FTTH Infrastructure Components and Deployment Methods

Network Infrastructure Committee

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Europe at the Speed of Light

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Index

1. Introduction

This white paper discusses the many different network infrastructure deployment options that may be considered when planning and building a Fibre to the Home (FTTH) network within Europe.

Optical fibre is considered to be the main building block for all future high capacity home broadband networks. Its transmission capacity is almost unlimited and unconditional compared to existing copper cabling systems. Recent investigations have shown little difference between the deployment costs of optical fibre and copper cables systems of equal capacity. However, the advantages of fibre offering high bandwidth and future upgrade potential over large distances and secondly much lower maintenance and operations costs make fibre a clear choice.

All deployment options discussed in this paper are based on a complete optical fibre path from the serving active equipment right through to the subscriber premises. This paper does not discuss hybrid options involving ‘part’ fibre and ‘part’ copper infrastructure networks.

All of the infrastructure deployment options described are currently available and have been successfully deployed throughout Europe and the rest of the world. These can be used either in isolation or in combination with the other options to form the most efficient overall solution for specific deployment circumstances.

The main purpose of this paper is to help the reader understand in detail the different deployment options available and to help choose (an) appropriate solution(s). All of the options described have particular features, benefits and of course limitations. None of the options described are in any order of importance.

When providing FTTH networks, it is key to understand the challenges for potential network builders and operators. Some of these may present conflicts between functionality and economic demands.

Key functional requirements for a FTTH network will include:

- Provision of high bandwidth services and content to each customer, with no restrictions
- Support for the required network architecture design (the fibre infrastructure must remain flexible at all times)
- Connection by fibre of each end subscriber directly to the serving equipment, avoiding intermediate active equipment (e.g. a fully passive optical network)
- Support future network upgrade and expansion

The economic requirements will include (but are not limited to):

- A successful business case, providing the lowest possible Capital Expenditure (CAPEX) and Operating Expenditure (OPEX) solutions for affordable infrastructure deployment
- Minimal deployment disruption where possible, to gain acceptance from network owners and to benefit FTTH subscribers

The need for a balance between functionality and economic needs is obvious. This paper highlights and reinforces the message that affordable, developed technologies and methodologies are available to build such FTTH networks in Europe.

Note: For further detailed reading it is recommended to consult the Cenelec document TC86A – ‘Fibre Optic Access to End User’, which is expected to be made available in late 2006.

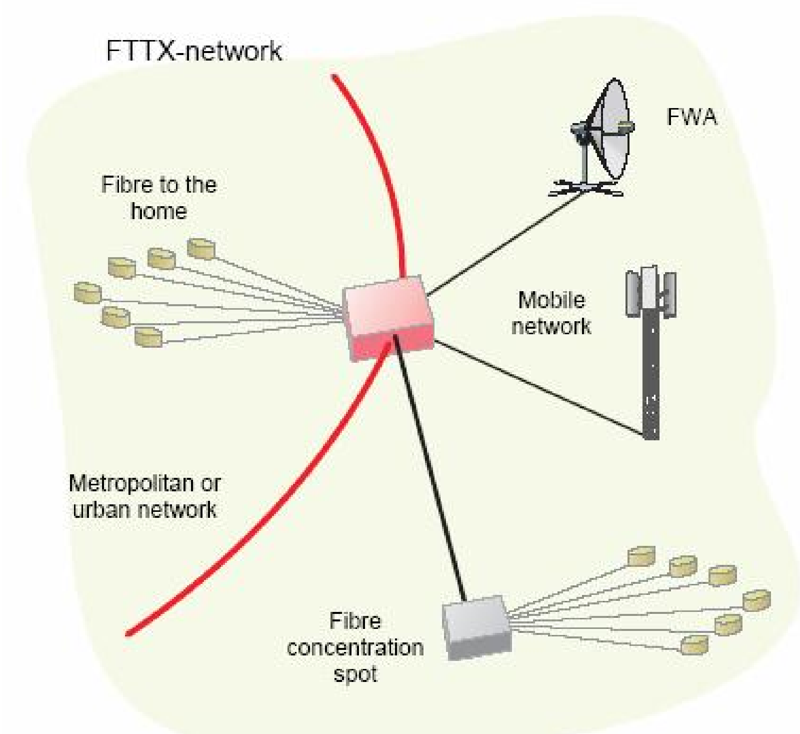
2. Basic Description of a FTTH Network Infrastructure

To describe an FTTH infrastructure network, it is essential to understand some of the basics. An FTTH network will normally form part of an existing access network, connecting a large number of end users back to a central point known as an Access Node. Each Access Node will contain the required active transmission equipment used to provide the applications and services over optical fibre to the subscriber. Each Access Node is served by a larger metropolitan or urban network fibre ring, connecting other Access Nodes throughout a large municipality or region.

Access Networks may connect by optical fibre some of the following:

- Fixed wireless networks (for example Wireless LAN or WLANs)
- Mobile network base stations (masts)
- A large number of subscribers in residential houses, terraces or blocks of flats and multi-dwelling units (MDUs)
- Larger buildings such as schools, hospitals and businesses
- Key security and monitoring structures like surveillance cameras, security alarms and control devices

Therefore, a FTTH network may be considered part of the FTTX area or Access Network as shown in the diagram below.



For a detailed explanation of the above, please refer to the planned Cenelec publication described in section 1.

2.1 FTTH Architecture PON versus P2P Ethernet

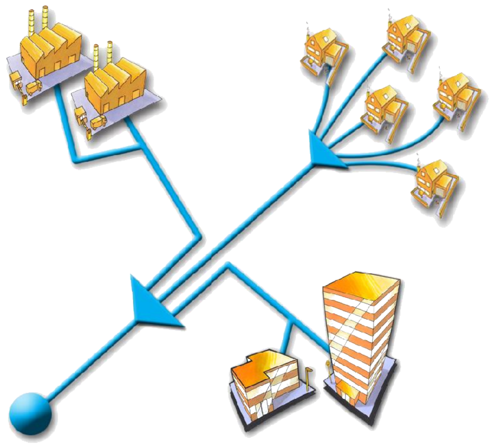
As this document only describes the passive infrastructure, it will not go into any depth on architecture. Basically there are two options in architecture that are important for the choice of passive infrastructure.

The drawings below show the PON and P2P Ethernet options schematically. The difference in the two options is mainly the number of fibres in the feeder cable.

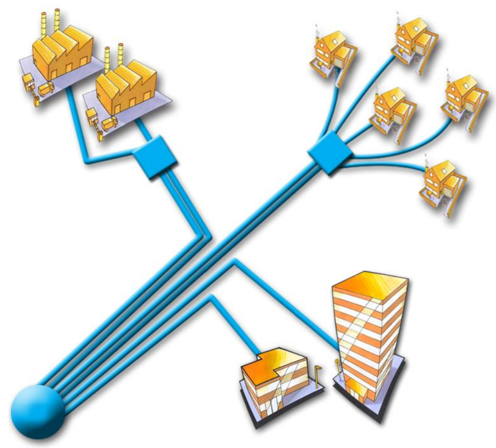
The PON architecture is based on one single optical driver for up to 64 users (in the future 128 users.) Passive splitters divide the signal somewhere in the network to the different users. The splitters can be placed in the Access Node or in one of the distribution points.

The P2P Ethernet Architecture has one optical port for every user thus creating a dedicated fibre connection from the POP to each individual user.

If the passive infrastructure needs to be able to handle both architectures it is necessary to calculate the highest fibre count in the feeder.



PON Architecture



Ethernet P2P Architecture

2.2 FTTH Network Infrastructure Environment

The deployment of fibre closer to the subscriber base will require that consideration be given to infrastructure deployment on public and private land, and also within public and private properties. These environments can be broadly split into:

- City
- Open Residential
- Rural

Apartment blocks or MDUs can be considered as part of all the above.

Each environment offers different customer densities (per sq km), and hence different challenges in providing a suitable infrastructure solution.

The main influences for the fibre infrastructure deployment costs will be determined by:

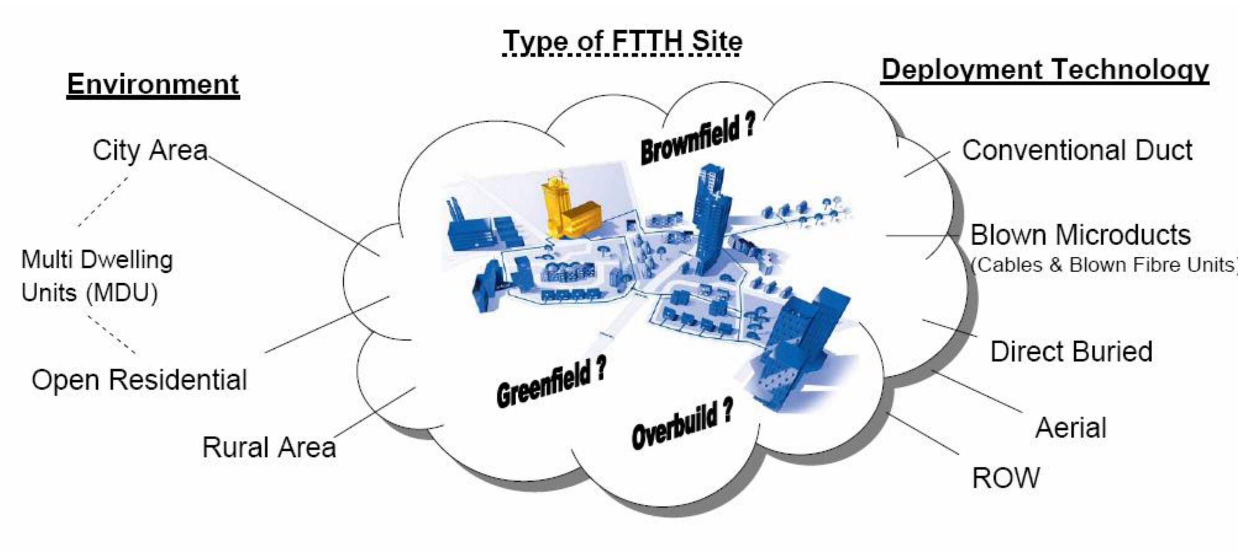
- FTTH environment - as described above
- Size of the FTTH network
- Initial deployment cost of the infrastructure elements (this is part of the overall Capex costs)
- Ongoing costs for network operation and maintenance (part of the overall Opex costs)
- Type of FTTH area e.g. Greenfield, Brownfield, or Overbuild.

- Architecture (PON, P2P,..)
- Local conditions e.g. local labour costs, local authority restrictions (traffic control) and others

The fibre deployment costs can be optimised by using a range of deployment technologies broadly grouped below. These are described in further detail later in this paper.

- Conventional underground duct and cable
- Blown microducts and cable
- Direct buried cable
- Aerial cable
- Other ‘Rights of Way’ solutions

For each environment, the optimal deployment solution will need to be determined by efficient infrastructure network design.



2.3 Description of FTTH Infrastructure Network Elements

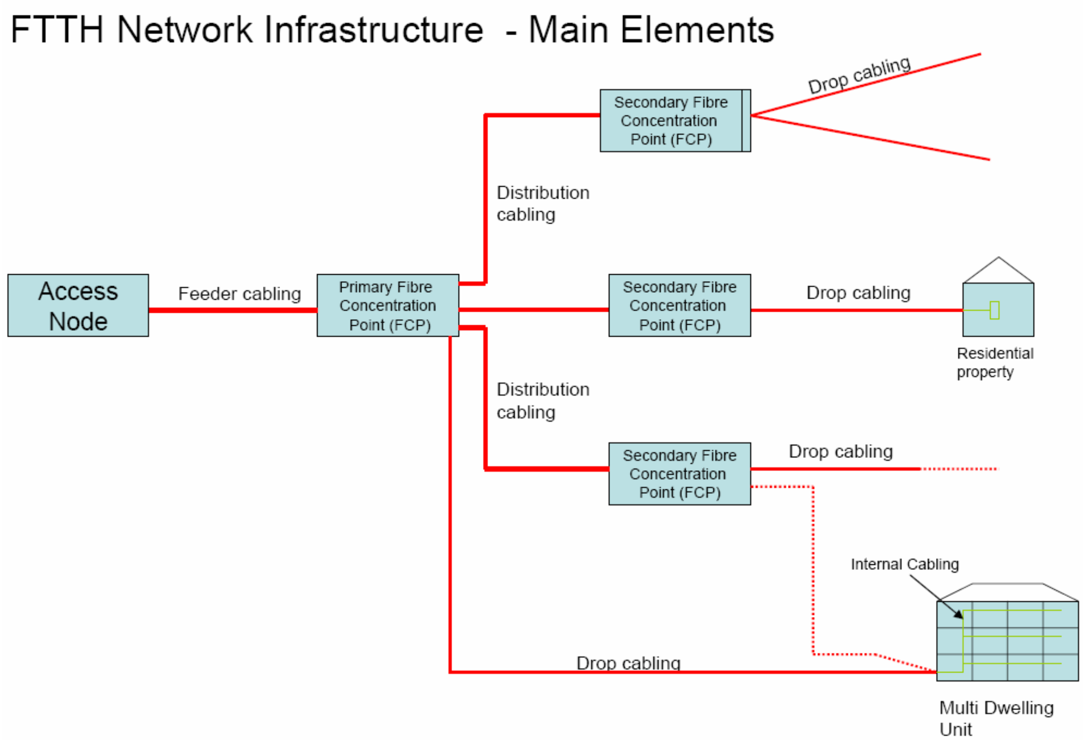
Expanding outwards from the Access Node towards the subscriber, the key FTTH Infrastructure Elements needed are:

1. Access Node
2. Feeder Cabling
3. Primary Fibre Concentration Points (FCP)
4. Distribution Cabling
5. Secondary Fibre Concentration points (FCP)
6. Drop Cabling
7. Internal Cabling (subscriber end)

	FTTH Network Infrastructure Elements	**Typical physical form**	**Refer to section**
1	Access Node (or POP)	*Building communications room or separate POP building.*	*2.3.1*
2	Feeder Cabling	*Large size optical cables and supporting infrastructure e.g. ducting or poles*	*2.3.2*
3	Primary Fibre Concentration Point (FCP)	*Easy access underground or pole mounted cable closure or external fibre cabinet (passive – no active equipment) with large fibre distribution capacity.*	*2.3.3*
4	Distribution Cabling	*Medium size optical cables and supporting infrastructure e.g. ducting or poles.*	*2.3.4*
5	Secondary Fibre Concentration Point (FCP)	*Small easy access underground or pole cable joint closure or external pedestal cabinet (passive– no active equipment) with medium/low fibre capacity and large drop cable capacity.*	*2.3.5*
6	Drop Cabling	*Low fibre count cables or blown fibre units/ ducting or tubing to connecting subscriber premises.*	*2.3.6*
7	*Internal Cabling**	*Includes external building fibre entry devices, internal fibre cabling and final termination unit, which may be part of the ONU.*	*2.3.7*

*Note: Internal Cabling does not cover the subject of Home Wiring, which is the subject of future FTTH EC publications.

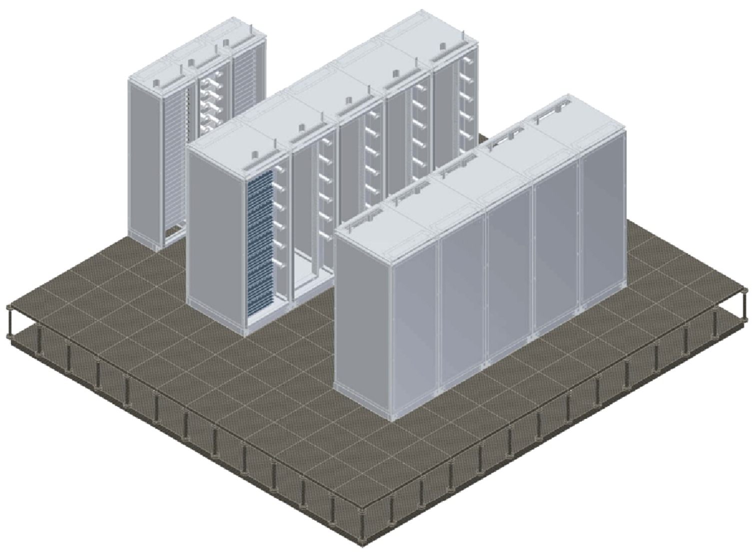
The diagram below gives a simple pictorial view of the FTTH Network Infrastructure Elements.

