobend problem?

Added loss due to microbending occurs when localized lateral forces along the length of the fibre appear. These may be caused by manufacturing and installation strains, as well as dimensional variations in the cable materials due to temperature changes. Sensitivity to microbending is a function of the difference of refractive index of the core and the cladding, and diameters of the core and cladding. Coating structure and material property have also an influence.

The effect of microbending in single-mode fibres is increasing optical loss at 1310 nm, 1550 nm and 1625 nm wavelength ranges as opposed to macrobend effects in single-mode fibres that are primarily present at the longer wavelengths of 1550 nm and 1625 nm.

To reduce microbending losses the cable structure must protect the optical fibres from lateral forces. Loose tube cable construction should be optimized to prevent buckling of the fibre in the tube during temperature changes leading to possible macrobending as well as microbending loss.

Cable components such as the cable sheath and the strength member are important because they also help to reduce the microbending caused by the external mechanical forces on the cable and by temperature changes.

Microbending losses may also be introduced in aerial cables subjected to excessive elongation (e.g. heavy ice loading).

Since 2006 an optical bend-insensitive single-mode fibre has been added as a new fibre category: ITU-T G.657 "Characteristics of a bending-loss insensitive single-mode optical fibre and cable for the access network". The rationale behind this new fibre was a demand to install fibres with tighter bends. However, the most common fibre today is still ITU-T G.652.D.

3.2.2 Choice of optical fibre type

The choice of optical fibre is determined by several parameters. The most important are:

- system costs,
- distance,
- transmission bit-rate.

The advantages of a single-mode fibre are high transmission capacity and low optical attenuation. If a single-mode fibre is used in FTTx, the same type can be used throughout the network, which gives transparency and uniformity. This also simplifies service, maintenance and new developments. Another advantage is that only tools and instruments for single-mode fibres need to be procured.

Table 1 – Single-mode fibre types as defined in ITU and EN/IEC

Single-mode (SM)	EN/IEC 60793-2-50	ITU-T
Unshifted dispersion	B1.1	G.652.A, B
Cut-off-shifted	B1.2	G.654
Low water peak	B1.3	G.652.C, D
Bending loss insensitive unshifted dispersion	B6_a1, a2, b2, b3	G.657.A1, A2, B2, B3
Dispersion-shifted	B2	G.653
Nonzero dispersion-shifted	B4	G.655, G.656

For FTTx-infrastructures single-mode optical fibre should be used. Recommended types are G.652.D in general, G.657.A1, A2 for access and G.657.B2, B3 for in-building networks.

The type G.652.D allows Coarse Wavelength Division Multiplexing (CWDM). This is a cost-effective way to transmit optical signals over multiple wavelengths.

The G.657 fibres are specially designed for the Access Network in terms of reduced bending sensitivity (including applications inside buildings). Types A1 and A2 are fully compliant to G.652.D for all other transmission parameters; types B2 and B3 may deviate from G.652.D in terms of mode field diameter, chromatic dispersion and Polarisation Mode Dispersion (PMD), but its bending sensitivity is further reduced compared to type A1.

Table 2 shows some optical properties for single-mode fibres. A schematic of the geometry is given in Figure 13.

Table 2 – Example of properties for single-mode fibres for FTTx

Single-mode fibre		Typical cabled attenuation (dB/km)	
EN/IEC 60793-2-50	ITU-T	1 310 nm	1 550 nm
B1.3 B6	G.652.D, G.657.A1, A2, B2, B3	≤ 0,36	≤ 0,25

