

# An Introduction to Telecommunication Cables



Brussels, 20 March 2013

## An Introduction to Telecommunication Cables

Table of content

Page | 2

<b>Chapter</b>	<b>Page</b>
<b>1. Introduction</b>	<b>3</b>
<b>2. Factors determining the choice of cable designs</b>	<b>3</b>
<b>3. Installation of telecommunication cables</b>	<b>7</b>
<b>4. Duct and direct buried cable technologies</b>	<b>10</b>
<b>5. Aerial cables</b>	<b>15</b>
<b>6. In house cabling</b>	<b>17</b>
<b>7. Combining copper and fibre technologies – VDSL2 Vectoring</b>	<b>19</b>
<b>8. Cost of cables</b>	<b>21</b>

## 1. Introduction

With this paper “Introduction to Telecommunication Cables” Europacable aims to provide a technical overview of cables used in communication access networks. The paper introduces the different cable technologies currently available – optical fibre cables, copper pair cable and coaxial cables – and their options for installation.

Much of the information on optical fibre cables and their installation is based on the FTTH Handbook “Creating a brighter future” Edition 5, published by Fibre To The Home Council Europe in February 2012. Europacable member companies have contributed to this publication which we believe provides a comprehensive overview of the optical fibre cables. We thank FTTH Council Europe for the right to reference their publication.

Telecommunication cables are used when connecting a number of end users to a central point known as an ‘Access Node’ or ‘Point of Presence’ (POP). Each Access Node contains the necessary electronic transmission (active) equipment to provide the applications and services to the subscriber. Each Access Node, within a large municipality or region, is connected to a larger metropolitan or urban optical fibre network.

Access networks may connect some of the following:

- fixed wireless network antenna, for example, wireless LAN or WiMAX;
- mobile network base stations;
- subscribers in SFUs (single family units) or MDUs (multi-dwelling units);
- larger buildings such as schools, hospitals and businesses;
- key security and monitoring structures such as surveillance cameras, security alarms;
- and control devices.

In order to ensure its future competitiveness, safety, personal and data security and to enable cloud computing, Europe needs high-speed data and telecommunication cable networks. The lack of such networks risks becoming an important bottleneck for achieving the objectives of Europe’s Digital Agenda.

## 2. Factors determining the choice of cable designs

Increasing subscriber needs for optical bandwidth will trigger the deployment of optical fibre closer to the subscriber. Europacable member companies believe that fibre optical cable technology will be most suited to ensure the deployment of “future proof grids”. Hence this initial section focusses on the deployment of optical fibre solutions.

The extent to which optical fibre cable are deployed instead of legacy copper pair cables or coaxial cables depends on many variables. Not only does each physical environment constitute different subscriber dwelling densities (per sqkm), but country conditions must also be taken into account. The nature of the site will be a key factor in deciding the most appropriate network design and will therefore also trigger the choice of cable design.

The main influences on the method of infrastructure deployment are:

- type of site;
- size of the network;
- initial cost of the infrastructure deployment (CAPEX);
- running costs for the network operation and maintenance (OPEX);
- network architecture, for example PON or Active Ethernet;
- local conditions, for example, local labour costs, local authority restrictions (traffic control), right of ways.

The choice for cable deployment method and technology will determine CAPEX and OPEX, as well as the reliability of the network. These costs can be optimized by choosing the most appropriate active solution combined with the most appropriate infrastructure deployment methodology. These cable installation methods, which are described later, include:

- conventional underground duct and cable;
- blown micro-ducts and cable;
- direct buried cable;
- aerial cable;
- other “right of way” solutions.

Key functional requirements for a high bandwidth access network include:

- provision of high-bandwidth services and content to each subscriber;
- a flexible network architecture design with capacity to meet future needs;
- an ultimate direct fibre connection of each end subscriber directly to the active equipment, ensuring maximum available capacity for future service demands;
- support for future network upgrades and expansion;
- minimal disruption during network deployment.

In order to specify the interworking of passive and active infrastructures, it is important to make a clear distinction between the topologies used for the deployment of the fibres (the passive infrastructure) and the technologies used to transport data over the fibres (the active equipment). The two most widely used topologies are point-to-multipoint, which is often combined with a passive optical network (PON) technology, and point-to-point, which typically uses Ethernet transmission technologies.