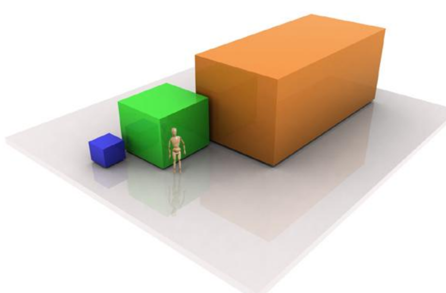


2.3.1 Access Node

The Access Node, often referred to as the Point of Presence (POP), acts as the starting point for the optical fibre path to the subscribing customer. The function of the Access Node is to house all active transmission equipment; manage all fibre terminations and facilitate the interconnection between the optical fibres and the active equipment. The physical size of the Access Node is ultimately determined by the size and capacity of the FTTH area in terms of subscribers and future upgrades.

A typical Access Node building/room layout could look like this:





Homes connected	Type of housing	
2 - 400	In-house	Street
400 - 2,000	In-house	Concrete
2,000 -	Building	

Size indication for Access Node. (P2P Ethernet)

The Access Node may form part of an existing or new building structure. The main network cables entering the Node will terminate and run to the active equipment. The feeder cables will also connect to the active equipment and run out of the Node building and onto the FTTH network area. All other physical items are used to manage the optical fibres within the Node. Separate cabinets and termination shelves may be considered for equipment and individual fibre management to simplify fibre circuit maintenance as well as avoid accidental interference to sensitive fibre circuits.

The key Network Infrastructure elements within an Access Node Building are:

- **Optical Distribution Frames (ODFs)**
- **Cable guiding system**
- **Uninterrupted Power Supply (UPS)**
- **Climate control**

Access Node Security
The Access Node should be classed as a secure area. Therefore, provision for fire and intrusion alarm, managed entry/access and mechanical protection against vandal attack must be considered.

2.3.2 Feeder Cabling

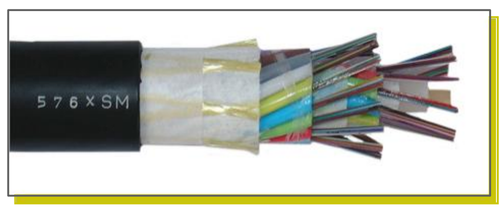
The feeder cabling runs from the Access Node to the first or primary Fibre Concentration Point (FCP). The feeder cabling may cover a few kilometres distance before termination and will generally consist of larger fibre count cables (100s of fibres) to provide the necessary fibre capacity to serve the FTTH area. For underground networks, suitably sized ducts will be required to match the cable design and additional ducts considered for network growth and maintenance. For aerial cable deployment, pole structures with sufficient cabling capacity will be required. Existing infrastructures may be available in full or in part to help balance costs.

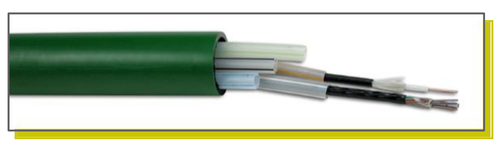
Feeder Cables

If smaller ducts or sub-ducts are used then the feeder capacity may be shared or grown using a number of smaller size cables e.g. 24 – 96f cables.

In the case of a PON (Passive Optical Network) the use of passive fibre splitting devices positioned further into the external network may enable smaller fibre counts cables to be used for the feeder portion of the network. As the decision of using PON or P2P is not always future proof, it is advisable to select a passive infrastructure that can handle both architectures. It is therefore advisable to factor modularity into the fibre count in the feeder cables.

Example – High Fibre Count Feeder Cable





Example – modular cable (duct system)

2.3.3 Primary Fibre Concentration Point (FCP)

The feeder cabling will eventually need to convert to smaller distribution cables. This is achieved at the first point of flexibility within the FTTH network, which can be generally termed the Primary Fibre Concentration Point (FCP).

Note: All fibre termination points within the FTTH network should be treated as points of flexibility in terms of providing fibre routing options. The term FCP is used throughout this document as a generic name for all of these points and classified as 'primary' or ' secondary' etc, to give relevance to their position within the network.

Ideally, the FCP should be positioned as close to subscribers as possible, shortening subsequent distribution cable lengths and hence minimising further construction costs. In principle, the location of the FCP may be determined by other factors such as the position of ducts and access points.

Feeder cable fibres are broken down and spliced into smaller groups for further routing via the outgoing distribution cables.

The FCP unit may take the form of an underground or pole mounted cable joint closure designed to handle a relatively high number of fibres and connecting splices. Alternatively, a street cabinet structure may be used. In either case, entry and further re-entry into a FCP will be required to configure or reconfigure fibres or to carry out maintenance and fibre testing. This activity must be achieved without any possibility of disturbing existing fibre circuits.

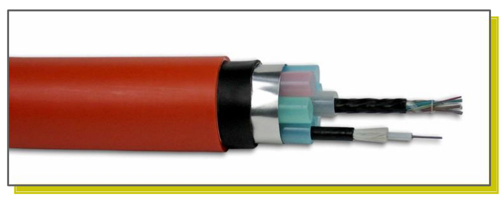
Underground and pole mounted cable joint closures are relatively secure and out of sight but immediate access may be hindered as special equipment is required for access. For street cabinet based FCPs, security and protection from vandal attack should be considered. However, immediate access to fibre circuits should be relatively simple.

2.3.4 Distribution Cabling

The distribution cabling runs from the FCP further into the FTTH network and closer to the subscriber base. Distribution cabling may only need to cover distances of less than1km before final breakout to the subscribers. Distribution cabling will generally consist of medium-sized fibre counts targeted to serve a specific number of buildings within the FTTH area.

For underground networks, distribution cables may be ducted, direct buried or grouped within a common microduct or tubing network to minimise construction costs and allow other cables to be added on a ‘grow as you go’ basis. For larger MDUs, the distribution cabling may form the last drop to the building and convert to internal cabling to complete the fibre link. For aerial networks the arrangement will be similar to that of feeder cables.

Distribution Cables
Distribution cables are smaller in size than the feeder cables. Fibre counts will generally be 48-192.



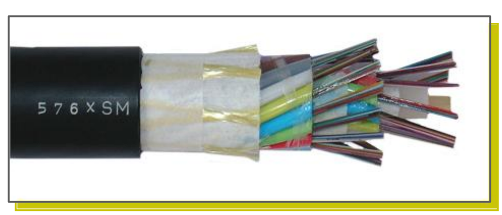
The diagram shows two examples:

- Microduct cable systems
- Conventional loose tube cables

The first picture shows direct burial tubes with microduct cables. The second picture shows standard ducts (f.i. 40 mm HDPE) with microducts and installed microduct cables.

These can blow over distances of 1km (typically). Micro ducts offer a means of deferred cable deployment.

The third picture shows a typical loose tube cable design. Loose tubes can be installed by blowing (as above), pulling into conventional ducts and sub-ducts; direct burial and by suspension from poles.



2.3.5. Secondary Fibre Concentration Point (FCP)

In certain cases, the fibres may need to be broken down at a second fibre concentration point within the FTTH network before final connection to the subscriber. As with the primary FCP, this second point also needs to be a point of flexibility allowing fast connection and re-configuration of the fibre circuits to the final subscriber drop cables. This is termed the secondary Fibre Concentration Point (FCP). The secondary FCP is positioned at an optimum or strategic point within the FTTH enabling the drop cabling to be split out as close as possible to the majority of subscribers. The location of the secondary FCP may be also determined by other factors such as position of ducts, tubing and access points.
Distribution cable fibres are broken down at this point and spliced to the individual or fibre pairs (circuits) of the drop cables.

The secondary FCP may take the form of an underground or pole mounted cable joint closure designed to handle a relatively small number of fibres and splices and outgoing drop cables. Alternatively, a small street pedestal structure may be used. In either case, entry and further re-entry into the secondary FCP will be required to configure or reconfigure fibres or to carry out maintenance and fibre testing.

In the case of air blown fibre deployment, the secondary FCP may take the form of a tubing breakout device designed to allow the microduct cable or fibre units to be blown 'through' and directly onto the subscriber premises. This reduces the number of splicing operations required. (Note - *this means that air drop cables/units are fed from further back in the FTTH network – from another FCP unit).*

Pole mounted secondary FCP cable joint closures are relatively secure and out of sight but immediate access may be hindered and requires special equipment for access.

Underground secondary FCP joint closures are also relatively secure and out of sight and will require a small access 'handhole' to be positioned nearby. Secondary FCPs based on street pedestal cabinets require security and protection from vandal attack. However, immediate access to fibre circuits should be relatively simple.

Architecture influence on the infrastructure:

If a PON system is used then it has to be possible to house the necessarily splitters in the closures. Most conventional closures have this option.

2.3.6. Drop Cabling

The drop cabling forms the final external link to the subscriber and runs from the last FCP to the subscriber building with a distance restricted to less than 500 mtrs and often much less for high density areas. The drop cables will contain only 1 or 2 fibres for the connecting circuitry and possibly additional fibres for backup or for other network architecture reasons. The drop cable will normally provide the only link to the subscriber, with no network diversity.

For underground networks the drop cabling may be deployed within small ducts, within microducts or by direct burial to achieve a single dig and install solution.

Overhead drop cables will feed from a nearby pole and terminate onto part of the building for routing to the subscriber fibre termination unit.

The above may take the form of pre-terminated or pre-connectorised cable assemblies to achieve rapid deployment and connection and to meet economic and minimal disruption demands.

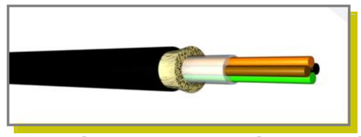
Air blown cables and fibre units are able to enter through the building fabric using suitable microduct products and route internally within the building. This will form part of the internal cabling network with the building entry device acting as the transition point for the microduct (external to internal material grade).

Drop cables can be divided into 3 types:

- Direct buried cable
- Blown fibre cable
- Aerial cable

Direct buried cables are available in 2 constructions; non-metal, and with metal protection (corrugated steel).

The advantage of the metal protected cables is their very high crush resistance and high-tension load.



Example – Direct Buried Drop Cables with Non-metal Protection

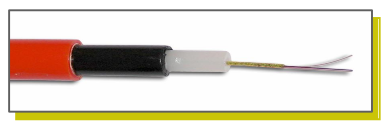
New non-metal strain relievers and protective sheets have been developed to give non-metal direct buried cables similar performance to metal protected cables. On average, non-metal cables are lower in cost.

Direct buried drop cables are available in fibre count from 1 to 12 (typical 2- 4).

Example – Direct Buried Drop Cable with Armour Protection

Direct buried cables and blown fibre cables can be pre-connectorised which gives an advantage on installation (less installation time in the home and better planning).

Blown fibre cable consists of a direct buried microduct (typical sizes inner tube: o.d 3, 4 and 5 mm) through which a fibre unit or microcable can be blown. Typically 2 to 12 fibres can be blown in this duct cable.

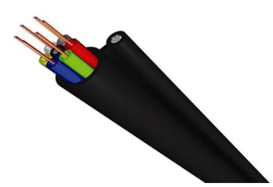


Example – Air Blown Unit Drop Cable

Aerial cables are available in 3 types:

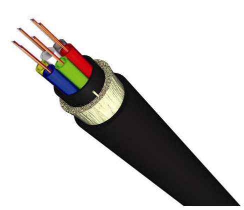
- ADSS: All Dielectric Self Supporting
- Figure 8 (cable fixed to a steel wire)
- OPGW (optical ground wire)

Both ADSS and Figure 8 cables can be used as a drop cable for fibre to the home applications. OPGW cables are mainly used in power line connections.



ADSS cable is a non-metal reinforced cable with typical tensile load up to 5000 Newtons and fibre counts from 2 to 48.

The Figure 8 cable consists of a central tube cable fixed to a steel wire (see picture). Typical fibre counts are 2 to 48. The tensile load is typically 6000 Newtons.



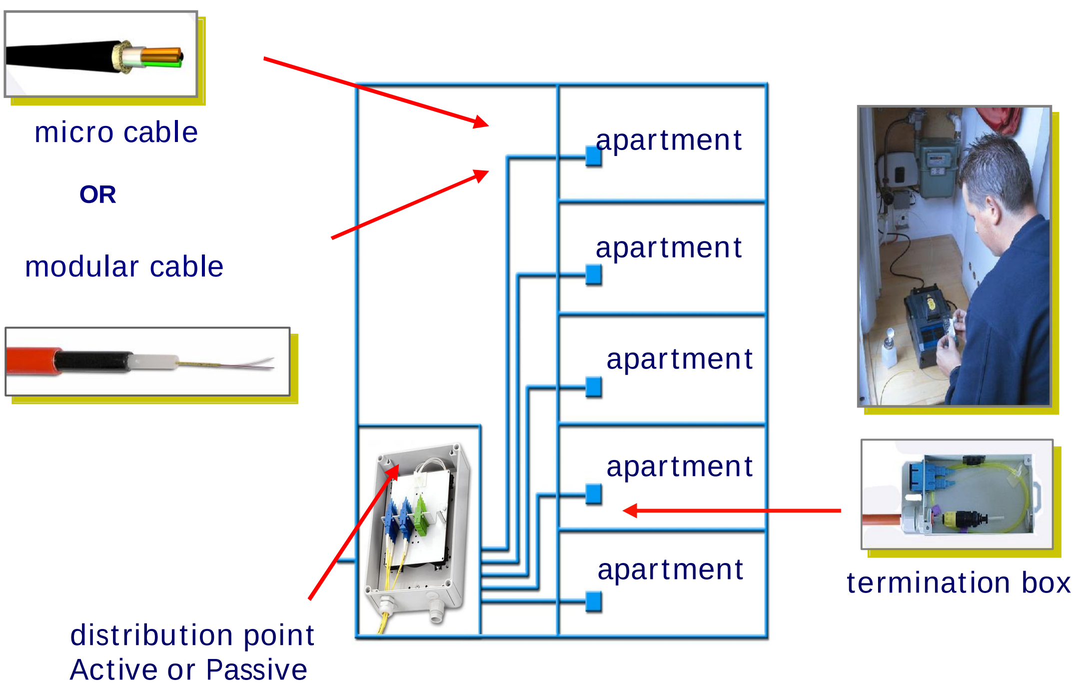
2.3.7. Internal Cabling

For residential properties, the drop cable will generally terminate onto the structure of the house and route externally to a termination box. This in turn routes the fibre to a Termination Unit (which may form part of the Optical Network Unit – ONU). If this unit is on the inside of the building, this will require the fibres to be routed through the building wall fabric via a suitable cable lead-in (CLI) and subsequently managed within the building to the ONU.
If the ONU is sited externally within a box, the drop cable is simply terminated in a similar manner to a utility feed. In both case there will be little or no internal optical cabling required unless this is added by the decision of the house owner/subscriber.

For larger multi dwelling properties, the internal cabling forms a major part of the FTTH Infrastructure. The diagram below is a schematic drawing for the internal cabling of a building using a microduct deployment or conventional cable. The microducts are run up riser shafts to each floor from an entry basement room. The ducts are routed horizontally to each apartment or room using breakout devices as necessary to distribute the tubes. Note: The internal micro ducting is graded for internal deployment from the basement entry point (i.e. low smoke/zero halogen). The micro-ducts are anchored at regular intervals in the horizontal position. The fibre units or cables are installed into the micro-ducts from the outside, up the riser section and onto the apartment rooms via the horizontal micro-tube drops.

A similar approach can be adopted for conventional cable.

When an Active Node as distribution is used in the basement of the MDU it can be considered to use multimode fibre instead of single mode fibre. This fibre type has been successfully used in the business environment for LAN. Multimode fibres are favoured here for its lower costs compared to single mode systems.



3. *Optical Fibre for FTTH Deployment*

A number of different optical fibre types are available (see Appendix I). The majority of FTTH schemes are likely to be based on single-mode fibre, but multimode fibre may also be used in specific situations. The choice of fibre will depend on a number of considerations. Those listed below are not exhaustive and other factors may need to be considered on a case-by-case basis.