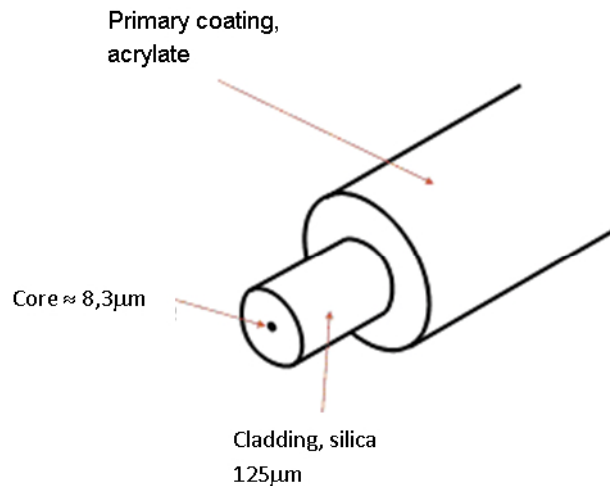


Figure 13 – Single-mode optical fibre geometry

3.2.3 Number of optical fibres provided to each end-user

The total number of fibres for each end-user is depending on the use of opto-electrical components in the network and installation technique. Most systems for point-to-point connections are based upon two-fibre solutions with one fibre up- and one downlink.

There are also systems based upon Wavelength Division Multiplexing (WDM) techniques, where the up- and downlink is on the same optical fibre, but using different wavelengths, which require only half the quantities of optical fibres, splices and connectors.

When the network is dimensioned it is necessary to take into account future possible requirements such as new establishments, alarms, different providers et cetera.

Different systems in the future may need more fibres.

Therefore:

- Each end-user should be provided with at least two optical fibres even if only one optical fibre is used initially.
- It is possible to add optical fibres where the end-user is served by microducts which allow either traditional installation or blowing techniques.

It is not necessary to mount connectors on unused fibres. Unused fibres can be stored in splice boxes or panels.

3.3 Cables and ducts

3.3.1 Cables

The installation of optical fibre cable can be performed by and/or in combination of:

1. Laying of direct buried fibre optic cable directly into the ground.
2. Laying of HDPE ducts and consequently blow or pull in duct type fibre optic cables.
3. Laying of a microduct system and consequently blow in micro fibre optic cable or blown fibre units.

For wide spread access networks such as residential and/or industrial areas a combination of these microduct optical fibre cables, blown fibre units, fibre optic duct cables and/or direct buried fibre optic cables may be used. Ducts / microducts can be installed from areas/buildings to one or several concentration points. Depending on technique micro fibre optic cables or blown fibre unit can be blown into the microducts from different directions.

In Figure 14 a short schematic/overview of fibre optical cable designs are shown, all of them being possible parts within the FTTx-network.

A more complete overview of the different cable constructions including the extractable cable design are given in Annex B.

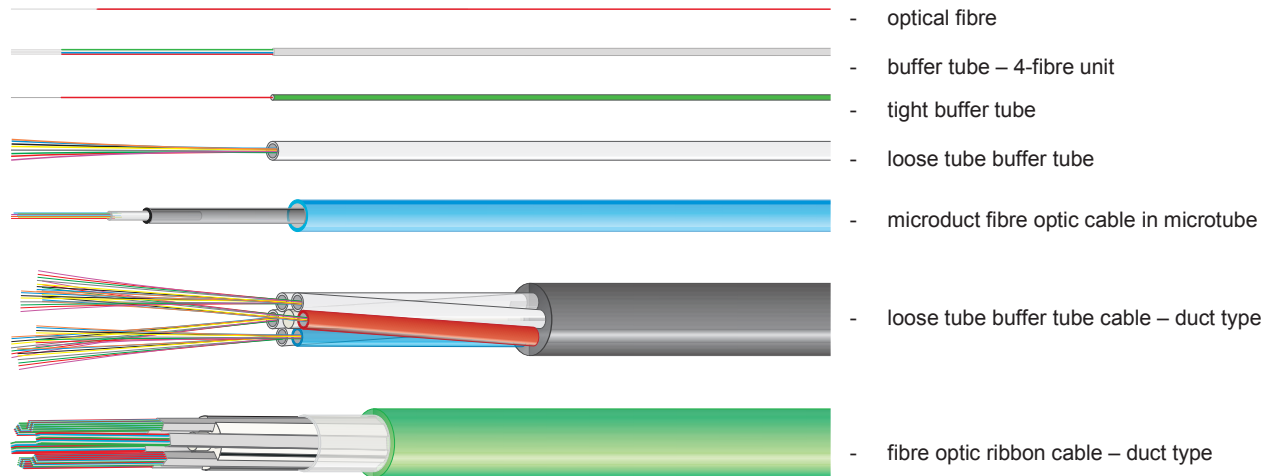
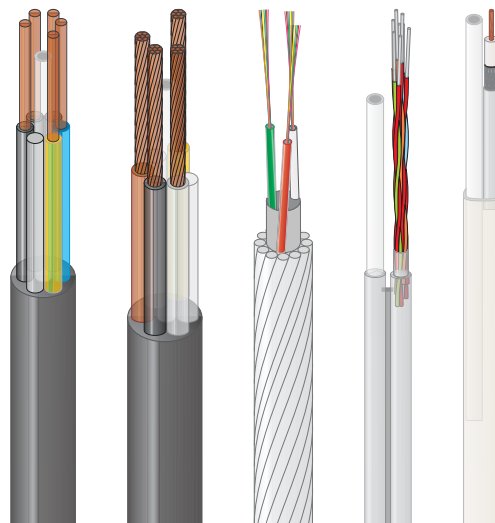