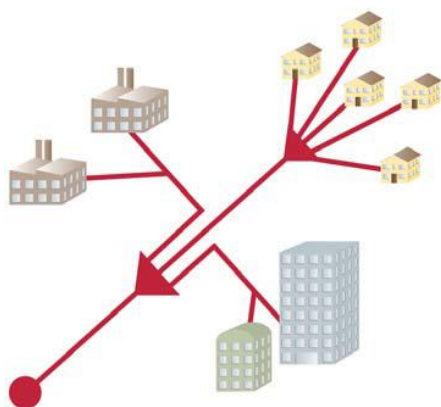


Figure 1: Passive Optical Network (PON)

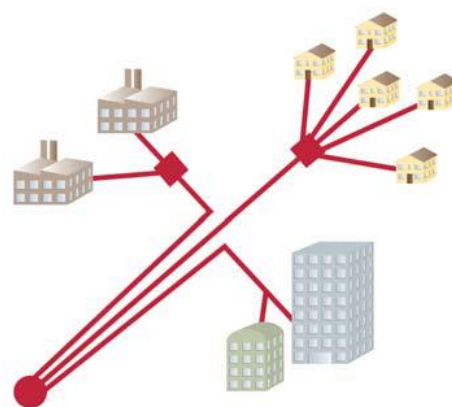


Figure 2: Active Ethernet Network

Various access network architectures can be implemented:

- **Fibre to the home (FTTH):** Each subscriber is connected by a dedicated fibre to a port on the equipment in the POP, or to the passive optical splitter, using shared feeder fibre to the POP and 100BASE-BX10 or 1000BASE-BX10 transmission for Ethernet connectivity or GPON (EPON) in case of point-to-multipoint connectivity.
- **Fibre to the building (FTTB):** Each optical termination box in the building (often located in the basement) is connected by a dedicated fibre to a port in the equipment in the POP, or to an optical splitter which uses shared feeder fibre to the POP. The connections between subscribers and the building switch are not fibre but can be copper based and involve some form of Ethernet transport suited to the medium available in the vertical cabling. In some cases building switches are not individually connected to the POP but are interconnected in a chain or ring structure in order to

utilize existing fibres deployed in particular topologies. This also saves fibres and ports in the POP. The concept of routing fibre directly into the home from the POP or through the use of optical splitters, without involving switches in the building, brings us back to the FTTH scenario.

- **Fibre to the curb (FTTC):** Each switch / or DSL access multiplexer (DSLAM), often found in a street cabinet, is connected to the POP via a single fibre or a pair of fibres, carrying the aggregated traffic of the neighbourhood via Gigabit Ethernet or 10 Gigabit Ethernet connection. The switches in the street cabinet are not fibre but can be copper based using 100BASE-BX10, 1000BASE-BX10 or VDSL2. This architecture is sometimes called “Active Ethernet” as it requires active network elements in the field.

FTTH/B access networks are considered the ultimate target architecture due to their virtually unlimited scalability. When designing and building access networks, it is helpful to understand the challenges and trade-offs facing potential network owners and operators. Some challenges may result in conflicts between functionality and economic demands. It is quite common that network operators choose for a tiered network upgrade by first deploying FTTC and in a second stage FTTH/B.