Network Architecture Type

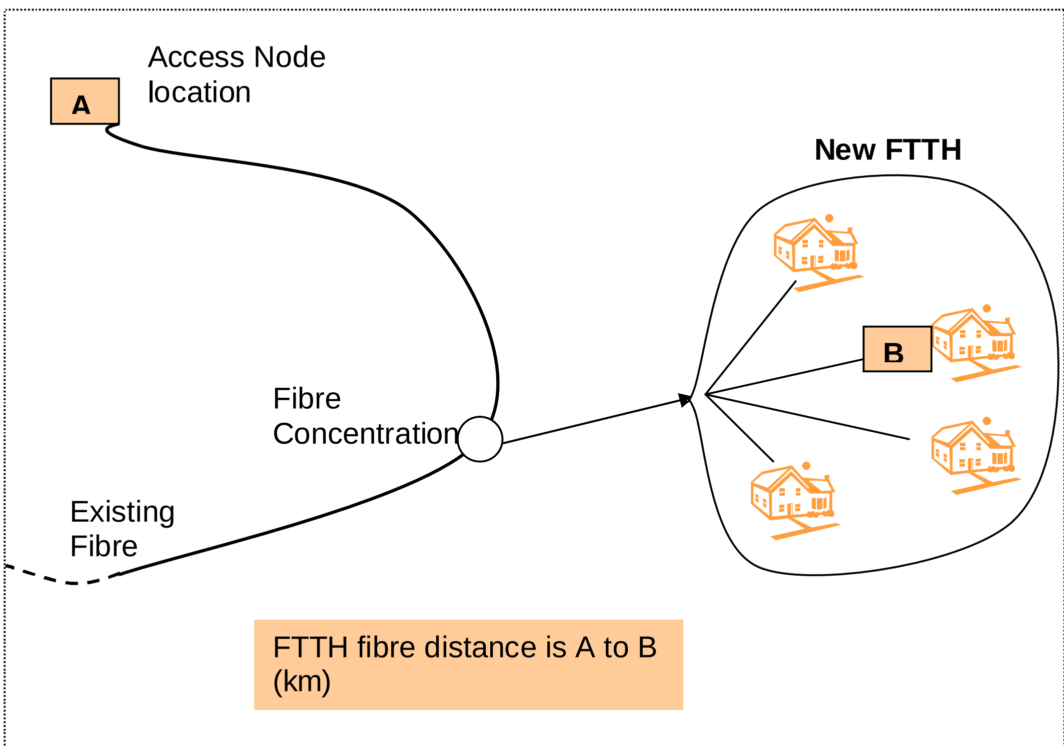
The network architecture options are covered by a separate document. This largely affects the amount and control (flexibility) of bandwidth fed to each subscriber.

Size of the FTTH network

The size of the FTTH network covers the numbers of house/apartments in the FTTH area. This is a measure of subscriber density and largely affects fibre counts within the network. The FTTH site may be a new greenfield type or a site requiring an overbuild of the existing communications network.

Location of the FTTH network to existing feeding fibre network

When siting a new FTTH network, care must be exercised regarding its position with respect to the existing or serving metropolitan/urban fibre network, or local access fibre network. Particularly, the overall optical distance that will need to be covered between the transmission equipment needs to be considered as this affects the fibre attenuation and bandwidth carrying capacity.



The Existing Network Fibre Type

The Existing Network Fibre Type is most likely to be single-mode fibre and this will link back to the Access Node (or POP) to the serving equipment. A fibre connection link to the FTTH network area will be required from a strategic point in the network (fibre concentration point).

Expected lifetime and future upgrade

The FTTH network lifetime could be 30 years or more. Therefore, it is imperative that any investment made in the FTTH infrastructure is able to serve future needs as well as those of today. Changing the fibre type halfway through the expected lifetime of the FTTH network is not a desirable option.

Single-mode fibre

Single-mode fibre offers the lowest optical loss (best distance) and highest bandwidth carrying capacity. Since it is the most widely used fibre, particularly further back in the network, it is likely to be the same and therefore compatible with the existing legacy fibre base. Thus any connection to a new FTTH network will be transparent (no additional active equipment) and uniform (common practices, tools and maintenance). It also offers the greatest potential for future upgrade, using higher-level active equipment to exploit its huge bandwidth-carrying capacity.

Single-mode fibre is the lowest cost fibre option but incurs higher equipment costs compared with multimode fibre systems. For the future, wide scale FTTH deployments may reduce single-mode equipment costs through increased volumes.

Multimode fibre

Multimode fibre is generally accepted as a solution for in-building and campus data networks. It has lower equipment and connection costs but higher fibre costs compared to single-mode fibre. It provides lower bandwidth carrying capacity compared to single mode fibre, although newer types of fibre (refer to Appendix 1 for details) offer more bandwidth capacity for short distance networks. A consideration for using multimode fibre is the connection to the existing fibre base, which is most likely to single-mode fibre. This will require some form of intermediate active equipment. Multimode fibres can successfully be installed in flats or multi-tenant buildings using a local active node (in the basement).

4. *Infrastructure Deployment Technologies*

This section provides a detailed analysis of available Infrastructure Deployment Options.

None of the options listed represent any form of importance or acceptance. Each option offers features and benefits as well as limitations. Deployment options may well be used in combination.

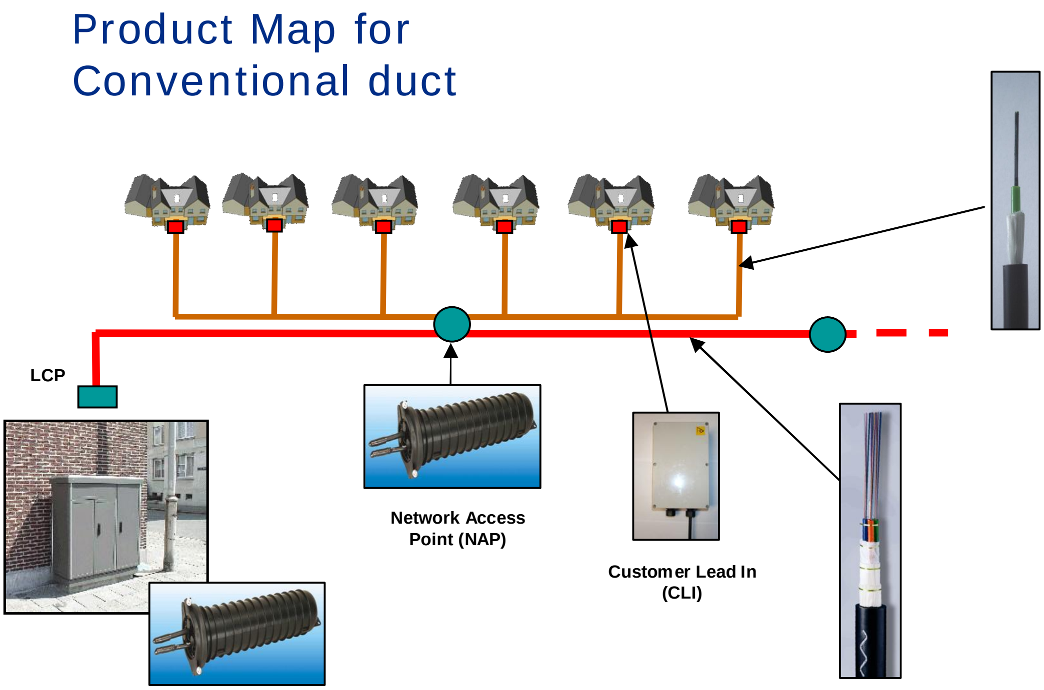
4.1 Conventional Duct Infrastructure

This is the most conventional method of underground cable installation and involves the creation of a duct network to enable subsequent installation of cables by pulling, blowing or using floatation techniques. This may comprise a large main duct that contains smaller sub-ducts (for individual cable installation), a large main duct into which cables are progressively pulled one over the other as the network grows or a small sub-duct for the installation of a single cable. Duct installation provides the easiest and safest deployment method and also enables further access and reconfiguration. As with direct burial (below) consideration needs to be given to other buried services. Efficiency of cable installation in ducts relies heavily on the quality of the duct placement; this applies to all installation methods.

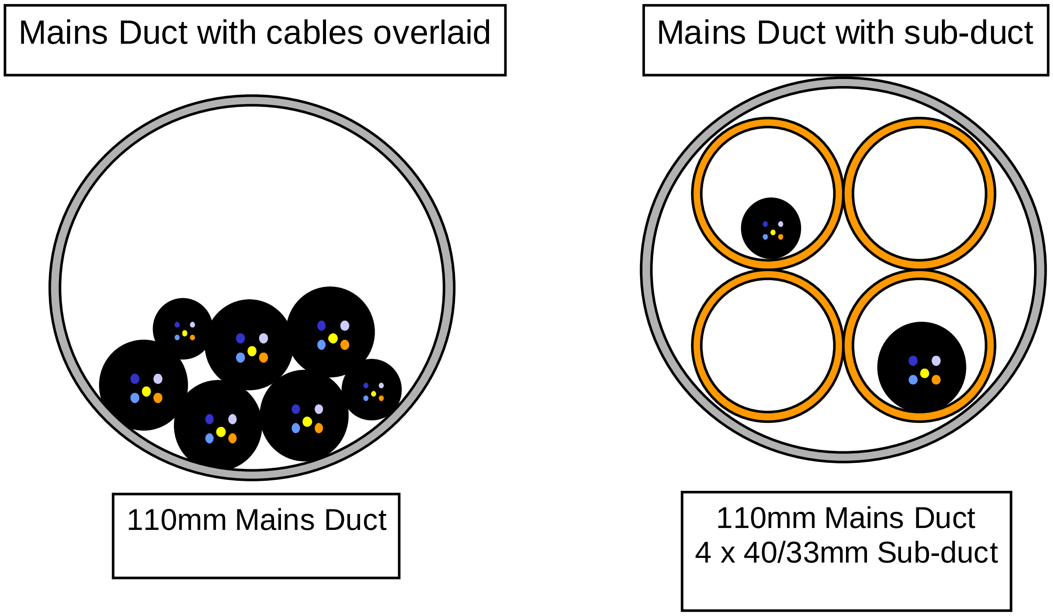
Necessary main elements

- Ducts and possible sub-ducts
- Duct cables
- Branch-off closures

4.1.1 Product Map



4.1.2 Duct network



The use of a single duct maximizes the number of cables that can be installed but full ducts make it difficult to extract older cables (typically at the bottom of the duct) to create room for new cables. Using sub-duct may reduce the total number of cables that can be installed, but at least older cables can be removed and new ones installed. It also allows the use of cable blowing as well as cable pulling, since it is easier to obtain an airtight connection to the sub-duct.

Typical duct sizes are 110mm, 100mm or 90mm for main duct and 50/43mm (50mm outer diameter, 43mm inner diameter), 40/33mm, 33/26mm or 25/20mm for sub-duct. Smaller ‘microducts’ may also be deployed (see below).

Cables are installed into the ducts by pulling, blowing or floating. If they are to be pulled, then the duct either needs to contain a pre-installed draw-rope or to have one installed by rodding and roping. If they are to be blown in or floated, then the duct and any connections between sections of duct need to be airtight.

The inner wall of the sub-duct is manufactured to ensure low friction with the cable sheath. This is typically achieved with a low friction coating. Alternatively, the sub-duct could contain a low friction extruded profile and/or special duct lubricants can be used.

A number of factors govern the continuous length that can be pulled or blown, including coefficient of friction, bends in the duct route (vertical as well as horizontal), the strength or weight of the cables and the installation equipment used. The cable diameter should not be too large compared to the duct inner diameter. Fill ratios should be calculated as part of the planning process. For cable blowing operations the duct joints must be airtight. For existing networks the condition of the ducts should be checked for any potential damage and suitable space and capacity for future cabling.

4.1.3 Type of Ducts

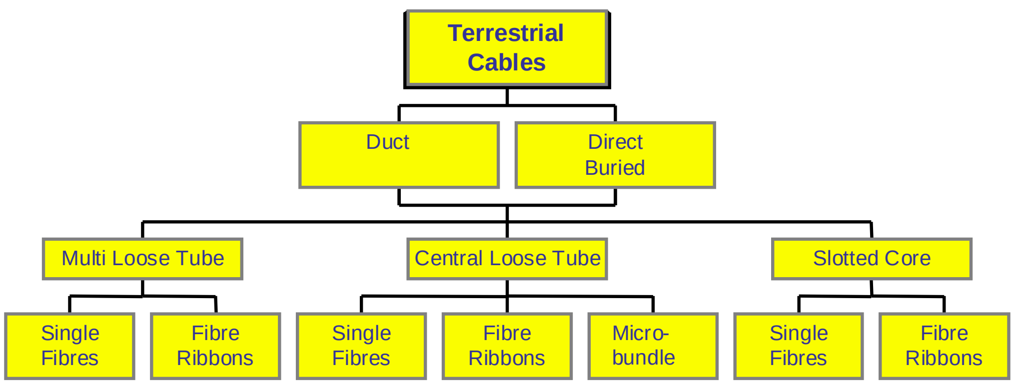
Main Ducts – Underground Systems

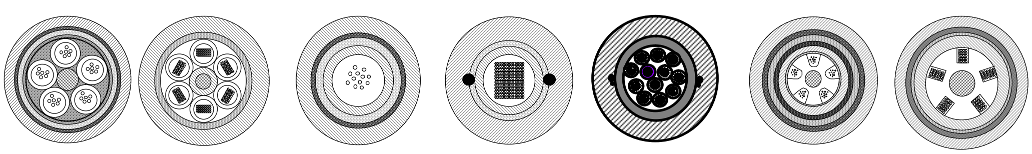
The feeder ducts run from the Access Node to the FCP.
The number of ducts required will be dictated by the size of the FTTH area and the size of feeder cables used.
Consideration may also be given for more than one cable to be installed in a single duct to save vital duct capacity (e.g. using over blowing or pulling techniques).
Ducts sizes will range from 25 - 50mm O.D. Larger ducts of 110mm O.D may be used and these may contain smaller sub-ducts between 20-40mm O.D.
The duct material is normally HDPE

Example – Main HDPE Duct cross section

4.1.4 Types of Duct Cables

A wide variety of cables exists for use in a duct network. If pulled in using a winch, then they may need to be stronger than blown versions, since the tensile force applied can be much higher. Blown cables need to be suitably lightweight with a degree of rigidity to aid the blowing process. The presence of the duct affords a high degree of crush protection, except where the cable emerges into the footway box. Duct cables are normally jacketed and non-metallic (to remove the need for earthing, for lightning protection and/or for environmental reasons). However, they may contain metallic elements for higher strength (e.g. steel central strength members), for remote surface detection (e.g. copper elements) or for added moisture protection (longitudinal aluminium tape). Duct environments tend be benign but the cables are designed to withstand potential long term flooding and occasional freezing.





There are a wide variety of cable designs, but these are based on a small number of elements. The first and most common 'building-block' is a loose tube, comprising a plastic tube containing the required number of fibres (typically 12) together with a tube filling compound that both buffers the fibres and helps them to move within the tube as the cable expands and contracts at environmental and mechanical extremes. Other building blocks include multiple fibres in a ribbon form or in a thin easy-strip tube coating. Fibres may also be laid in narrow slots grooved out of a central cable element.

Typically, the tubes (containing individual fibres or multiple ribbons) are laid around a central cable element that comprises a strength member with plastic up jacketing. Water blocking materials such as waterswellable tapes and threads (or grease) can be included to prevent moisture permeating radially or longitudinally through the

cable, which is over-sheathed with polyethylene (or alternative materials) to protect it from the external environment.
Fibres, ribbons or bundles may also be housed within a large central tube. This is then over sheathed with strength elements being included.

4.1.5 Cable Installation by Pulling

The information below is an outline of the required installation and equipment considerations. Reference should also be made to IEC specification 60794-1-1 Annex C 'Guide to the installation of optical fibre cables'.

When cables are pulled into a duct, there needs to be either a pre-existing draw-rope or this needs to be installed prior to cable winching. The cable should be fitted with a swivel, that allows the cable to freely twist as it is installed, and a fuse rated at or below the cable's tensile strength. Long cable section lengths can be installed if the cable is rated to take the additional tensile pulling load or by 'fleeting' the cable at suitable section mid points to allow a secondary installation pull operation, or by using intermediate assist pullers (capstans or cables pushers).

When installing cables, due account should be taken of their given mechanical and environmental performances as given by the supplier's datasheets. These should not be exceeded. The tensile load represents the maximum tension that should be applied to a cable during the installation process and ensures that any strain imparted to the fibres is within a safe working limit. The use of a swivel and mechanical fuse will protect the cable if the pulling force is exceeded. Cable lubricants can be used to reduce the friction between the cable and the sub-duct, hence reducing the tensile load. The minimum bend diameter represents the smallest coil for cable storage within a cable chamber. Suitable pulleys and guidance devices should be used to ensure that the minimum dynamic bend radius is maintained during installation. If the cable outer diameter exceeds 75% of the duct inner diameter the pulling length may be reduced.

4.1.6 Cable Installation by Air Blowing

Traditionally, cables were pulled into ducts. More recently, particularly with the growth of lightweight non-metallic designs, a considerable proportion of cables are now installed by blowing. This can be quicker than pulling, and may allow longer continuous lengths to be installed (thus reducing the amount of cable jointing). If a number of spare ducts are installed, then subsequent cables can be installed as the need arises ('just in time').

When cables are blown into a duct, it is important that the duct network is airtight along its length. This should be the case for new-build but may need to be checked for existing ducts, particularly if they are an old-build (e.g. legacy network). A balance needs to be struck between the inner diameter of the duct and the outer diameter of the cable. If the cable outer diameter exceeds 75% of the duct inner diameter, air pressures higher than those provided by conventional compressors are required or the blow length may be reduced. Nevertheless good results have also been obtained for higher filling degrees, e.g. a 7.1 mm cable was blown over 1 km in a 10 mm microduct with inner diameter of 8 mm (filling degree 89%). If the cable is too small then this can lead to other installation difficulties, particular if the cable is too flexible. In such cases, a semi-open shuttle attached to the cable end can resolve these difficulties.