Figure 14 – Constructions of optical fibres/cables in FTTx infrastructures

3.3.2 Hybrid cables

At new constructions, hybrid cables for electricity and fibre optics can be installed. It is also possible to install a power cable or a telecom copper pair cable with microducts and later blow the fibre. This reduces the cost for the fibre optic installation. A number of variant hybrid cables exist; see Figure 15 for some examples: power cables with microducts for fibre blowing, and with built-in fibre (OPGW, optical ground wire) to feed to the connection node through the high tension voltage network. Figure 15 also shows microducts in combination with twisted pair cables and a combination with coax cables.



From left to right: A power cable with five conductors of 10 mm² and a centred microduct, a cable with four conductors of 16 mm² and a centred microduct, an OPGW cable, a combination of microduct and twisted pair, and finally a combination of microduct and coax cable.

Figure 15 – Examples of hybrid cables

3.3.3 Outdoor

From access node (Point Of Presence) to Distribution Point (DP):

A microduct system with microduct cables or optical cables in ducts or direct buried.

From distribution point to customer:

A microduct system with microduct optical fibre cables or microduct fibre unit cables or a direct buried cable.

Aerial cable installations should be taken into account as a possible solution.

3.3.4 Indoor

Flame retardant/halogen free components should be used.

Inside buildings and construction work the cable installations – including cable, installation materials - have to be protected against fire also in accordance to the local fire regulations based on the European Legislation on CPD/CPR valid for all European Member states distinguishing between 'reaction to fire' and 'resistance to fire'.

The procedural instructions are given / published in the mandated standards:

- classification standard for reaction to fire (B2, C, D, E, F)
- product standard for reaction to fire including third body certification and CE marking
- test standards for reaction to fire
- Classification standard for resistance to fire (p-, ph-classification; 15 min, 30 min, ...)
- Product standard for resistance to fire including third body certification and CE marking
- Test standards for resistance to fire
 - cable diameter $\Phi \leq 20$ mm
 - cable diameter $\Phi > 20$ mm

3.3.5 Blown fibre units

Optical fibre cables and optical fibre units for blowing in microducts offer the advantage of flexible extensions according to the needs and of distributing the financial investments according to the connection rate over a longer period of time in a "pay as you grow" approach.

Blown fibre units exist in several types, typically from 1 to 12 fibres. When more than one fibre is blown, it is necessary to identify the fibres for easier handling. Ribbons or bundled fibres can be used.