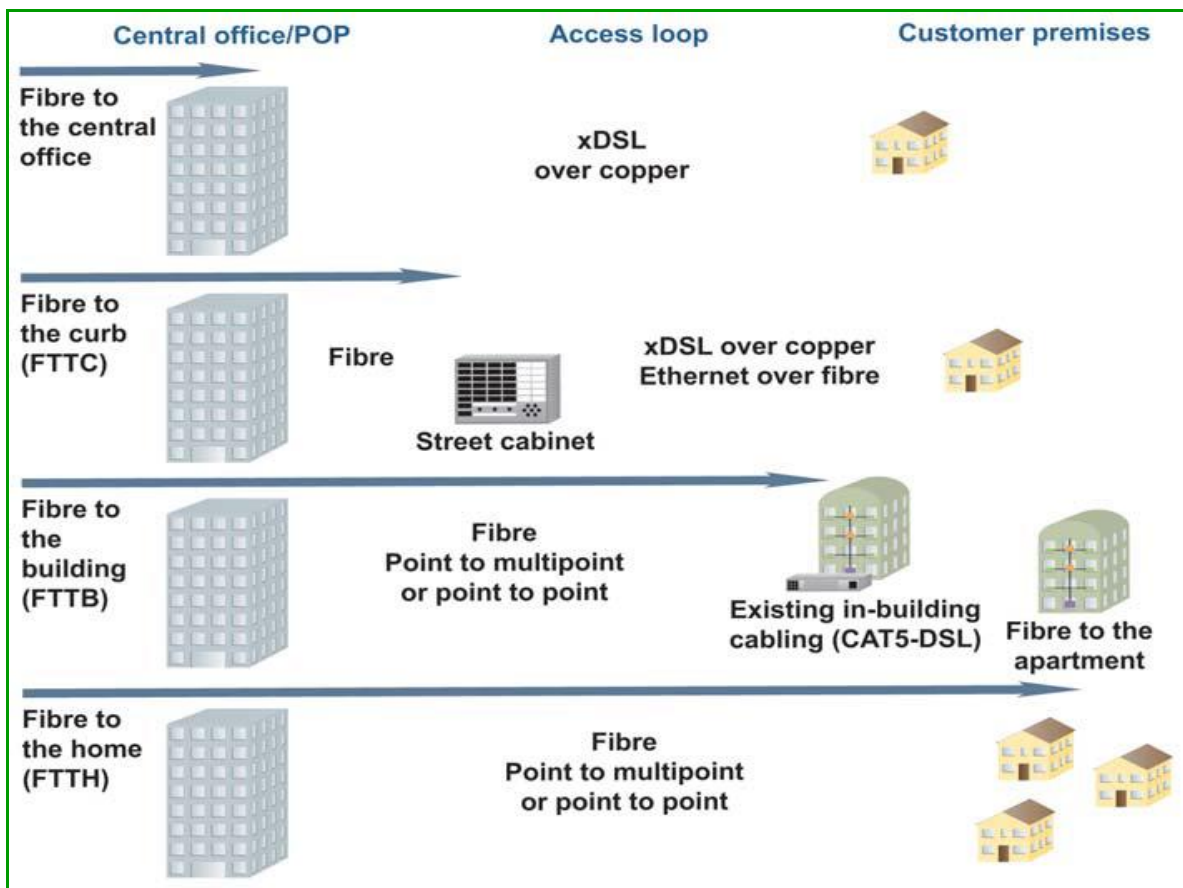


Figure 3: Different types of access networks

Expanding outwards from the Access Node towards the subscriber, the key infrastructure elements are:

Infrastructure elements	Typical physical form
<b>Access Node or POP (Point of Presence)</b>	Building communications room or separate building
<b>Feeder cable</b>	Large size mostly optical cables and supporting infrastructure e.g. ducting or poles
<b>Primary fibre concentration point (FCP)</b>	Easy access underground or pole-mounted cable closure or external optical fibre cabinet (passive, no active equipment) with large distribution capacity.
<b>Distribution cabling</b>	Medium size optical cables and supporting infrastructure, e.g. ducting or poles, multi pair copper cable
<b>Secondary fibre concentration point (FCP)</b>	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.
<b>Drop cabling</b>	Copper cables, low fibre-count cables or blown fibre units/ ducting or tubing to connect subscriber premises.
<b>Internal cabling</b>	Internal cabling Includes external building cable entry devices, internal cabling and final termination unit.