A cable blowing head is required to both blow and push the cable into the duct. The pushing overcomes the friction between the cable and duct in the first few hundred metres and hauls-off the cable from the drum. The ducts and connections must be sufficiently 'air tight' to ensure an appropriate flow of air through the duct. A suitable air compressor is required at the cable payoff end of the duct section and will connect to the blowing head. Hydraulic pressure at the blowing head used to provide drive/push traction to the cable must be strictly controlled to ensure no damage to the cable.

4.1.7 Cable Installation by Floating

Considering that most outside plant underground cables are exposed to water over a major part of their life, floating is an alternative method to blowing. Floating can be done with machinery originally designed for blowing. Air is simply replaced by water. Compared to blowing, floating enables to place considerably longer cables sections in ducts without intermediate access point. Floating can prove very efficient for over laying cable in many situations. Also with floating the performance decreases when placing cables having an outer diameter exceeding 75 % of the duct inner diameter. Nevertheless good results have also been obtained for higher filling degrees, e.g. a 38 mm cable was floated over 1.9 km in a duct with inner diameter of 41 mm (filling degree 93%). It enables to safely remove cables out of their duct (float out), thus making possible the re-use of such cable. Blowing out cable is by comparison a hazardous operation.

4.1.8 Cable de-coring

New techniques have been developed to successfully de-core cables. With this method, virtually every cable's copper core can be replaced cost-effectively and speedily with fibre optics.

Instead of, as previously, digging up the entire cable length, the cable is now only accessed at two points, 50 to 400 metres apart. A special fluid is pumped under pressure into the space between cable sheath and cable core wrapping, detaching the core from the sheath. Next, the old cable core is extracted mechanically and treated for clean, environmentally friendly disposal or recycling. Simultaneously, an empty, accurately fitted sheathing for the new fibre optics cable is drawn into the old cable sheath. Afterwards these so-called 'microducts' are connected, the pits are closed and, finally, the empty cable sheath is refilled with fibre optics.

Apart from the positive environmental aspects – old cables can be recycled homogenously, and the fluid is biodegradable –, this technique can save 40 to 90 percent of costs in comparison to traditional cable replacement system especially due to the much faster completion time and reduction in planning and building costs.

4.1.9 Access & Jointing Chambers

Suitable sized access chambers are required to be positioned at regular intervals along the duct route. These can be located to provide the optimum position for connection to the customer drop cables. The duct chambers must be sized large enough to enable all duct cable installation operations, storage of slack cable loops for jointing and maintenance, cable hangers and bearers, and the storage of the cable splice closure. The chambers may be constructed 'on site' or be provided as pre-fabricated units to minimise construction costs and site disruption. On site constructed modular chamber units are also available. Where existing legacy access chambers are insufficient due to size or over population of cables/ closures then an 'off-track or spur' chamber should be considered. In certain circumstances the chamber may require prevention of unauthorised access and security. In these cases, special armoured cover plates and tamperproof security locks should be considered.

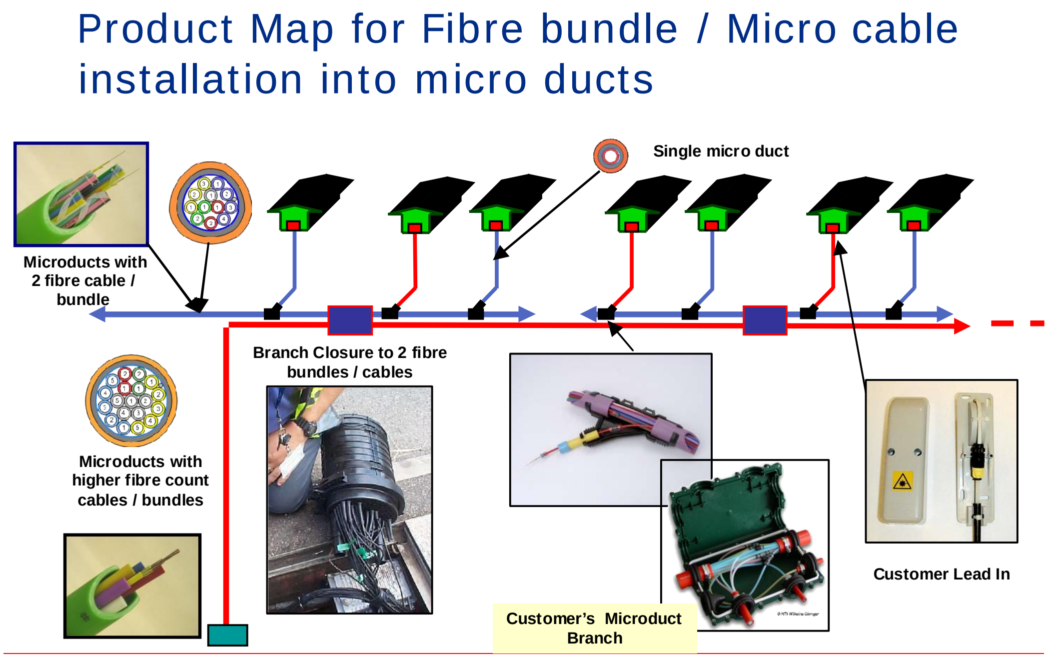
4.1.9.1 Cable Joint Closures

The cable joint closures may act as track or straight through joint, to join sequential cable and fibre lengths together, or provide a function for distribution of smaller drop cables. Closures will be sited in the manhole or underground chambers. Occasionally the cable joint may take place within an off-track chamber or above ground cabinet. The main closure considerations must be resistant to long term flooding and any future need to re-enter for adding or reconfiguration of customer fibre circuits. Typically, closure placement may occur as regularly as every 500m for medium density areas and as frequently as every 250m in high-density areas. Certain networks may require the use of mid-span joints, which enable the fibre elements to be continued through the joint un-spliced. Only the required fibres are intercepted for splicing.

4.2 Blown Microducts & Microcable Infrastructure

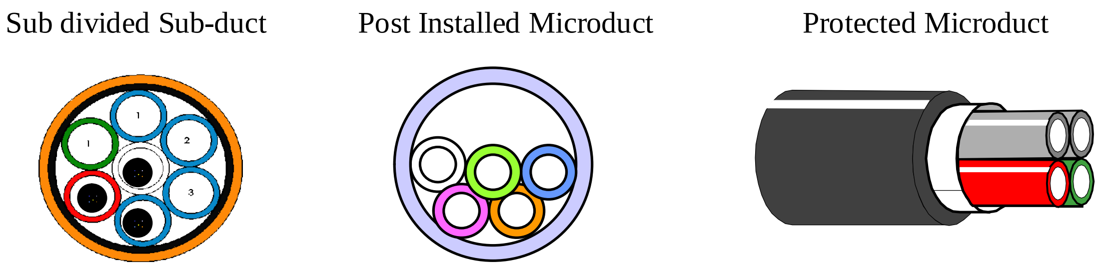
This option utilises compressed air to blow fibre unit and small diameter cables quickly through a network of tubes to the customer/ premises. Fibre deployment can be deferred until the customer requirement has been confirmed, hence deferring costs compared to speculative up-front build programmes. Also, the number of splices can be minimised by blowing long lengths of fibre through the network of tubes (which themselves are easily joined via push-fit connectors). This option may be used in combination with duct, direct buried and aerial infrastructure and the tubes may be housed in constructions designed for any of these three methods.

4.2.1 Product Map



4.2.2 Microducts

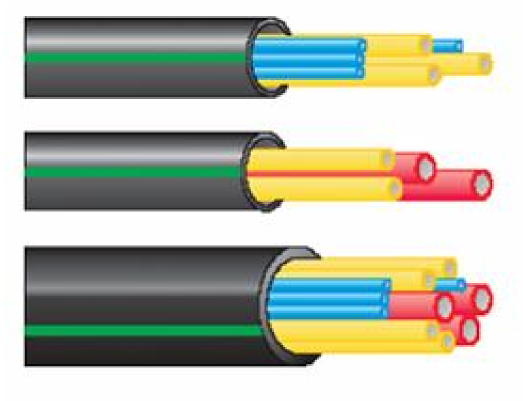
Microduct cabling uses small, flexible, lightweight tubes. These could be a small conventional duct typically less than 16 mm in diameter (e.g. 10 mm outer diameter, 8 mm inner diameter) that is pre-installed or blown into a larger sub-duct. These can be used to further segment a sub-duct (for example using five 10 mm microducts). They could also be small tubes (e.g. 5mm outer diameter, 3.5 mm inner diameter) that are actually manufactured as a single or multi-tube cable assembly, known as 'protected microduct'. The larger microducts may be blown directly into the sub-ducts. The protected microduct assemblies (typically containing from one to twenty-four microducts) may be constructed in similar fashion to the aerial, direct buried or duct cables described elsewhere (e.g. 7 small tubes bundled together and over-sheathed). They would then be installed in a similar fashion to those cables.



Microducts

Microducts are sized to suit the accommodating main duct and the cables to be installed. Unlike normal ducting, microducting needs to be matched to the optical cables to be used to ensure compatibility during installation.

Microducts can be provided as separate loose tubing, pre-bundled or for direct burial. Other versions are available for wall mounting (tunnels) or pole structures for aerial drops.



Example – Illustration of Microduct variants

4.2.3 Microduct Tube Connectors and Closures

A range of specialist connectors exist to join sections of tube. These are available in water and gas-sealed easy-fit versions.

Push/ Easy Fit Tube Connectors

Gasblock Tube Connector

Straight Tube Connector

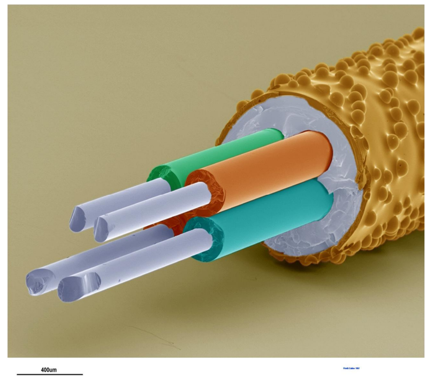
End Tube Connector

4.2.4 Types of Microduct cable and Fibre Units

The microduct cables can be microduct cables (e.g. 72 fibre 6mm diameter for use in a 10/8 microduct) or very small blown fibre unit cables containing up to 12 fibres within 1 to 3mm (e.g. 4 fibre x 1mm diameter for use in 5/3.5mm tubes). The cables used in these tubes are small lightweight designs that typically require the tube for protection. In other words, the tube and cable act together as a system. The cables are installed by blowing. Both cable types may have special outer coatings to assist with air blowing.

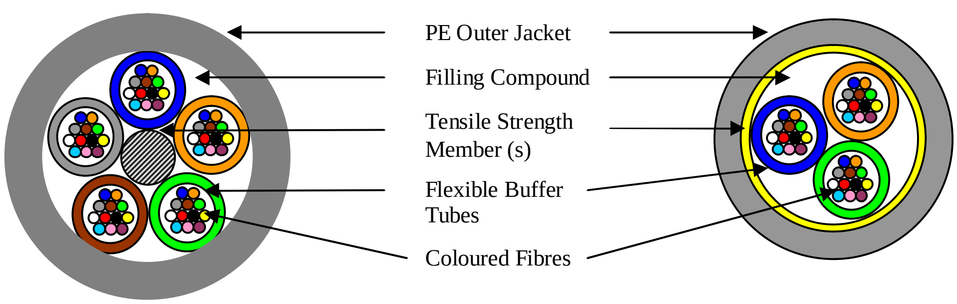
Microduct Optical Fibre Cables

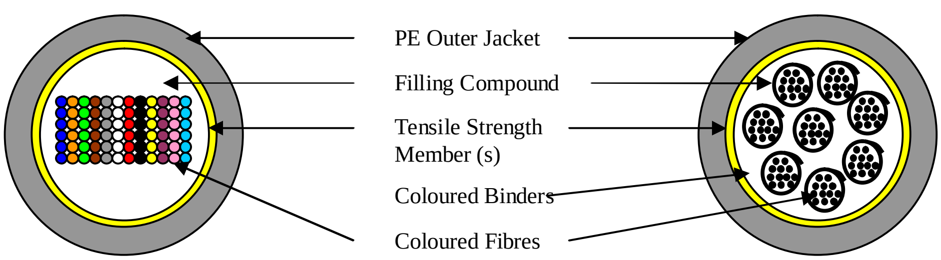
Microduct Fibre Unit Cables



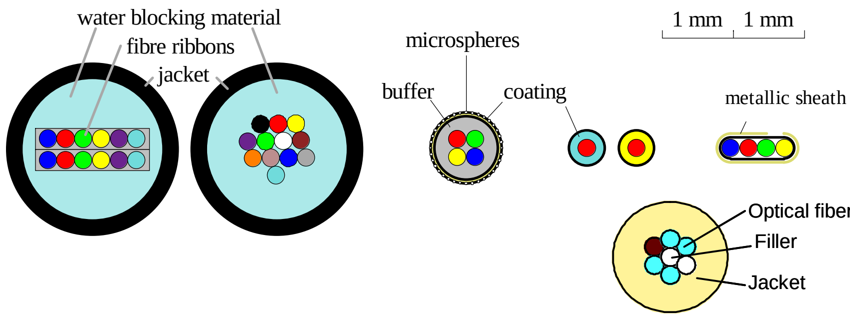
The microduct size is chosen to suit the cable and required fibre count. Typical combinations of cable size and duct size are given below. Other sizes and combinations can be used.

Microduct outer diameter (mm)	Microduct inner diameter (mm)	Typical fibrecounts	Typical cable diameter (mm)
12mm	10mm	72-96	7-8mm
10mm	8mm	48-72	6-6.5mm
7mm	5.5mm	6-12	2.5mm
5mm	3.5mm	2-1-12	1-1.6mm
4 mm	3 mm	2-6	1.8-2 mm

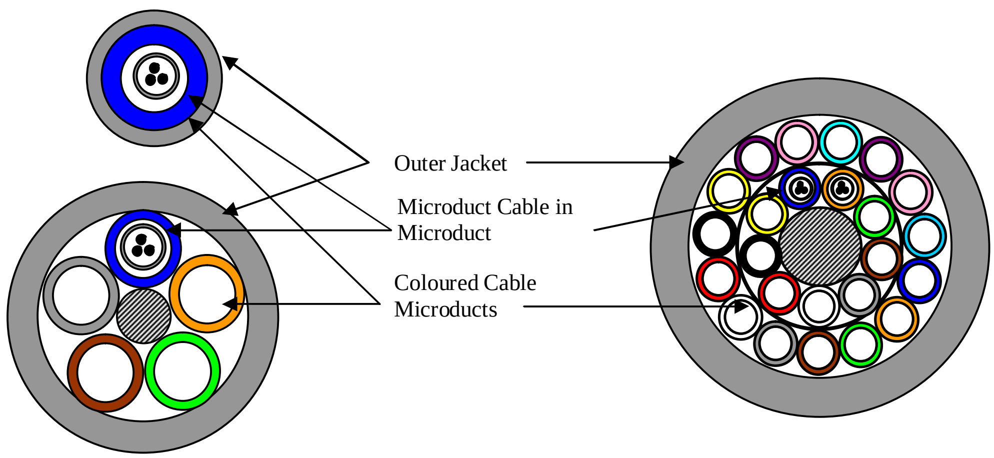




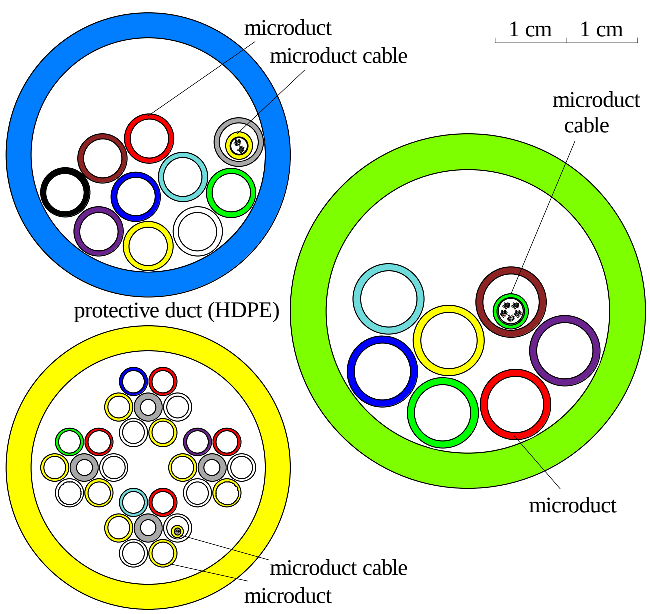
Microduct optical fibre cables (not to scale)



Fibre units



Protected cable microduct with tight integral outer duct (not to scale)



Protected microducts, loose package

The distance achieved by blowing will depend on the microduct, cable and installation equipment used plus route difficulty (particularly turns in the route and vertical deviations). As the fibre reaches its last drop to the home, it may be possible to use even smaller tubes (e.g. 4mm OD/2.5mm ID or 3mm OD/2.1mm ID), since the blowing distance may be quite short.