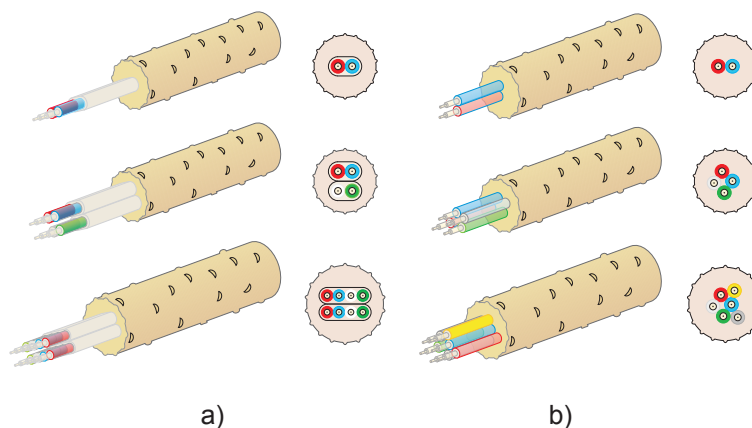


Figure 16 – Some examples of blown fibre units

The roughened surface is there to improve blowing. The units can be built from ribbons (Figure 16a) or single fibres (Figure 16b).

3.3.6 Microduct optical fibre cables for blowing

In the market there are systems with very thin cables up to 216 f, which are blown into microducts. This technique can also be used to replace traditional cable techniques and to concentrate fibres for several subscribers in the network. One specific requirement for microduct optical fibre cables is to use the specified type and dimensions to secure a standardized development of the network.



Figure 17 – Microduct with blown microduct optical cable

3.3.7 Cables for blowing

Almost all optical cables can be blown over a certain distance when the correct cable and duct characteristics are selected. The ratio of the cable diameter and inner duct diameter has to be limited to about 0,65. Low friction materials should be applied for the cable sheath and the inner duct surface. The cable stiffness has to be limited.

3.3.8 Dimensions for microducts and multi duct bundles

In Figure 18, examples of different designs of microducts and multiduct bundles for the use of optical fibre micro cables and/or blown fibre units are given:



Figure 18 - Examples of microducts / microduct bundles

Different rules may be required for different countries related to indoor and outdoor ducts.

Microduct systems are developed and tested as a complete system. They are available as single and multiple microduct constructions and are constructed both with and without additional protection layers.

Microducts are used for the blowing in of optical fibre micro cables and/or blown optical fibre units. Additional microduct optical fibre cables or optical fibre units may be blown into them also in later stage, as illustrated in Figures 16 and 17

The number of microducts in a bundle depends upon the technical solution. A general recommendation employs larger number of microducts for longer routes.

It is recommended to install enough microducts in order to be able to provide connections to all future subscribers in a given area with one microduct for each potential dwelling.

There are in principal two technical solutions for microducts:

- a microduct optical fibre cable is installed into the microduct. The cable generally has a sheath, a strength member and may be gel-filled. The microduct does not need to be humidity protected since the cable provides adequate protection;
- single optical fibres or blown optical fibre units are installed into a microduct which provides humidity protection. For an outdoor solution all joints needs to be humidity protected.

Microducts exist in different designs:

- loose microducts for installations in new or existing HDPE-ducts of typical sizes (16/12, 25/21, 32/26, 40/32 or 50/41). With special equipment, it is possible to install these types of microducts next to existing cables in larger ducts;
- multi ducts consisting of preinstalled loose microducts in a conventional HDPE duct for all buried applications;
- flame retardant, halogen free microducts for indoor installations;
- multi ducts for indoor use;
- multi ducts combined in a larger tube with extra sheath and humidity protection to be used outdoor in a protective standard duct;
- multi ducts combined in a larger duct with extra sheath and humidity protection to be directly buried in soil surrounded with loose sand and no stones;
- outdoor designs for pole assembly. This type can be equipped with a suspension cord or reinforced with aramid yarn to take its own weight at the assembly on the pole.