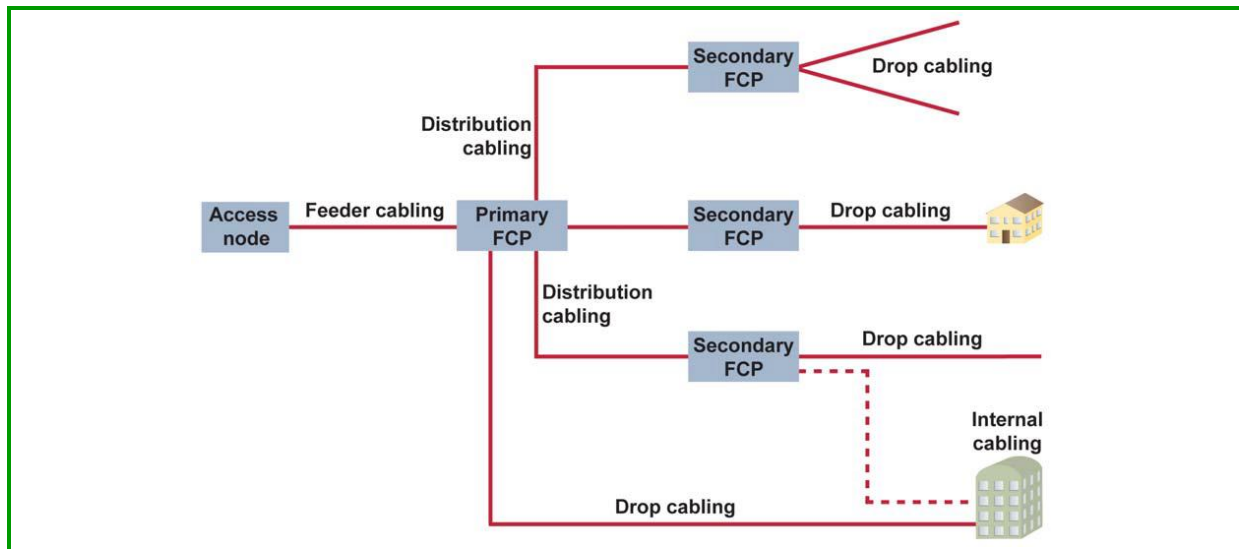


Figure 4: Main physical elements including cabling in an access network

### 3. Installation of telecommunication cables

#### 3.1 Installation in ducts

Installing telecommunication cables in ducts is the most conventional method of underground cable installation. It involves creating a duct network to enable subsequent installation of cables using a pulling, blowing or floatation technique.

A conventional duct infrastructure can be constructed in several ways:

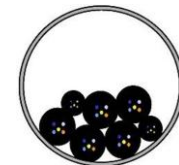
- main duct system containing smaller, rigid flexible ducts for individual cable installations;
- large diameter ducts allowing cable to be pulled progressively as the network grows;
- small diameter ducts for single cable installation.

Multiple cables can be installed in a single duct, but need to be put in place simultaneously or alternatively, multiple draw ropes need to be pre-installed. However, a single duct system can limit the number of cables that can be installed.

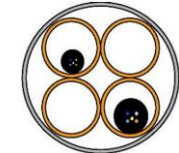
Entanglement of the cables and high friction between cable jackets may make it difficult to extract older cables from full ducts to allow space for new cable. It is normal for older cables to be located at the bottom of the duct.

Rigid sub ducts reduce the total number of cables that can be installed but also involve the need to remove the older cables. This method incorporates both cable blowing as well as cable pulling, as it helps to create an airtight connection to the sub duct.

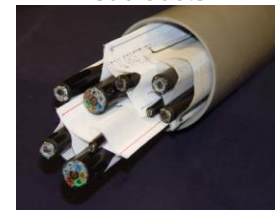
Flexible textile sub ducts maximize the total number of cables which can be installed in a duct and at the same time allow older cables to be removed easily. In general, flexible sub ducts triples the number of cables which can be installed in a main duct.



110mm main duct



110mm main duct with four rigid sub ducts



110mm main duct with nine flexible sub ducts

Figure 5: Duct installation options

#### 3.2 Installation in micro ducts

Installing telecommunication cables in so called ‘micro ducts’ utilises compressed air to blow fibre units and small diameter cables rapidly through a network of tubes to the subscriber/ premises. Fibre deployment can be deferred until subscriber requirement has been confirmed thus avoiding speculative up-front build programmes.

In addition, 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). Blown micro ducts may be used in combination with ducts, direct buried and aerial infrastructure and the tubes may be housed in constructions designed for any of these three methods.

Thick-walled micro ducts do not need to be placed or blown inside another duct or tube. Bundles of thick-walled micro ducts offer the most user-friendly connector solution.

From a technical perspective, this is the optimal solution for near-surface needs where temperatures may vary significantly. These products can be direct buried over long distances in bundles of 2, 4, 6, 7, 12, or 24, or buried individually over shorter distances. In addition, micro ducts offer the easiest solution for branching, remove the thin outer coating and snap on a connector.

Tight-bundled micro ducts offer a larger number of micro ducts pre-installed in a standard duct. They consist of a standard HDPE duct pre-sheathed around a bundle of micro ducts. Both the main duct and the micro ducts come in a variety of sizes to accommodate different types of fibre cables. Tight-bundled micro ducts are sheathed to avoid buckling which makes them less susceptible to temperature changes.

Loose bundled micro ducts are notable for their high crush resistance and record-breaking distances over which fibre can be blown. Loose bundled micro ducts are installed in two ways: Pre-installed in various size HDPE ducts suitable for laying directly in trenches and branched where necessary. Blown in after the HDPE ducts have been buried and an optimal solution for network expansion flexibility.