4.2.5 Microcable/ Blown Fibre Unit Installation by Blowing

This will be very similar to the equipment as shown in section 4.1 but with smaller blowing equipment and using smaller, lighter and more flexible cabling payoff (e.g. reels opposed to drums and cages and pans). Under specific conditions, microcables can be floated using smaller floating equipment

4.2.6 Access and Jointing Chambers

The same principles apply as for duct cable in section 4.1. Additionally, it is possible to branch-off microduct tubes at hand-hole locations using a suitable swept branch closure, rather than requiring a full-size chamber.

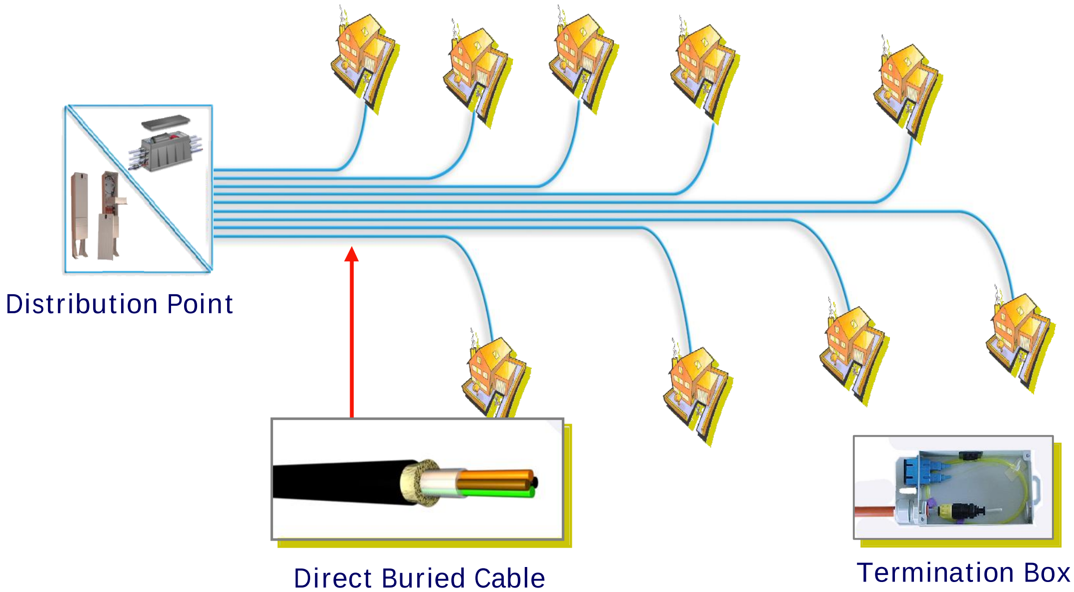
4.2.7 Microcable Joint Closures

The basic features of duct joint closures can also be applied to microduct cables. Different options apply, depending on whether the joint is being used to join or branch fibres, or whether it is the tubes themselves that are to be branched or jointed. This allows considerable flexibility with the routing of the ducts whilst minimising the installation steps, since the cables or fibres may be blown through the whole route, once the tubes are connected, and may be facilitated using simple joints rather than full-scale joint closures. This also permits external tubing to be joined directly to suitable indoor tubing and hence avoiding the need for a joint splice at the building entry point.
Additional safety features may be required, particularly with respect to pressure relief. If a fully jointed airtight closure is required, then dangers may occur when fibre is blown through a joint if there happens to be an air-leak within the tubes housed in the joint. To prevent pressure build-up in the joint that could cause it to blow apart, the fitting of a reliable safety valve or other pressure relief mechanism, is strongly recommended.

4.3 Direct Buried Cable Infrastructure

This requires a narrow trench to be excavated in order to effectively bury and protect the cable. A number of excavation techniques are available including mole-plough, open trenching, slotting and directional boring. A combination of these options is possible over an area of deployment. Direct burial offers a safe protected and hidden environment for cables but requires careful planning and survey to avoid damaging other buried services.

4.3.1 Product Map

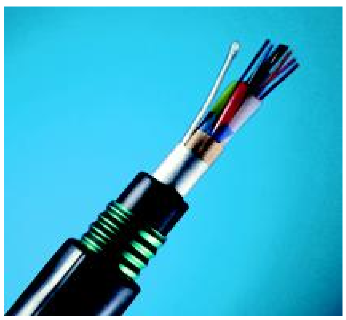


4.3.2 Installation Options

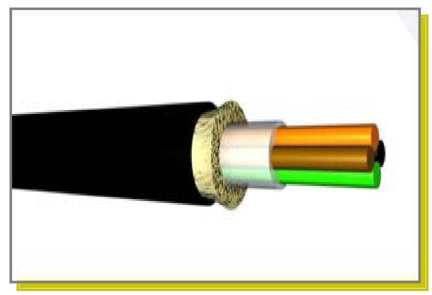
A number of excavation techniques are available including mole-plough, open trenching, slotting and directional boring. A combination of these options is possible over an area of deployment.

4.3.3 Types of Direct Buried Cable

Direct buried cables are designed in a similar fashion to that described in section 4.1 for duct cables, employing similar building blocks such as filled loose tubes. However, depending on the burial technique, the cables typically have additional armouring to protect them. Pre-trenching and surrounding the buried cable with a layer of sand can permit the use of quite lightweight designs whereas direct mole-ploughing or backfilling with stone-filled soil can require a more robust design. Crush protection is a major feature and could consist of a corrugated steel tape or the application of a thick sheath of suitably hard polyethylene.



Direct Buried cable with corrugated steel protection



Non Metal Direct Buried cable

4.3.4 Lightning protection

Non-metallic designs are favoured in areas of high lightning activity, but may therefore have less crush protection than a cable with a corrugated steel tape. The steel tape option can survive quite well when struck by lightning, particularly if the cable contains no other metallic components (since it can absorb the 'steam-hammer' effect of a direct strike), and offers excellent crush protection.

4.3.5 Rodent protection

Corrugated steel tape has proven to be one of the best protections against rodent damage or other burrowing animals. If the cable has to be non-metallic, then a complete covering of glass yarns may deter rodents to some degree.

4.3.6 Termite protection

Nylon sheaths, though costly, can give excellent protection against termites. It is hard, which resists 'bite' damage, and is chemically resistant to substances excreted by the termites.

4.3.7 Access and Jointing Chambers

Depending on the actual application, buried joints are typically used *in lieu* of the access and jointing chambers used for duct installation.

4.3.8 Direct Cables Joint Closure

Whilst the basic joint closures may be similar to that for duct cables described above, consideration should be given to additional mechanical protection. The closure may also need to facilitate the distribution of smaller drop cables.

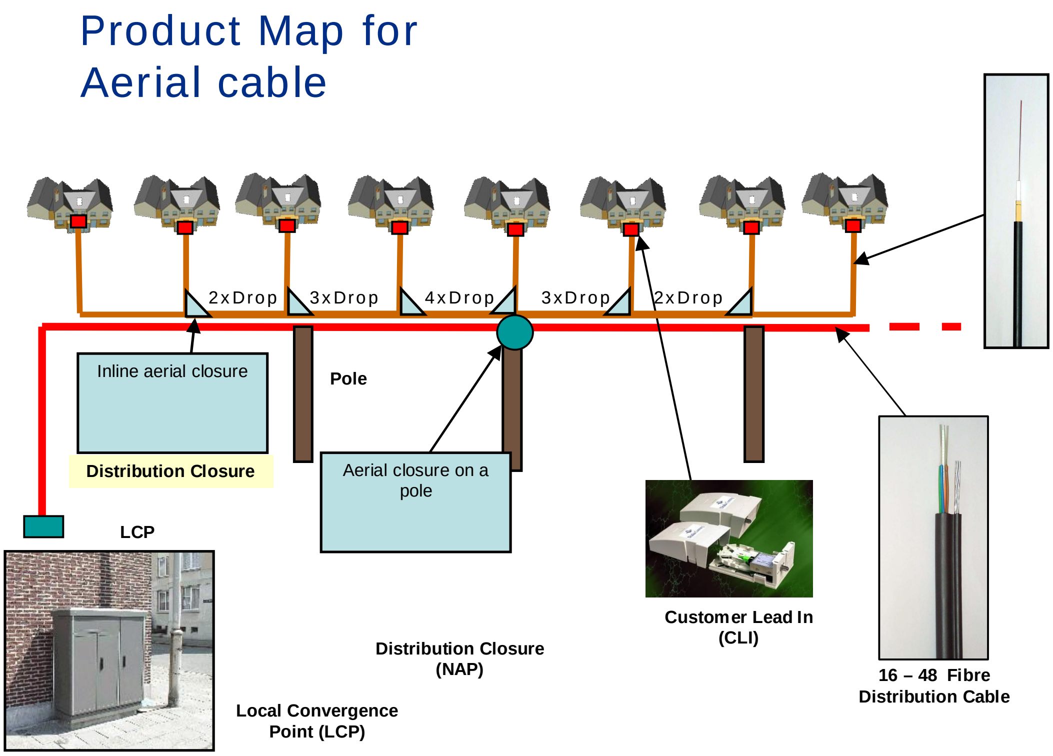
4.4 Aerial Cable Infrastructure

This involves distribution of fibre using a range of cables supported on poles or other tower infrastructure. The main benefits are the use of existing pole infrastructure to link customers, avoiding the need to dig roads to bury cables or new ducts. Existing ducts may be congested or access may be restricted and costly (i.e. way leaves). Aerial cables are relatively quick and easy to install, using hardware and practices already familiar to local installers.

Necessary main elements

- Poles and fittings to support the cables
- Aerial cables
- Branch off closures

4.4.1 Product Map – Aerial Cable



4.4.2 Condition of the Pole Infrastructure:

The poles to which the optical cable is going to be attached could already exist and have other cables already attached to them. Indeed, the pre-existence of the pole-route could be a key reason for the choice of this type of infrastructure, particularly if it avoids road digging for the installation of new ducts. Adding cables will add to the loading on the poles, so it is important to check the condition of the poles and their total loading capability.

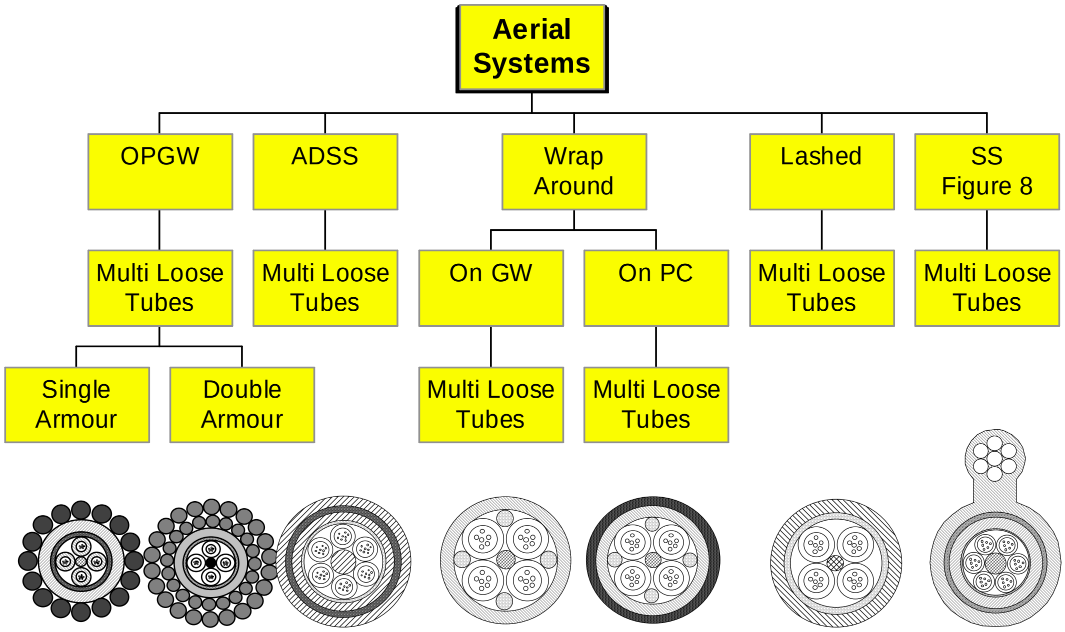
4.4.3 Types of cable (aerial feeder, distribution and drop cables)

It may be that the feeder cable is an underground design, with aerial distribution and drop cables used in the final link to customer. Fibre counts may taper between POP and customer.

Aerial designs could be circular self-supporting, ‘Figure 8’ or lashed. ADSS is useful where electrical isolation is important (e.g. on a pole route shared with power or data cables). ‘Figure 8’ allows easy splitting of the optical cable package away from the strength member. It may be favoured by companies used to using copper cables, since similar hardware and installation techniques may be used. The cable can be quite heavy, giving additional pole loadings, and is more prone to galloping vibration. Lashed cable can use more conventional cable that is then attached by a lashing wire to a separate catenary strength member. This can simplify the choice of cable but requires the use of a special lashing machine and can add to pole loading.

All aerial cables need to incorporate a sheath material that is suitably stabilised against solar radiation.

Aerial cables can have similar cable elements and constructions to those for duct and buried optical fibre cables described above. Extra consideration needs to be taken for the particular environmental extremes that aerial cables could experience (e.g. ice and wind loadings, solar radiation) and for the installation medium (e.g. poles, power lines, short or long spans).



Circular designs, whether self-supporting, wrapped or lashed, may include additional peripheral strength members plus a sheath of polyethylene or special anti-tracking material (when used in high electrical fields). Figure eight designs combine a circular cable with a high modulus catenary strength member.

Aerial Cables
If the feeder cable is fed by an aerial route then the cable fibre counts will be similar to the underground version

Example – Aerial Feeder Cable Installation

4.4.3.1. Aerial Blown Fibre Unit Cables

All of the above considerations are equally valid for blown fibre systems deployed in overhead technology.

4.4.4 Cable Pole Support Hardware

Support hardware can include tension clamps (to anchor a span of cable to a pole or to control a change of pole direction) and intermediate suspension clamps (to support the cable between the tensioning points). Both types of clamps should be carefully selected for the particular diameter and construction of the cable. Vibration dampers may be needed for spans in open country that is prone to Aeolian or galloping effects.

The cable may need protection if it is routed down the pole, for example by covering with a narrow metal plate.

Bringing FTTH in MDU’s often requires different specifications regarding cable materials, rights of way inside private owned buildings and more. This is a specific topic we would like to expand on in a next revision of this document.

4.4.5 Cable Tensioning

Cables are installed typically by pulling them over pre-attached pulleys, and then clamped via tension and suspension clamps to the poles. The installation is typically carried out in reasonably benign weather conditions and the installation loading is often referred to as the everyday stress (EDS). As the weather changes temperature extremes (maxima, minima), ice and wind can all affect the stress on the cable. The cable needs to be strong enough to withstand these extra loadings. Care also needs to be taken that the installation sag and subsequent additional sagging due to, for example, ice loading, does not compromise the cable's ground clearance (local authority regulations may need to be considered with respect to road clearance) or lead to clashing with other pole mounted cables with different coefficients of thermal expansion.

4.4.6 Aerial Cable Joint Closures

In addition to duct closure practice, consideration should be given to UV and possible shotgun protection suitable for mounting on the pole/tower. The closure may require a function for the distribution of smaller drop cables.

Alternatively, the closure may be located in a footway box at the base of the pole.

4.4.7 Pre-Terminated Drop cables

Drop cables can be terminated with a fibre optic connector in a factory such that connecting a customer to a network terminal in the field can be realized in a fast way. The terminals with the female side of the connector are typically installed prior to the drops. Drops are installed when a residence takes service. This operation does not require any splicing at that event.

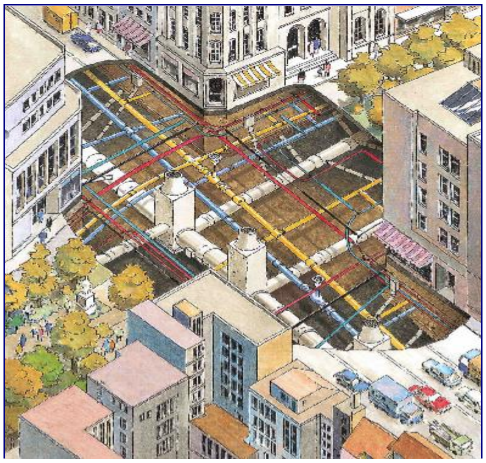
4.4.8 Other Deployment Considerations

Aerial products could be more accessible to wanton vandalism than ducted or buried products. Cables could, for example, be subject to shotgun damage. This is more likely to be low energy impact, due to the large distance from gun to target, if the target is a bird perched on the cable (the prey may be scared away if the hunter gets too close!). If, however, this is a concern then corrugated steel tape armouring within a figure eight construction has been demonstrated to be very effective. For non-metallic designs, use of thick coverings of aramid yarn, preferably in tape form, can also be effective. The OPGW cable probably has the best protection, given its metallic wire protection.