3.4 Connectivity products

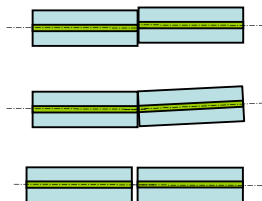
3.4.1 Connectors in the FTTx-network

Fibre optic connectors are passive optical components and are used to align optical fibres together or to connect fibres to transmitters or receivers.

Connectors are designed to be easily demated and are generally used at the end of networks and at other points where reconfiguration may be required. Most connector styles are durable with repeated mating as long as they are kept clean and in good condition.

Connection loss is mainly caused by following factors:

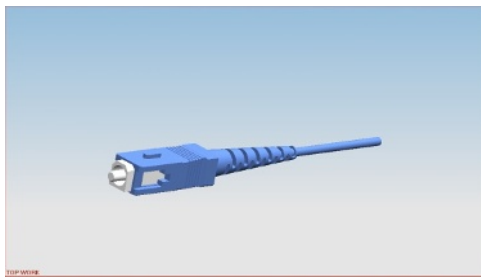
- lateral offset of two aligned fibres
- angular mismatch of two fibre axes
- end face air gap



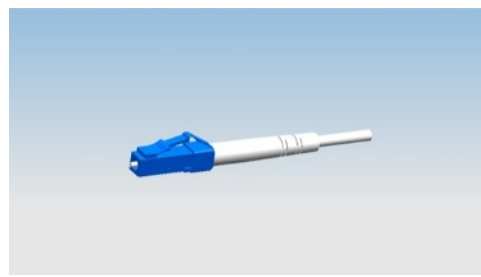
The following criteria and requirements are internationally agreed and published as standards:

- mechanical intermateability,
- optical intermateability,
- optical performance requirements,
- reliability requirements,
- end face geometrical requirement,
- end face cleanliness (dust, contamination, etc.) and polishing condition (scratches, pits, debris, etc.),
- guaranteeing the required performance of connector sets from different suppliers.

A number of different connector types are defined in international standards. They can be distinguished by the size, shape of the body, coupling mechanism and the way the two fibres are held in contact with each other. Normally the connectors of different types cannot be mated together unless hybrid adaptors are used.



SC
(ferrule diameter 2,5 mm)



LC
(ferrule diameter 1,25 mm)

Figure 19 – Examples of ferrule based connector types

Common connector types currently used in FTTx are the SC and the LC style connectors (see figure 19). The LC has a ferrule (the part that holds the fibre) of half the size of the SC and generally two LCs will fit in the space of one SC.

Connectors may be fitted to the cabling in a number of ways. Traditionally either direct field termination, which generally involved polishing the connector end face, or splicing on of connector pigtails have been used. Factory polished field terminated or 'splice-on' connectors are also quite common. These have a factory finished end face with a splice directly at the rear or inside the connector. This avoids the need to find storage for fusion or mechanical splice holders and can be particularly useful at the customer interface. Other connector options include multifibre connectors (frequently 12 fibres) which find applications in multi dwelling units where a number of fibres are required in the riser or horizontal cabling.

The most important parameters in connector choice are attenuation (lost power from the connection) and return loss (the amount of power reflected back from the connection). Attenuation is influenced by the types and parameters of the optical fibres installed. Return loss is influenced by the type of connector and the quality of the assembly. Angled Physical Contact (APC) connectors provide enhanced return loss, better than 55 dB, both when the connectors are mated or unmated by using angled end faces, although Physical Contact (PC) connectors may be polished to give better than 50 dB return loss when mated.

When terminated onto patchcords connectors are sometimes used with one fibre (simplex) or two fibres (duplex)

The deployment and the choice of the connector type depend on the following:

- type already deployed in the system,
- handling required,
- application,
- availability from different sources,
- price,
- space available.

Fibre optic connectors can be mounted in the field or be supplied as pre-connectorised pigtails.