### 3.3 Direct buried installation

Direct burial of telecommunication cables offers a safe, protected and hidden environment for cables. However, before the cables are laid in a narrow trench, a detailed survey must be conducted to avoid damaging other buried services which may be in the vicinity. There are a number of excavation techniques that can be used to dig the trench including mole ploughing, open trenching, slotting and directional drilling. A combination of these options can be used in a deployment area.

### 3.4 Aerial installation

Aerial cables are supported on poles or other tower infrastructures and represent one of the more cost-effective methods of deploying drop cables in the final link to the subscriber. The main benefits are the use of existing pole infrastructure to link subscribers, avoiding the need to dig in roads to bury cables or new ducts. Aerial cables are relatively quick and easy to install, using hardware and practices already familiar to local installers.

The poles to which the optical cable is to be attached may already be loaded with other cables attached to them. Indeed, the pre-existence of the pole route could be a key reason for the choice of this type of infrastructure. Adding cables will increase the load borne by the poles, therefore it is important to check the condition of the poles and their total load capacity. In some countries, such as the UK, the cables used in aerial cabling have to be designed to break if they come into contact with high vehicles to avoid damage to the poles.



Figure 6: Example of micro ducting: thick walled micro duct and branching



Figure 7: Aerial cable installation



## 3.5 Other installations options using rights of way

In addition to traditional cabling routes, other right of way (RoW) access points can also be exploited if they are already in situ. By deploying cables in water and sewage infrastructure, gas pipe systems, canals and waterways as well as other transport systems, savings can be made in time as well as costs. Cable installations in existing pipe-networks must not intrude on their original function. Restrictions to services during repair and maintenance work have to be reduced to a minimum and coordinated with the network operators.

### *Cables in sewer systems*

Sewers may be used for access networks as not only do they access almost every corner of the city they also pass potential subscribers.

In addition the utilisation of the sewage system negates the need to seek digging approval and reduces the cost of installation.



Figure 8: Cable installation in sewers

Tunnel sizes in the public sewers range from 200mm in diameter to tunnels that are accessible by boat. The majority of public sewer tunnels are between 200mm and 350mm in diameter which is a sufficient cross-section for installation of one or more micro duct cables.

Various installation schemes are possible depending on the sewer cross-section. One scheme uses steel bracings that fix corrugated steel tubes, which are used to transport the cable, to the inner wall of the smaller sewer tube without the need to drill, mill or cut. This is done by a special robot based on a module used for sewer repairs.

### *Optical cables in gas pipes*

Gas pipelines can also be used for deploying optical fibre networks without causing major disruption and requiring extensive road works to the community which is the norm in the case of conventional cut and fill techniques. The fibre network is deployed using a specially developed I/O port which guides the cable into and out of the gas pipe, bypassing 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 infrastructures.

### *Underground and transport tunnels*

Fibre optic cable can be installed in underground tunnels, often alongside power and other data cabling. These are most frequently attached to the wall of the tunnel on hangers. They may be fixed in a similar manner to cables used in sewers. Two key issues to consider are fire performance and rodent protection. Should a fire occur in a transport tunnel, the need to evacuate personnel is critical.