If a power line is being exploited to deploy the fibre, then this may involve OPGW (optical ground wire), earth or phase wrap cables or ADSS designs. Optical Ground Wire (OPGW) protects the fibres within a single or double layer of steel armour wires. The grade of armour wire and cable diameters are normally selected to be compatible with the existing powerline infrastructure. OPGW offers excellent reliability but is normally only an option when the ground wire itself needs to be installed or refurbished. Wrap cables use specialised wrapping machines to deploy cables around the earth or phase conductors. ADSS cables have the advantage of being independent of the power conductors. ADSS and phase wrap cables use special anti-tracking sheath materials when used in high electrical fields.

4.5 Other Deployments Options Using Rights of Way

In addition to the traditional cabling routes discussed above, it can also be advantageous to exploit other Rights of Way (RoW) that already exist within towns and cities. Deployment costs and time may be reduced by deploying cables within water and sewer networks (sanitary and stormy), gas pipe systems, canals, waterways and other transport tunnels.



Cable installations in existing pipe-networks must not influence their original function. Restrictions during repair- and maintenance work have to be reduced to a minimum and coordinated with the network operators.

4.5.1 Fibre optic cables in sewer systems (sanitary and stormy ones)

Sewers may be used for access networks, since they reach about every corner of the city and pass all potential customers. Utilising sewers avoids the need to gain digging approvals and reduces the cost below traditional digging installations.

Tunnel sizes in the public sewer range from 200 mm diameter to those that can be entered by boat. The majority of public sewer tunnel ranges between 200 mm to 350 mm. They provide sufficient cross section for installation of one or more microduct cables.

Various installation schemes exist, depending on the sewer cross section (for example man accessible and non man accessible sewer tubes).

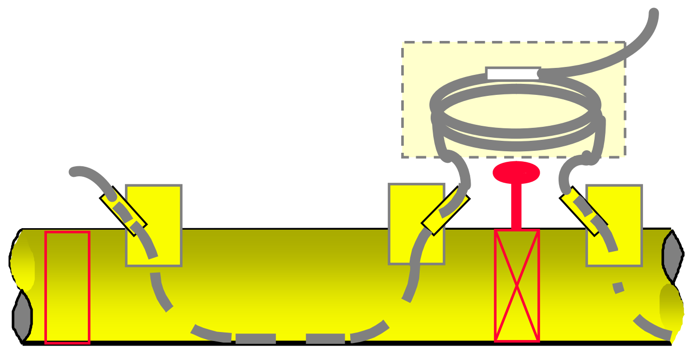
One of the schemes uses steel bracings that fix the corrugated steel tubes (that will carry the cable after blowing in) to the inner wall of the smaller sewer tube without drilling, milling or cutting. This is done by a special robot based on a module used in many systems for sewer repairs.

4.5.2 Fibre optic cables in gas pipes (fibre-in-gas)

Gas pipelines can also be used for deploying optical fibre networks without major disruption and destruction of the streets and sidewalks normally caused by conventional cut- and- fill techniques. The fibre network is deployed using a specially developed I/O-port to guide the cable into and out of the gas pipe so as to bypass the gas valves. The cable is blown into the gas pipes by means of a stabilized parachute either by using the natural gas flow itself or by using compressed air, depending on the local requirements.

The gas pipeline system provides good protection for the optical fibre cable, being situated well below the street surface and other infrastructure.

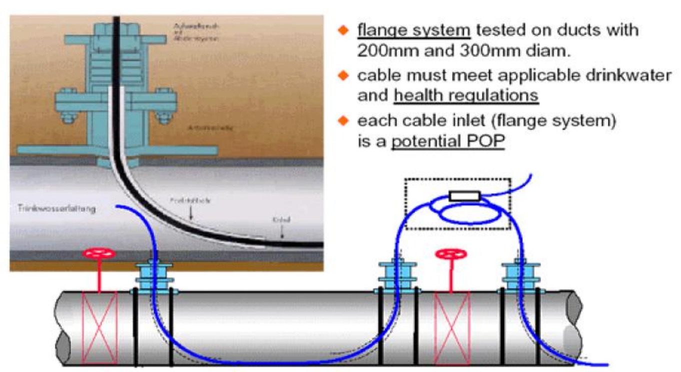
Gas pipeline section, including I/O-ports and the bypassing of a valve defining one point-of-presence for the fibre optic cable.



4.5.3 Fibre optic cables in drinking water pipes

Drinking water pipes can be used for the deployment of fibre optical cables in a quite similar manner as in the case of gas pipes.

Water pipeline section



4.5.4 Canals and Waterways

To cross waterways and canals hardened fibre optic cables can be deployed without any risk as fibre is typically very insensitive to moister.

4.5.5 Underground and Transport Tunnels

Underground/metro tunnels can be used to install fibre optic cable, often alongside power and other data cabling. Typically, they are installed on hangers on the wall of the tunnel. They may be fixed in a similar manner to cables used in sewers (see above). Two key issues to consider for these applications are fire performance and rodent protection.

Should a fire occur in a transport tunnel then the need to evacuate personnel is critical. IEC TR62222 gives guidance on "Fire performance of communication cables in buildings" which may also be applied to transport tunnels if the fire scenarios are similar. This lists potential hazards such as smoke emission, fire propagation, toxic gas/fumes and acid gas, which can all be detrimental to evacuation. Potential users of underground and transport tunnels should ensure that all local regulations for fire safety are considered prior to installation. This would include fixings, connectivity and any other equipment used.

Cables in tunnels can also be subject to rodent attack which could require the cable to have extra protection, such as a corrugated steel tape.

4.6 Internal Cabling

4.6.1 Indoor Cables

Indoor cables can be used from the building entry and may be for short runs within a house or long runs through a building. These may range from single fibre cables, possibly pre-connectorised, through to multi-fibre designs using tight-buffered or loose tube designs, as described below. There are also microduct blown fibre versions.

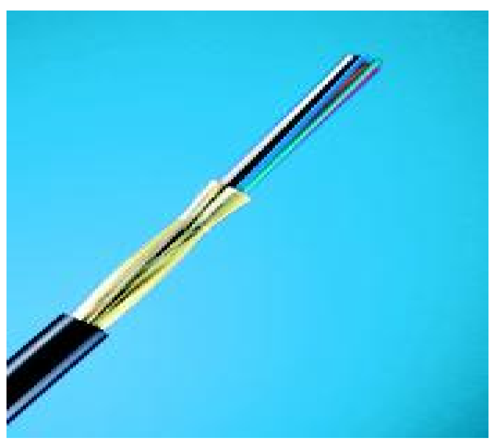
Whilst the designs may vary, they are all used in customer premises, therefore they should all typically offer some form of fire protection. This would typically include the use of a low smoke zero halogen sheath. The cable would be constructed in such a way as to afford some degree of protection from flame propagation (for example IEC60332-1 and IEC 60332-3 category C) and smoke emission (IEC61034-2). The materials may be characterized for halogen content in line with IEC60754-1 and for conductivity and pH in accordance with IEC60754-2.

Other criteria may apply, depending on the user's exact requirements, but attention to public safety is paramount.

Typical cable performance requirements are given in the IEC60794-2 series of specifications.

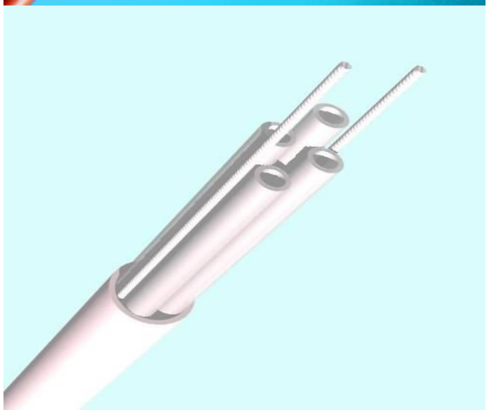
The simplest cable type is the patchcord or tail cable. This comprises a 250 micron diameter acrylate coated fibre upjacketed, typically with nylon, to 0.8-1mm. This improves the handling properties of the fibre and allows for a more robust connectorisation. This may be applied as a tight buffer for optimum robustness, or as a semi-tight layer to enable easy-strip (for example where 1m or more is stripped for ease of tray storage). Strength is given by a layer of aramid yarns. This is covered with a low smoke sheath material.

For distribution of fibres through a building, one popular construction is the 'multi-tight' design. This is similar to the cable above, except that it would typically house up to 24 fibres.

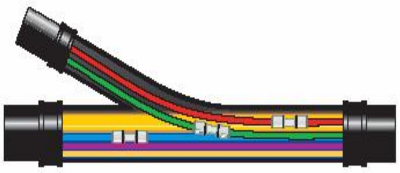


Fibres may also be housed within loose tubes, either central loose tube (for up to 24 fibres) or multi-loose tube for up to 144 fibres, for connection to racks in exchange buildings.

Microduct cables can be constructed with low smoke zero halogen materials for indoor applications.



Tubing Distribution and Breakout Device.

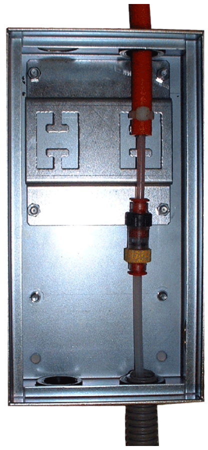


To connect and distribute the in-building tubes, there are several options available. From small (slim) boxes up to large distribution boxes for high-count tubes, these boxes are available in watertight, open and vandal proof construction.

4.6.2 Building Entry Point

Cable Lead – In

Single Building/
Residential



Example of External Cable Lead-In showing tube transition (CLI cover removed)

Example of Cable Lead-In allowing fibres to pass 90^{o} through Premises Wall

4.6.3 Customer Premises Equipment (CPE)

External Fibre Termination Unit (part of ONU)

This is the point where the passive network ends and the active equipment is installed.

The fibre is terminated inside the CPE with connectors (commonly used: SC/pc and LC)

Example – External Mounted ONU

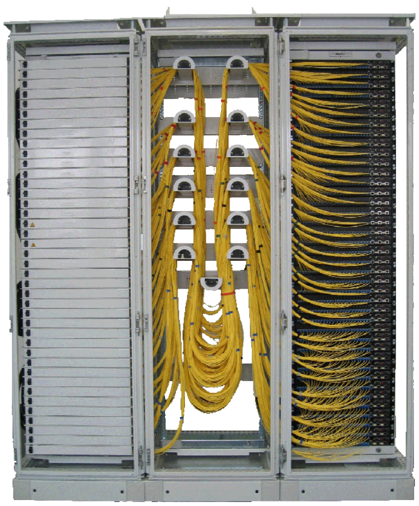
5. *Other Common Network Materials*

5.1 Optical Distribution Frames

An optical distribution frame (ODF) is the interface between the outside plant cables (outdoor network) and the active transmission equipment. Typically these locations are somewhat larger in size and bring together several hundreds to several thousands of fibres.

Outdoor cables are generally terminated within an ODF using an optical connector. This normally consists of splicing a connectorised optical fibre pigtail to each individual fibre end.

In most cases, the ODF offers flexible patching between active equipment ports and the field fibre connectors. Fibres are identified and typically stored in physically separated housings or shelves to simplify fibre circuit maintenance and protect or avoid accidental interference to sensitive fibre circuits.

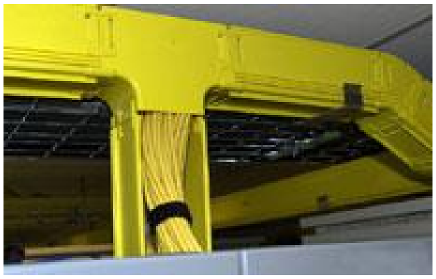


Examples of ODF units

Cable Guiding System

Internal optical 'tie' cables are run between the ODFs and active equipment. A fibre-guiding platform is built between the active equipment and the ODF cabinets.

This provides a protected path for the internal optical cables to run within the central office in between 2 locations.



Examples of overhead cable guide systems

Un-interrupted Power Supply (UPS)
A UPS provides essential emergency power back up in case of external power supply failure.
The Access Node may also require a second diverse external power supply which may form part of local & statutory requirement (provision of emergency services).
Available UPS modules vary in size & depend upon the power requirement to be backed up.

Example of Un-interrupted Power Supplies (UPS) units

Climate Control
Suitable Air Conditioning plant is required to keep the Activate Equipment within environmental operation limits.
The size & capacity of the unit will depend on the size of the equipment room to be served.

Example of Air Conditioning Unit

Access Node Security
The Access Node should be classed as a secure area therefore provision for fire & intrusion alarm, managed entry/access & mechanical protection against vandal attacked must be considered.

5.2 Patchcords and Pigtails

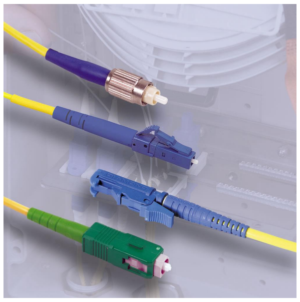
Patchcords are fibre optic cables that are fitted at one end (pigtail) or both ends (jumper) with a connector.

The cable is available in two different constructions:

- 900 micron (typical) tube or buffer without any strength member
- 1.7 mm to 3.0 mm ruggedised cable. The construction is based mostly on a 900-micron tubing combined with aramid yarns as strength members and a plastic jacket over sheath

Cable regulation in Europe mostly requires that the polymeric materials for indoor wiring are LSZH-rated (Low Smoke, Zero Halogen) to prevent high smoke concentrations and toxic gasses when burned.

Various optical connector designs exist on the market. These are supplied without angle polishing (PC or UPC) and with angle polishing (APC).



Standard size connector styles include:

- SC
- FC
- E2000
- ST, DIN

Small form factor connector styles (half size) include:

- LC
- MU
- F3000

The optical loss of a connector is the measured loss of two mated connectors fitted within an adapter housing. A typical loss of a mated connector is 0.5dB when randomly mated and 0.2dB when mated against a reference connector (which is an 'ideal connector').

For many connector types, low loss versions also exist with a typical insertion loss of 0.15dB, random mated. Power budget considerations dictate the class of connector to be used. Where low loss connector performance is required, many vendors are able (through design) to achieve lower loss by tuning connectors to minimise the lateral fibre offset between a mated pair.

Connectors are also characterised with a return loss value. When light is transmitted into a connector, a portion of the light is reflected back from the fibre end face with an attenuation of a defined dB value. For PC connectors this value is 45dB; for UPC types this value is 50dB and for APC this value adds up to 60dB (non-mated versions). It is desirable for this figure to be as high as possible to avoid problems with transmission lasers. Pigtails can be deployed in OSP conditions with temperature ranges from –40/+70ºC. Connectors should be protected from high amounts of dust and humidity.

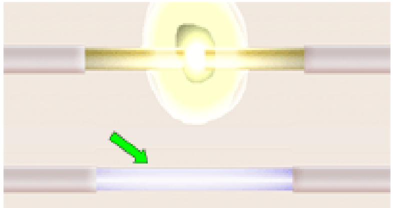
5.3 Splicing of Fibres

1. Fibre Splicing

Two technologies are common for splicing fibre to fibre:

a. Fusion Splicing:

Fusion splicing is based on the creation of an electric arc between two electrodes. In this arc two cleaved fibres are brought together where both ends melt one to the other.



Based on the alignment mechanism used the optical losses can vary from splicer to splicer.

For splicers using core alignment, align the light-guiding channel of the fibre (9 micron core) one to the other. These splicing machines generate splices with losses typically <0.05dB

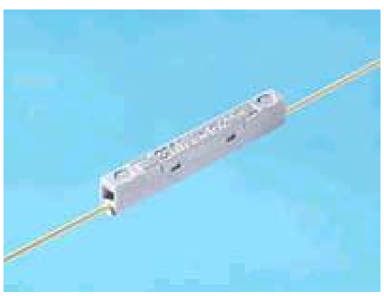
 

Some splice machines (smaller handheld versions for example) align the cladding (125 micron) of a fibre one to the other instead of the cores that transport the light. This is cheaper technology but can cause more error due to the dimensional tolerances of this cladding. Typical insertion loss values for these splice machines are <0.1dB.

b. Mechanical Splicing

Mechanical splicing is based on the mechanical alignment of two cleaved fibre ends such that the light can be coupled from one fibre into the other. To facilitate the light coupling between the fibres, mostly an index matching gel is used. Most often a tooling is used to bring the fibre ends together in the mechanical splice.