Table 3 summarises the typical optical performance requirements for connections in an FTTx infrastructure:

Table 3 – Typical proposed connection requirements for FTTx infrastructures

Connection type	Optical attenuation, typical dB	Optical attenuation, 97 % value dB	Return loss dB
Single-mode	$\leq 0,25$	$\leq 0,5$	≥ 45 $\geq 60^a$
^a Return loss ≥ 60 dB: For a video overlay network (with analog RF modulation) APC (angled polished connector) are recommended. Higher reflections may result in a distortion or a poor S/N ratio of the video signal.			

3.4.2 Optical fibre splicing

3.4.2.1 General

Permanently joining optical fibre together is called fibre splicing. When splices are made on either primary coated or buffered optical fibres, they are usually stored in a protected environment, such as a tray, with a length of slack fibre to aid resplicing if required. Splices are generally expected to last the lifetime of the cable installation.

Both fusion splicing (using an electric arc to weld the two optical fibres together) and mechanical splicing (aligning two prepared fibres in a protective cover) are used in FTTx. The attenuation of a splice (when like fibre is spliced together) is typically 0,05 dB to 0,3 dB

The deployment and the choice of the splicing type depends on the following:

- Performance required;
- Cost of the splice and splicing equipment;
- Skill level required to make the splice;
- Time required to make the splice;
- Configuration and location of the splicing (mass splicing or a few fibres);
- Power availability for the splicing equipment.

Splice technique can vary due to cable type and transmission requirements and the requirements for demountability and the number of fibres to be spliced. Fusion splicing is typically chosen where there are a large number of splices to be made at one location (a multifibre cable), but closer to the subscriber's premises mechanical splicing or field mountable connectors may be economical choices. The splicing can be done above the surface in special vehicles or in tents. It can also be performed in manholes or in shafts. It is important that the environment is clean and with right humidity and temperature. Recommended splicing temperature is between +10 °C to +30 °C without condensation for fusion splicing machines (due to electronics in splicing machine) and 0 °C to +40 °C for mechanical splicing and connectorisation.

3.4.2.2 Splice boxes

Direct buried cables do not require any special attention compared to duct cables. Each splice point should have the splice box and extra cable in a large cement ring made of plastic or other material.

Splicing of aerial cables should be performed on ground level. Box and extra cable are attached high up on to the pole with special devices. If it is not possible to splice the cable on the ground, it is necessary to use a sky lift or similar.

A protection box for outdoor splicing of microducts/cables or optical cables should:

- be easy to handle and install,

- be easy to open and close without using a lot of extra material,
- give good mechanical protection to the fibres under difficult conditions,
- make it possible to respect the minimum fibre bend radius,
- give the same protection for extra reinforced as not-reinforced duct/cable,
- give the same protection for different diameters of duct/cable,
- give the same protection for buried as for aerial installations.

Splice boxes should work both indoor and outdoor. They should be watertight to withstand water during flooding. Regulations depend on local requirements.

A careful and accurate installation is therefore required. Area of application and number of fibres can vary from box to box.

3.4.3 Pre-connectorised fibre

Today it is a common method to supply fibres and cables with pre-connectorised end(s). Both one-end (pigtails) and double-ended pre-connectorised products (patch cords) are readily available. Traditionally, these cables contain one or two fibres, but it is also possible to use pre-connectorised inner cables with a large number of fibres. In this case the cable terminals must be accordingly protected for the installation. Industrial connectorisation guarantees high quality for the pre-connectorised products and reduces installation time and cost.

3.5 Optical splitters

3.5.1 General

Optical splitters are used in passive optical networks (PON) to divide the outgoing signal and recombine the incoming signal to the subscriber. Two types of splitters may be used, fused biconic taper or planar waveguide

3.5.2 Fused biconic taper technology

Fused biconic tapered splitters (see Figure 20) are:

- made by fusing a section of two parallel fibres;
- available with split ratios up to 1 x 4 (split ratios up to 1 x 32 are built by splicing splitters in a cascade).