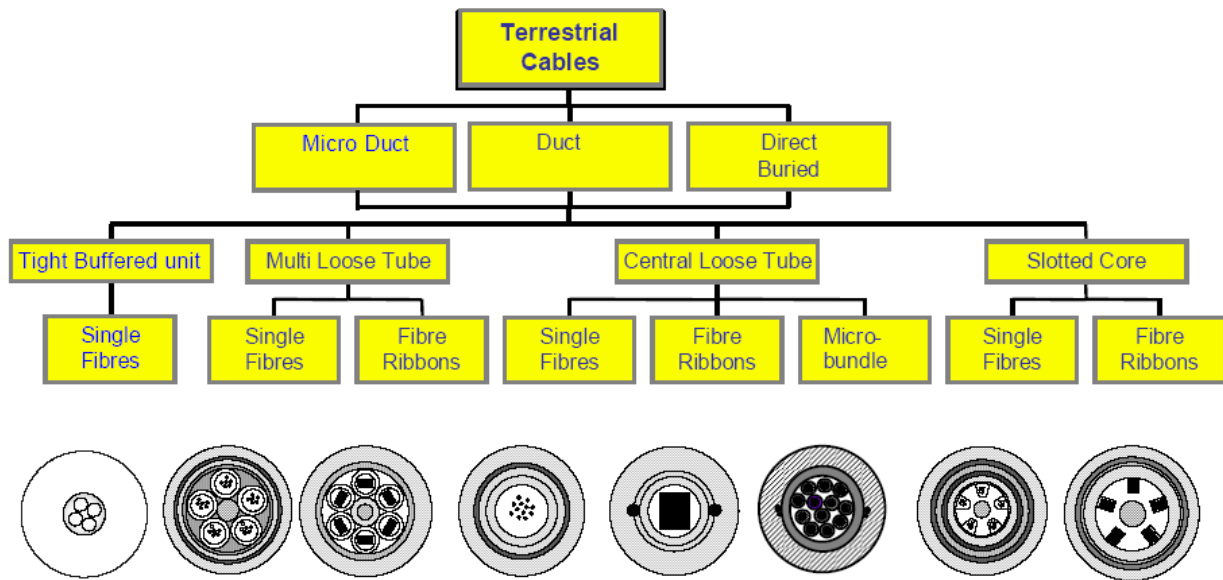


Figure 9: Cable installation in tunnels

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 and fumes, which can all hinder 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 and therefore may need extra protection in the form of corrugated steel tape, for example.

### 4.1 Optical fibre cables



Although optical fibre cable designs can vary, they are, however, based on a small number of elements. The first and most common building block is a loose tube. This is a plastic tube containing the required number of fibres (typically 12). This tube is lined with a tube filling compound that both buffers the fibres and helps them to move within the tube as the cable expands and contracts according to environmental and mechanical extremes. Other building blocks include multiple fibres in a ribbon form or a thin, flexible easy-strip tube coating also called micro module. Both ribbon and micro modules allow smaller diameter cables relative to loose tube. Smaller cable diameters are increasingly important when using existing and already occupied ducts where there is less space available for blowing cables.

Tubes containing individual fibres or multiple ribbons are laid around a central cable element that comprises of a strength member with plastic jacketing. Water blocking materials such as waterswellable tapes 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 external environments. Fibres, ribbons or micro modules (protected by a coloured micro-sheath or identified by a coloured binder) may also be housed within a large central tube. This is then over sheathed with strength elements. If cables are pulled using a winch, they may need to be stronger than those that are blown as the tensile force applied may be much higher.

Blown cables need to be 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 which negates the need for them to be earthed in the event of lightning. However, they may contain metallic elements for higher strength (steel central strength members), for remote surface detection (copper elements) or for added moisture protection (longitudinal aluminium tape). Duct environments tend to be benign, but the cables are designed to withstand possible long-term flooding and

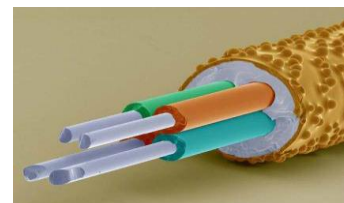


Figure 10: Blown fibre cable with 4 fibres

occasional freezing.

Micro duct tubes house micro duct cables (e.g. 96 fibre 6.4mm diameter for use in a 10mm/8mm micro duct) or very small blown-fibre unit cables 1 to 3 mm in diameter which allows for up to 12 fibres (e.g. 4 fibres in a 1 mm cable for use in 5 mm/3.5 mm tubes).

The cables used in these tubes are of a small lightweight design that needs a tube for protection. In other words, the tube and cable act together as a system.



Figure 11: Micro duct cable

The cables are installed by blowing and may be coated with a special substance to aid blowing. The micro duct size must be chosen to suit the cable and required fibre count. Typical combinations of cable and duct sizes are given in the following table, however other sizes and combinations can be used.

Micro duct outer diameter (mm)	Micro duct inner diameter (mm)	Typical fibre counts	Typical cable diameter (mm)
16	12	24–216	9.2
12	10	96–216	6.5–8.4
10	8	72–96	6–6.5
7	5.5	48–72	2.5
5	3.5	6–24	1.8–2
4	3	22–12	1–1.6