Both angle cleaved and non-angle cleaved mechanical splices exist where the angled versions have higher return loss values.
The typical insertion loss of a mechanical splice <0.5 dB.

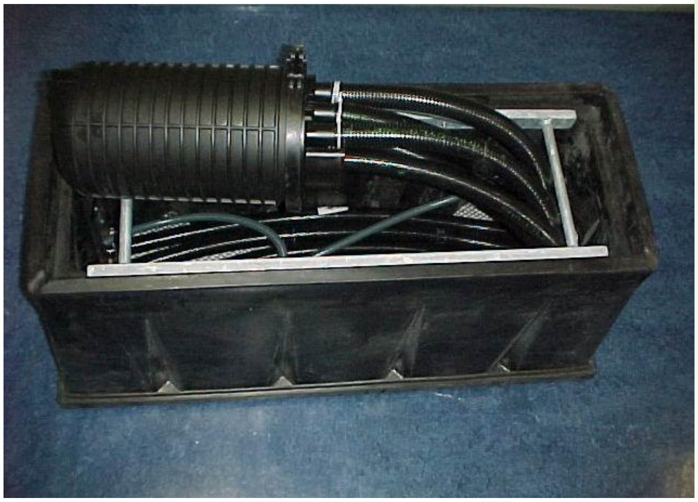
  

5.4 Cable Joint Closures

As cables are not endless in length and need to be branched off at several locations, intermediate splice closures are needed. These are environmental and mechanically protected housings for outdoor use that offer a small compact means of managing fibres for storage within underground chambers and on overhead poles. Security risks are low and easy access is possible if the underground chamber in which the enclosure is stored is well managed. Closures are available in many different sizes and shapes. The typical splice capacity rises above 500 fibre circuits per joint closure. The fibre management system allows for fibre identification and to protect against and avoid accidental interference of fibre circuits when specific fibres are accessed.

Some closures offer the opportunity to access only selected fibres out of a complete cable for splicing while all other fibres in the cable are left uncut during the installation of the closure. This is mostly referred to as mid-span cable access. This capability reduces drastically the installation time of a branch and the required down time of a link.
For overhead applications specialist equipment may be required to access the closure for configuration. The environmental protection level can depend on the application and deployment area (underground versus pedestal, versus aerial mount).

A differentiation between closures can also be made on the cable sealing features. Today most joint closures seal the cables using heat shrinkable tubing or are cold sealable using gel or rubber sealing elements.



Typical examples of Underground closures

The fibre deployment technology used will also influence the joint closure features. For example, deployments in sewer systems require closures that are suitable to deal with very harsh chemical environments. Blown fibre closures need to handle the blown fibre tubes and allow for access of the blowing equipment. For this reason, each application might require a different closure solution.

Typical examples of blown fibre closures

5.5 Access and Jointing Chambers (Handholes and Manholes)

Handholes in FTTH networks are used for easy access to splice closures, duct distribution points and cable slack storage. There are basically four types of handholes available:

- Concrete handholes
- HDPE handholes
- Polyester handholes
- Polycarbonate handholes

Different sizes and shapes are available for all types and most of the plastic types are available in fixed sizes and modular build up.

The choice of a type of handhole is based on the following criteria:

- Where will it be installed? (mainly security reasons)
- What is the maximum load that it has to take?
- How much space is required?
- What are local regulations?
- Is it at underground or ground level?

In situations where there is danger for demolition it is sometimes wise to place the handhole completely underground. The disadvantage of this is difficult access in case of success-based engineering. Alternatively you can use a handhole with a cover that can be locked with special keys. Several types are available for all types of handholes.

The load that the handhole has to take is regulated in the European Standard: EN 124. All required tests are also described in this standard.

COVER LOAD	FIELD OF APPLICATION
A 15 15 kN test load 	Traffic areas utilised by pedestrians and bicycles only and similar areas (i.e. park areas) - can be crossed by cars in restricted extension
B 125 125 kN test load 	Foot-walks, pedestrian areas, parking areas – can be crossed by cars in restricted extension
D 400 400 kN test load 	All traffic ways (except landing runways)

If the handhole is used for cable slack, it is important to respect the maximum bend radius that the installed cable will allow. This is also important for handholes with splice closures.

Remember: once installed you will always have the advantage of the space. It is advisable to do a full installed test before selecting type and size.

Most types of handholes can fulfil the local regulations such as load profile (anti slip) and type of topping that fits in the pavement (tiles; concrete etc).

HDPE Handhole

Polycarbonate Handhole

5.6 Street Side Cabinets

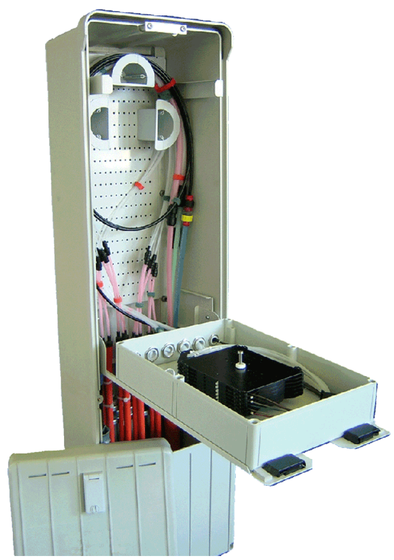
Cabinets are metal or plastic housings placed above ground often on pedestrian pathways. Cabinets often are placed for relatively easy and rapid access to fibre circuits. Compared to fibre joint closures they can handle larger fibre capacities and can offer ODF type of flexibility. These are often used to store splitter devices in PON architectures that still require flexible connectivity to customer-dedicated fibres.

Strong consideration needs to be given for security and prevention of vandal attack and traffic accidents.

Positioning may also be restricted by local authority rules (historic city centres, secure public places etc.). For this reason, several hardware suppliers offer underground solutions for cabinets as well that can be raised out of the ground when accessed only. When stored no more than a manhole cover is seen.

Typical Street Cabinets

5.X Street Pedestal



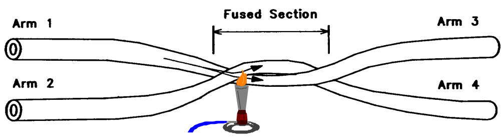
The Street Cabinet is to be used as a tube and/or fibre optic cable distribution point in the access area. The Street Cabinet consists of 3 parts: Base, Tube Management and Splice Management part. Tubes, Modular Cables and Fibre Optic Cables can be fixated in the base on a mounting rail. The tube management compartment is used to connect, divide and store tubes and cables. The same compartment can be used as point of access to facilitate blowing in (also midpoint blowing) of the Fibre Units, tubes or Fibre Optic Cables. From the tube management part the tubes and cables are guided into the splice management part (Closure, Termination Box). In the splice management part the fibres of the different cable types can be spliced. This construction enables easy and fault free connection of different cable types.

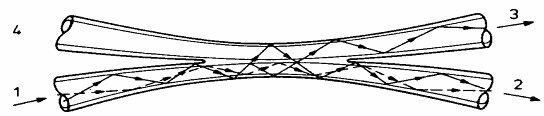
5.7 Optical Splitters

Two technologies are common in the world of passive splitters:

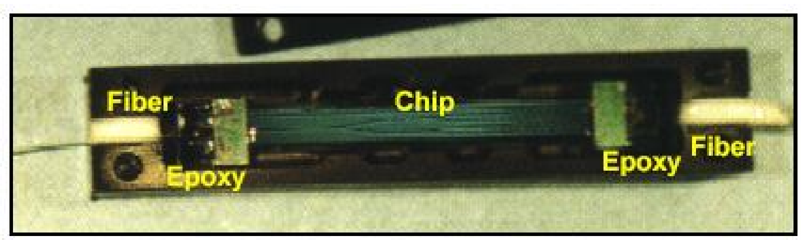
FBT (Fused Biconic Tapered)

- FBT splitters are made by fusing two wrapped fibres
- Well known production process
- Proven technology for OSP environments
- Monolithic devices are available up to 1x4 split ratio
- Higher split ratios (>1x4) are built by splicing 1x2, 1x3 or 1x4 splitters in a cascade
- Split ratios from 1x2 up to 1x32 and higher (dual input possible as well)
- Higher split ratios have typically higher IL (Insertion Loss) and lower uniformity compared to planar technology
- Asymmetrical split ratios possible e.g. 1x2 splitter with 30/70% split ratio (any ratio possible)





- Optical paths are buried inside the silica chip
- Exist from 1x4 to 1x32 split ratios and higher become available (dual input possible as well)
- Only symmetrical splitters available as standard devices
- Compact compared to FBT at higher split ratios (no cascading)
- Better IL and uniformity at higher wavelengths compared to FBT over all bands
- Better for longer wavelength; broader spectrum



6. Network Infrastructure Planning, Operation & Maintenance Guidelines

This section covers the planning, operational and maintenance aspects of a FTTH network infrastructure. Whilst each FTTH network design will differ and operate in different environments and conditions, the planning, operation and maintenance remains a common requirement to all.

During network construction, the builder will need to ensure minimum disruption to the general public and surrounding environment. This will most likely be a requirement through a contract to ensure that installation and build processes cause little or no disturbance within the FTTH area. This can only be achieved by careful planning and execution. This will also drive the need for efficient build methods to be deployed that will ultimately benefit the FTTH business case. Poor planning will have the opposite effect and potentially lead to poor build performance and a failing build programme.

Whilst fibre is a reliable medium with proven reliable service over tens of years, it is still vulnerable to unexpected breakdown that will require mobilisation and rapid and efficient repair. During such times immediate access to the networks records by those tasked with repair is essential. It is vital from the onset of the network build that records and documentation are collated and centralised to support all subsequent network analysis.

Maintenance procedures must be planned in advance and contractual arrangement put in place to ensure the appropriate manpower is on hand when needed.

6.1 Network Infrastructure Network Build Planning Guidelines

Site Control and Installation Operation Planning

Work with underground duct systems or installations on sideways or poles, will require careful planning and in many cases cause disruption to traffic. Liaison with local authorities will be required and suitable controls put in place. The following points briefly list the main installation considerations that need to be taken into account when embarking upon a duct type installation:

General Management Considerations

- A working familiarity with underground or aerial duct and cable systems, practices and working operations is essential.
- Careful planning of the installation will lead to an efficient and safe operation. Liaison with the Local Authorities prior to installation is recommended, where appropriate.
- A full appreciation of nearby Utility Services must be obtained both from the local authorities and by 'on site' confirmation using suitable detection equipment.

Safety

- Proper safety zones using marker cones and traffic signals should be organised. Disruption of traffic should be coordinated with local officials.
- All manholes and cable chambers should be identified and those intended for access should be tested for flammable and toxic gases before entry.
- For confined spaces, full air and oxygen tests should be carried out before entry and forced ventilation provided as necessary. Whilst working underground, all personnel must have continuous monitoring gas warning equipment in operation at all times – flammable, toxic, carbon dioxide and oxygen levels.
- In cases where flammable gas is detected, the local Fire Service should be contacted immediately.
- All existing electrical cables should be inspected for any possibility of damage and exposed conductors.

Construction, Equipment and Planning

- A full survey of the complete underground duct system or aerial plant should be carried out prior to installation.
- Manhole and cable chambers with excess levels of water should be pumped out.
- Ducts should be checked for damage and potential obstructions. Rodding of the duct sections using a test mandrel or brush is recommended prior to installation.
- Manholes should be checked to ensure suitable space for coiling slack cables, provision of cable supports and space for mounting Splice Joint Closures.
- A plan should be established to optimally position the cable payoff, mid point fleeting and cable take-up/ winching equipment. The same also applies if the cables are to be blown into the duct which requires Blowing Head and Compressor Equipment. Allowances for elevation changes should be taken into account accordingly.
- Fleeting the cable at mid sections using a Figure of 8 technique can greatly increase the pulled installation section distance using long cable lengths. However careful planning must ensure these locations are suitable for cable fleeting.
- The duct or inner duct manufacturer should be contacted for established cable installation guidelines.
- Ribbed, corrugated ducts and ducts with a low friction liner are designed to reduce cable/duct friction during installation. Smooth non lined ducts may require a suitable compatible cable lubricant.
- Pulling grips are used to attach the pulling rope to the end of the cable. These are often mesh/weave based or mechanically attach to the cable end minimising the diameter and thus space of duct used. A 'fused swivel' device should also be applied between the cable pulling grip and pulling rope.
- The swivels are designed to release any pulling generated torque and thus protect the cable. A mechanical breakaway fuse protects the cable from excess pulling forces by breaking a 'sacrificial' shear pin. Pins are available in different tensile values.
- A Pulling Winch with a suitable capacity should be used. These should be fitted with a dynamometer to monitor tension during pulling.

- Sheaves, capstans and quadrant blocks should be used to guide the cable under tension from the pay-off, to and from the duct entry and to the take-up equipment to ensure that the cable's minimum bend diameter is maintained.
- Communication radios, mobile phones or similar should be available at all locations in the operation.
- Use of mid point or assist winches may be recommended in cases where the cable tensile load is approaching its limit and could expedite a longer pull section.
- Cable Payoff Device: a reel or drum trailer is recommended.
- For aerial applications appropriate equipment such as bucket trucks should be foreseen. Specific safety instructions for working in altitudes need to be respected. Specific hardware is available for cable and closure fixture.

Cabling Considerations

Duct and Microduct Cabling

- Duct installation and maintenance is relatively straightforward. Occasionally cables may be dug up inadvertently hence maintenance lengths should be available at all times.
- Duct and buried optical fibre cables can have similar constructions, with the latter obviously having more protection from the environment in which it is to be installed and operates.
- Route length plus allowance of jointing (typically 3-5 meters).
- Cable spare/slack loops at chamber positions of typically 20 mtrs. This will allow for later 'mid-span' access joints to be added at a later date.
- Minimum Bend Radii (MBR) and maximum tensile load values for the cables must not be exceeded.
- MBR is usually expressed as a multiplier of the cable diameter (e.g. 20xD) and is normally defined as a maximum value for static and dynamic situations
- Static MBR is the minimum allowable bend value for the cable in operation (i.e. coiled within a manhole or chamber). The dynamic MBR value is the minimum allowable bend value for the cable under installation pulling conditions.
- Pulling Load (or Pulling Tension; N, or Force; Kgf) values are normally specified for short and long-term conditions. Short-term load values represent the maximum tension that can be applied to the cable during the installation process and long-term values represent the maximum tension that can be applied to the cable for the lifetime of the cable in service.
- In cases where cables are to be installed by blowing, the cable and duct must be compatible for a blowing operation. The cable and duct supplier/s must be contacted for installation guidelines.

Direct Buried Cable

Installation techniques for burying cables can include trenching, ploughing, directional drilling and thrust boring. Reference should also be made to IEC specification 60794-1-1 Annex C.3.6 'Installation of buried cables'.

- Confirm minimum bend radii of cable and maximum pulling tensions for installation and long-term service conditions.
- Ensure cable tension is monitored during burial and cable maximum limits are not exceeded.
- A full survey of the buried section will ensure an efficient installation operation
- Cross over points with other services and utilities must be identified
- All buried cables must be identified and marked for any future location
- Backfilling must ensure the cables are suitably protected from damage from large rocks e.g. sand. All back filling must be tamped to prevent future ground movement and settlement
- All surfaces must be restored to local standards

Aerial Cable

Reference should be made to IEC specification 60794-1-1 Annex C.3.5 'Installation of aerial optical cables'.

§ Cables used in aerial plant type of installations are mostly different compared to underground applications and are designed to handle wind and snow/ice loads. Requirements may differ from geographic area. For example, wind loads are often dependant from regions (hurricane areas etc.)
§ Cable needs a defined slack between poles to reduce the cable load (own weight)
§ On poles slack needs to be stored for cable access or closure installation.

§ Sharing of poles between operators or service providers (CATV, Electricity, POTS etc.) is common practice and will require specific organisation as well.

6.2 Network Infrastructure Operation and Maintenance Guidelines

Considerations should be made about:

- Measurements
- Fibre cable and duct records
- Marking of key infrastructure items
- Complete documentation
- Identification of key infrastructure elements subject maintenance operations
- Minor maintenance list
- Plan for catastrophic network failure from external factors (accidental digging of cable and duct)
- Spare infrastructure items to be kept on hand in case of above cables and ducting
- Location and availability of network records for above
- Provision of maintenance agreement

6.3 Fibre Optic Measurements

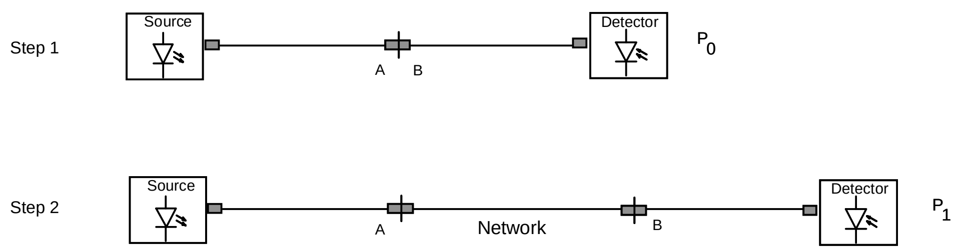
In the following cases optical measurements are performed in an FTTH network:

- Network conformance and acceptance test
- Maintenance
- Fault location in case of a failure

The most popular methods are the LSPM (Light Source Power Meter) and OTDR (Optical Time Domain Reflectometer) methods.