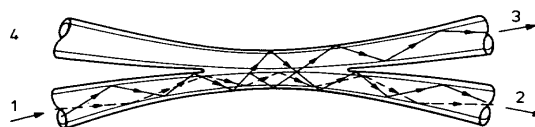


Figure 20 – Fused biconic tapered splitter

3.5.3 Planar splitter technology

Planar splitters (see Figure 21) feature optical paths embedded inside a silica chip and are:

- available with split ratios from 1 x 4 to 1 x 64 (dual input 2 x N possible);
- more compact compared to fusion biconic tapered at higher split ratios (no cascading);
- able to provide lower insertion loss and better uniformity over the complete wavelength range (1 260 nm – 1 625 nm) compared to fusion biconic tapered.

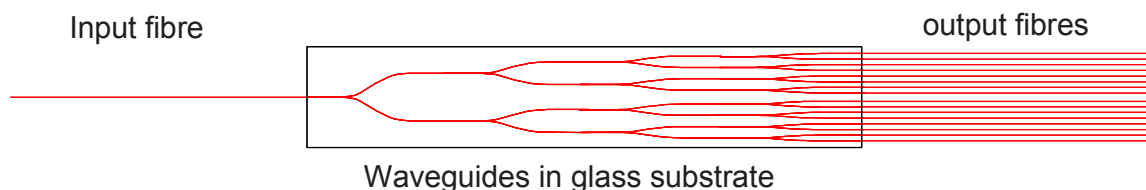


Figure 21 – Planar splitter

3.6 Fibre organisers and closures

3.6.1 Closures

3.6.1.1 General

Closures generally act as protection for joints in cable or microduct. Closures may be placed underground, in handholes, in duct chambers, direct buried, or mounted on a pole. Occasionally a closure may be placed within an off-track chamber or in an above ground cabinet.

Closures can be provided pre-connectorised.

3.6.1.2 Optical fibre management system closures (FMSC)

Closures for FMS should be water-tight and have easy access for future reconfiguration of customer circuits. The closures are generally arranged at a distance of 250 m to 500 m depending on the requirements of the network structure (P2P, PON) and the population density in the regions. Certain networks may require the use of mid-span joints, which enable the optical fibre elements to be continued through the joint un-spliced. Only the required optical fibres are intercepted for splicing. Optical fibre management systems in closures are designed in such a way as to allow frequent re-entries without disturbing the traffic on existing optical lines. Closures are necessary for microduct installations as the last switching point in the field and can supply between 100 and 1 000 accommodation units depending on the network structure.

There are three typical FMS closures types; Dome, Pan or Inline (Figure 22), which may contain three typical FMS organiser types; tree, book or jukebox (Figure 23).