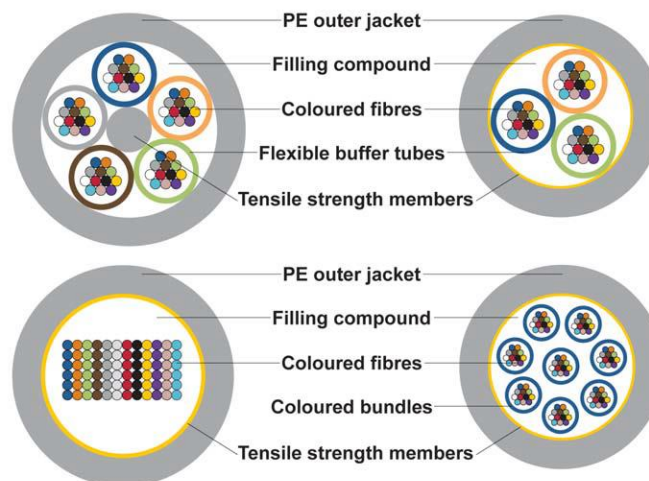


Figure 12: Micro duct optical fibre cables (not to scale)

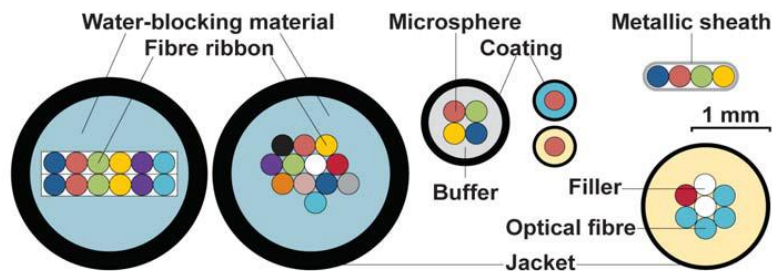


Figure 13: Examples of Fibre units. Micro duct spelling in diagram

Direct buried cables are similar to duct cables as they also employ filled loose tubes. The cables may have additional armouring to protect them, although this depends on the burial technique.

Pre-trenching and surrounding the buried cable with a layer of sand can be sufficient to allow for lightweight cable designs to be used, whereas direct mole-ploughing or backfilling with stone-filled soil may 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.

For direct buried applications, additional protection has to be considered. Non-metallic designs may be favoured in areas of high lightning activity. However these have less crush protection than a cable with a corrugated steel tape. The steel tape can cope with a direct lightning strike, particularly if the cable contains no other metallic components and it also offers excellent crush 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 comprise of non-metallic materials then an option could be a complete covering of glass yarns which may deter rodents to some degree. Nylon sheaths, though expensive, offer excellent protection against termites. Nylon resists bite damage, and is chemically resistant to the substances excreted by termites.

## 4.2 Copper cables

Access networks still consist partly of copper cable, mostly from the Fibre Concentration Point or street cabinet to the building. Copper cables are then installed similar to fibre optical cable in ducts, direct buried or aerial.

### 4.2.1 Twisted (multi) pair telecom cables

Twisted pair cabling is a type of wiring in which two conductors of a single circuit are twisted together for the purposes of cancelling out electromagnetic interference (EMI) from internal and external sources. Twisted pair cables are found in many Ethernet networks and telephone systems.

For indoor telephone applications, twisted pairs are often grouped into sets of 25 pairs. Two type of twisted pair cable are used: UTP (Unshielded Twisted Pair) and STP (Shielded Twisted Pair).

The cables are typically made with copper wires measured at 22 or 24 American Wire Gauge (AWG), with coloured insulation made of polyethylene and PVs or halogen free jackets.

For urban outdoor telephone cables containing hundreds or thousands of pairs, the cable is divided into smaller but identical bundles. Each bundle consists of twisted pairs that have different twist rates. The bundles are in turn twisted together to make up the cable. Pairs having the same twist rate within the cable can still experience some degree of crosstalk.

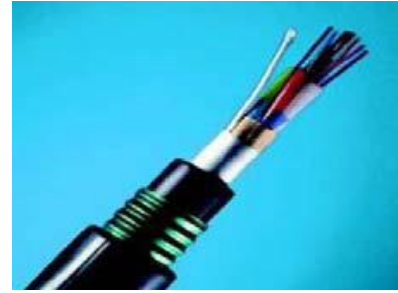


Figure 14: cable with corrugated steel protection



Figure 15: Non-metal direct buried cable

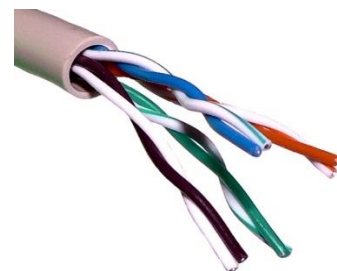


Figure 16: Unshielded twisted pair cable

Wire pairs are selected carefully to minimize crosstalk within a large cable. Twisted pair cabling is often used in data networks for short and medium length connections because of its relatively lower costs compared to optical fibre and coaxial cable.