<u>LSPM method</u>:

Light from a stable light source is launched into one end of the network. The Power Meter will measure the received optical power at the other end of the network. The total optical loss of the line can be easily calculated by:



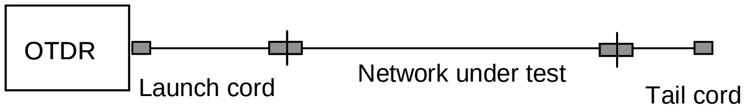
$$IL = P_0 - P_1$$

This method will give the exact point-to-point attenuation in an optical network and is therefore often used for acceptance testing. In single mode networks there is no need to measure the attenuation from both sides.

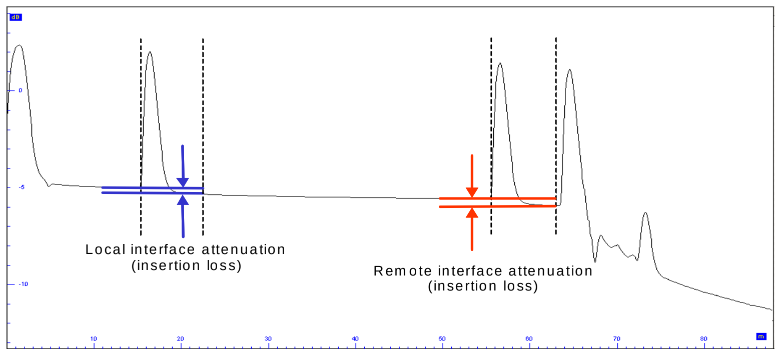
The disadvantage of this method is that it will not give any spatial information about the location of a failure (for example a lost splice or connector). In this case the OTDR will provide more information.

OTDR method:

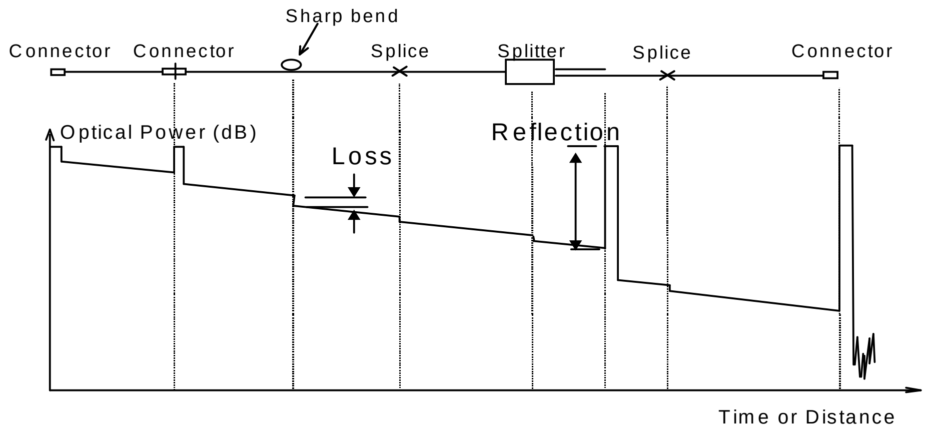
The OTDR test equipment will launch a light pulse into the network.



The reflected light will be detected and with this time dependent information the following trace will be generated:

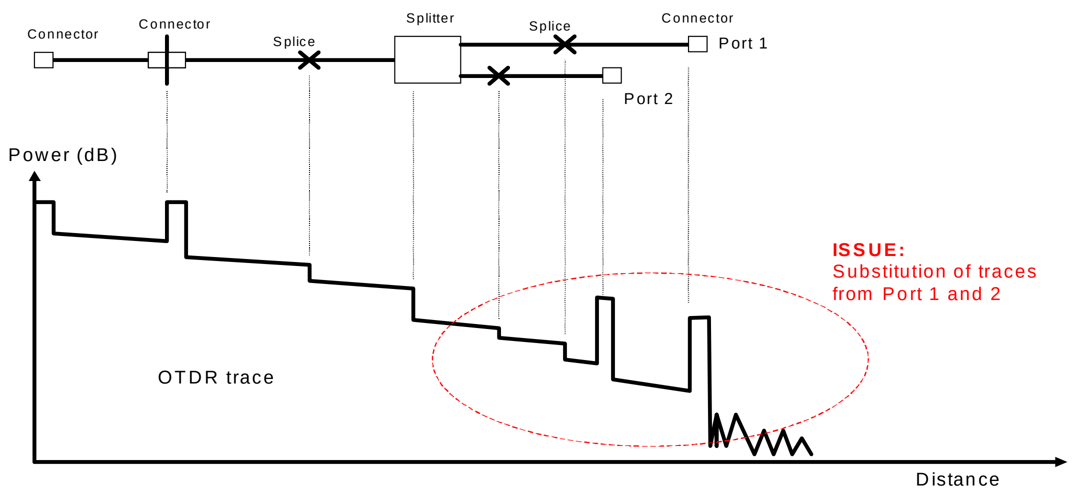


The OTDR method allows to measure attenuation and reflection at a certain point in the network. Therefore this method allows the localisation of a high loss or high reflection point (broken fibre, open connector) in the network.



To measure the attenuation of a device or splice more accurately one must measure the loss from both sides of the network and calculate the average of the 2 measured losses.

The splitters in a PON network will make the identification of a failure beyond the splitter very difficult. The signal from all the splitter ports is added into one trace. Therefore it can become very complicated to localise the failure in the correct split branch of the PON network.



FTTH Optical Fibre Overview

What is Optical Fibre ?

Optical fibre is effectively a 'Light Pipe' carrying pulses of light generated by lasers or other optical sources to a receiving sensor (detector). Fibre light transmission can be achieved over considerable distances supporting high speed, high bandwidth applications unsustainable by today's copper based networks. Conceived in the 1960's, optical fibre has been highly developed and standardised to form a reliable, proven backbone of today's modern telecommunication transmission systems.

Fibre Basics

Fibre is manufactured from high purity silica glass-like rods drawn into fine hair-like strands and covered with a thin protective plastic coating. Fibres are subsequently packaged in various cable configurations before installation in the external and/or internal networks. Whilst there are many different fibre types, this document concentrates on fibre for FTTH applications.

Fibre is essentially made up of a core, cladding and outer coating. The light pulses are launched into the core region. A surrounding cladding layer keeps the light traveling down the core and prevents light from leaking out. An outer coating, most commonly made of a protective polymer layer, is applied during the drawing process.

The fibre core can be designed in varying geometrical sizes. These impact how the light pulse travels thus producing differing optical performance.

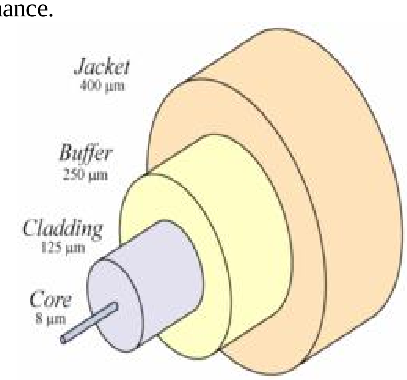


Figure: The basic design of an optical fibre.

Fibres are connected together either by fusion splicing (ends welded together) or by butt jointing using a mechanical splice or precision optical connector (end polished).

A number of key parameters determine how effective the light pulses transmit down the fibre. The two main fibre performance parameters are attenuation and dispersion.

Attenuation is the reduction of light power over distance. Even with the highly pure materials used to manufacture the fibre core/cladding, light power is lost over distance by scattering and absorption within the fibre. Fibre attenuation limits the distance light pulses can travel while still being detectable. Attenuation is expressed in decibels per kilometer (dB/km) at a given wavelength or range of wavelengths.

Dispersion is inversely related to bandwidth, which is the information carrying capacity of a fibre. This can be broadly described as the amount of distortion or spreading of a pulse during transmission. If pulses spread out too far, the detection unit at the other end of the fibre is not able to distinguish one pulse from another, causing loss of information. Chromatic dispersion occurs in all fibres and is caused by the various light colours (components of a light pulse) traveling at slightly differing speeds along the fibre.

There are many other parameters, which affect fibre transmission performance. Further information can be found in IEC 60793 series of specifications.

Types of Fibre

The two main fibre types used for optical transmission are described as single-mode and multimode.

Single-mode fibres

Single-mode fibre comprises a small core size (<10um) which supports one mode (ray) of light.

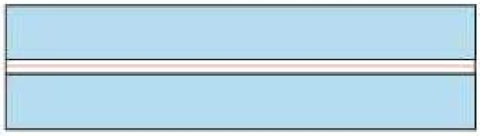


Figure: Single-mode fibre

Single-mode fibre provides the lowest optical attenuation loss and highest bandwidth transmission carrying capacity of all the fibre types. Single-mode fibre incurs higher equipment cost compared with multimode fibre systems. Most of the world's fibre systems are based on this type of fibre. For FTTH single-mode applications, the reference to the ITU-T G.652 recommendations should adequately cover most user's needs.

More recently, a newer type of single mode fibre was introduced to the market that has decreased optical losses at reduced fibre bends. This fibre is standardized as ITU-T G.657 and is available from several fibre suppliers. This type of fibre is most beneficial when optical fibre needs to be installed in environments where cables need to be installed in tighter bends like in-home wiring,…

Graded Index Multimode Fibres

Multimode fibres comprise a larger core size (50 or 62.5 micron) which supports many modes (different light paths through the core). Depending on the particular launch characteristics, the input pulse power is divided over all or part of these modes.

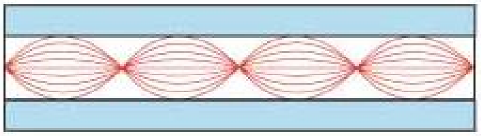


Figure: Multimode fibre

The different propagation speed of individual modes (modal dispersion) can be minimised by adequate fibre design. Multimode fibre can operate with less costly light sources and connectors, but incurs a higher fibre cost than single-mode fibre. Multimode fibres are used effectively for short distance transmission networks e.g. campus and in-building applications. The ISO/IEC11801 specification gives the data rate and reach of multimode fibre grades referred to as OM1, OM2 and OM3.

Appendix 2

International Standards

Overview of Optical Fibre related IEC International Standards

IEC 60793-1-1 Ed. 2 Optical fibres - Part 1-1 – Measurement methods and test procedures: General and guidance
IEC 60793-2 Ed 5 Optical fibres - Part 2: Product specifications – General
IEC 60794-1-1 Ed2* Optical fibre cables - Part 1-1: Generic specification – General
IEC 60794-1-2 Ed2* Optical fibre cables - Part 1-2: Generic specification - Basic optical cable test procedures
IEC 60794-2-10 ED 3.0 Optical Fibres – Part 2-10: Product specifications – sectional specification for category A1 multimode fibres
IEC 60794-2-50 ED 2.0 Optical Fibres – Part 2-50: Product specifications – sectional specification for class B single-mode fibres
IEC 60794-2 Ed3* Optical fibre cables - Part 2: Indoor cables - Sectional specification
IEC 60794-2-10 Ed1* Optical fibre cables - Part 2-10: Indoor cables - Family specification for simplex and duplex cables
IEC 60794-2-11 Ed1 Optical fibre cables - Part 2-11: Indoor cables - Detailed specification for simplex and duplex cables for use in premises cabling
IEC 60794-2-20 Ed1 Optical fibre cables - Part 2-20: Indoor cables - Family specification for multi-fibre optical distribution cables
IEC 60794-2-21 Ed1 Optical fibre cables - Part 2-21: Indoor cables - Detailed specification for multi-fibre optical distribution cables for use in premises cabling
IEC 60794-2-30 Ed1 Optical fibre cables - Part 2-30: Indoor cables - Family specification for optical fibre ribbon cables
IEC 60794-2-31 Ed1 Optical fibre cables - Part 2-31: Indoor cables - Detailed specification for optical fibre ribbon cables for use in premises cabling
IEC 60794-2-40 Ed1* Optical fibre cables - Part 2-40: Indoor cables - Family specification for simplex and duplex cables with buffered A4 fibres
IEC 60794-2-40 Corr.1 Ed1* Corrigendum 1 - Optical fibre cables - Part 2-40: Indoor cables - Family specification for simplex and duplex cables with buffered A4 fibres
IEC/PAS 60794-2-50 Ed1* English Optical fibre cables - Part 2-50: Indoor optical fibre cables - Family specification for simplex and duplex cables for use in patch cords
IEC 60794-3 Ed3 Optical fibre cables - Part 3: Sectional specification - Outdoor cables
IEC 60794-3-10 Ed 1* Optical fibre cables - Part 3-10: Outdoor cables - Family specification for duct and directly buried optical telecommunication cables
IEC 60794-3-12 Ed1 Optical fibre cables - Part 3-12: Outdoor cables - Detailed specification for duct and directly buried optical telecommunication cables for use in premises cabling
IEC 60794-3-20 Ed1* Optical fibre cables - Part 3-20: Outdoor cables - Family specification for optical self-supporting aerial telecommunication cables
IEC 60794-3-21Ed1 Optical fibre cables - Part 3-21: Outdoor cables - Detailed specification for optical self-supporting aerial telecommunication cables for use in premises cabling
IEC 60794-3-30 Ed1* Optical fibre cables - Part 3-30: Outdoor cables - Family specification for optical telecommunication cables for lake and river crossings
IEC 60794-4 Ed1 Optical fibre cables - Part 4: Sectional specification - Aerial optical cables along electrical power lines
IEC 60794-5 Optical fibre cables - Part 5: Sectional specification for microduct cabling for installation by blowing
IEC 60794-5-10 Optical fibre cables - Part 5-10: Family specification for outdoor microduct optical fibre cables, microducts and protected microducts for installation by blowing
IEC 60794-5-20 Optical fibre cables - Part 5-20: Family specification for outdoor microduct optical fibre units, microducts and protected microducts for installation by blowing

Require references to Rights of way

Glossary

ADSS	All-Dielectric Self-Supporting
APC	Angle Polished Connector
ATM	Asynchronous Transfer Mode
Bps	Bit per second (bit/s)
CATV	Cable Television
CWDM	Coarse Wavelength Division Multiplexing
DWDM	Dense Wavelength Division Multiplexing
FCP	Fibre Concentration Point
FCPM	Fibre Concentration Point Multiple
FBT	Fused Biconic Tapered
FDF	Fibre Distribution Field
FttC	Fibre to the Curb
FttB	Fibre to the Building
FttH	Fibre to the Home
FttN	Fibre to the Node
FttX	Generic Term for all of the Fibre-to-the-xxx above
FWA	Fixed Wireless Access
G.650	ITU Rec.G.650 Definition and testing methods for single mode fibres
G.651	ITU Rec. G.652 50/125µm raded –index multimode fibres
G.652	ITU Rec. G.652 single mode fibre
G.655	ITU Rec. G.652 non-zero dispersion shifted single mode fibre
Gbps	Gigabit per second
HDPE	High Density Polethylene
IEEE	Institute for Electrical and Electronics Engineers
IL	Insertion Loss
ISO	International Organisation for Standardisation
IEC	International Electrotechnical Commission
ITU	International Telecommunication Unit
LAN	Local Area Network
LI	Local Interface
LSZH	Low Smoke, Zero Halogen
Mbps	Megabits per second
MMF	Multimode fibre
MDU	Main Distribution Unit
MDU	Multi-Dwelling Unit
ODF	Optical Distribution Frame
OLT	Optical Line Terminal
ONT	Optical Network Terminal
Open Network	Network with several operators under same conditions
OPGW	Optical Power Ground Wire
OTDR	Optical Time Domain Reflectometer
PE	Polyethylene
PMD	Polarisation Mode Dispersion
PON	Passive Optical Network
POP	Point of Presence
PTP	Point-to-Point
P2P	Point-to-Point
PVC	Polyvinylchlorine
RL	Return Loss
RoW	Right-of-Way
SMF	Single mode fibre
STP	Shielded twisted pair
UPC	Ultra polished connector
UPS	Uninterruptible power supply
UTP	Unshielded twisted pair
WDM	Wavelength Division Multiplexing
WLAN	Wireless LAN (Local Area Network)

FTTH COUNCIL Europe