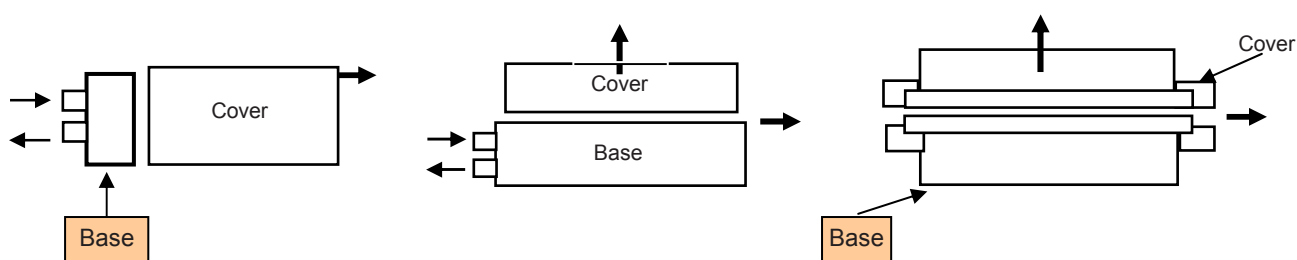


Figure 22 – Dome, Pan and Inline closures

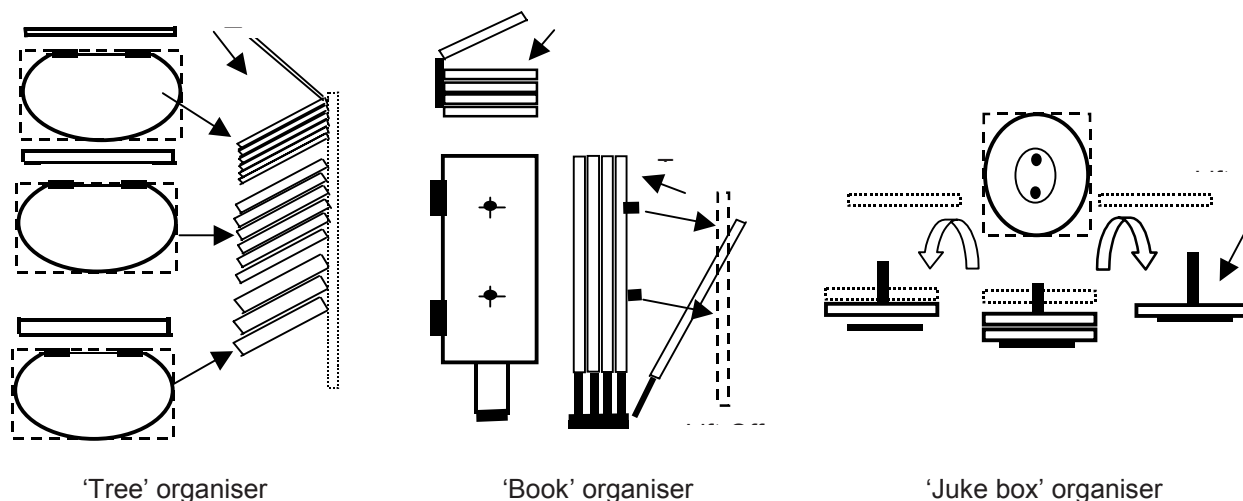


Figure 23 – Different organisers

3.6.1.3 Air blown optical fibre closures (ABFC)

Closures should have easy access for future additions of customer microducts. Typically 'protected microduct' and ABF closures are pre-installed during the network build, in order to blow optical fibre through the microducts at some future point in time.

There are different configurations of ABF closures: Dome, Pan or Inline, and Y, T and X among others. Fig. 24 shows some of them. Contained within an ABF closure is microducts routing for purposes of microduct storage, blow from and re-configuration (interception).

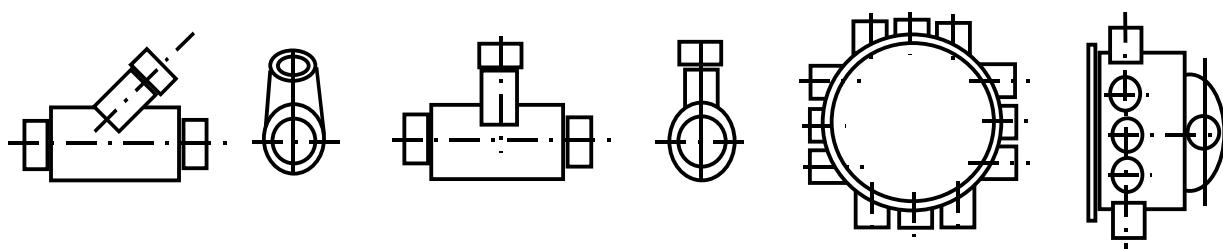


Figure 24 – "Y", "T" and "X" closures

3.6.2 Optical Distribution Frame (ODF)

The term "ODF" refers to a frame, including the optical fibre management system and the means to store and guide pigtails, patchcords and cables inside the frame. ODF does not include the means for routing cables or pigtails outside the frame (also known as pigtail ducts or "raceway" systems). The frame is a mechanical structure to which cables are attached and that holds all the elements of the ODF. It may be a rack and shelf type of structure, similar to that used to contain the electronics, or another type of structure. Its main functions are mechanical support and a basic level of protection of its content