In multipair cables, 2 pairs can also be grouped into quads. Pairs/quads can be grouped together. The transmission performance of twisted pair cables depends on many components.

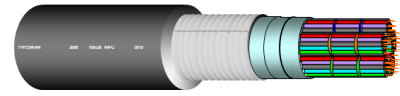


Figure 17: Shielded twisted pair cable

For VDSL application, pairs are often grouped together and slightly larger copper wire diameter may be used.

Like optical drop cables, copper drop cables provide the home connection and can be provided by direct buried, duct or aerial installation. Typical pair count for a drop cable is from 1 to 8 pairs per home.

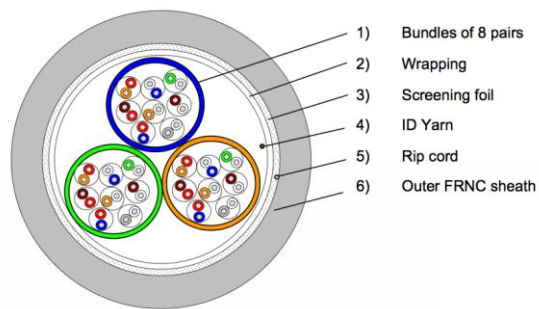


Figure 18: 3\*8 pair VDSL cable

#### 4.2.2 Coaxial cables

Coaxial cables can be used as an alternative to copper pairs. Coaxial cables conduct electrical signal using an inner conductor (usually a solid copper, stranded copper or copper plated steel wire) surrounded by an insulating layer and all enclosed by a shield, typically one to four layers of woven metallic braid and metallic tape.

The cable is protected by an outer insulating jacket. Normally, the shield is kept at ground potential and a voltage is applied to the centre conductor to carry electrical signals.

The advantage of coaxial design is that electric and magnetic fields are confined to the dielectric with little leakage outside the shield. On the converse, electric and magnetic fields outside the cable are largely kept from causing interference to signals inside the cable. Larger diameter cables and cables with multiple shields have less leakage.

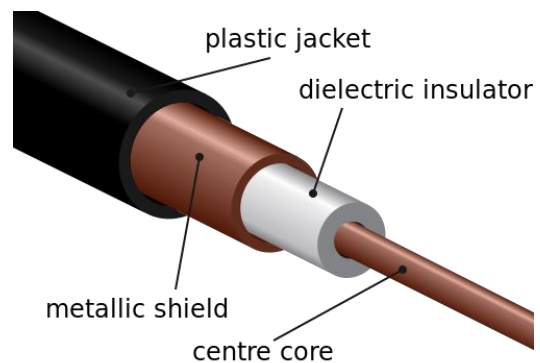


Figure 19: Coaxial cable

This property makes coaxial cable a good choice for carrying weak signals that cannot tolerate interference from the environment or for higher electrical signals that must not be allowed to radiate or couple into adjacent structures or circuits.

Common applications of coaxial cable include video and CATV distribution, RF and microwave transmission, and computer and instrumentation data connections. Coaxial cable design choices affect physical size, frequency performance, attenuation, power handling capabilities, flexibility, strength, and cost. The inner conductor might be solid or stranded; stranded is more flexible. To get better high-frequency performance, the inner conductor may be silver-plated. Copper-plated steel wire is often used as an inner conductor for cable used in the cable TV industry.

The insulator surrounding the inner conductor may be solid plastic, a foam plastic, or air with spacers supporting the inner wire. The properties of dielectric control some electrical properties of the cable. A common choice is a solid polyethylene (PE) insulator, used in lower-loss cables. Solid Teflon (PTFE) is also used as an insulator. Some coaxial lines use air (or some other gas) and have spacers to keep the inner conductor from touching the shield.

Many conventional coaxial cables use braided copper wire forming the shield. This allows the cable to be flexible, but it also means there are gaps in the shield layer, and the inner dimension of the shield varies slightly because the braid cannot be flat. Sometimes the braid is silver-plated. For better shield performance, some cables have a double-layer shield.[4] The shield might be just two braids, but it is more common now to have a thin foil shield covered by a wire braid. Some cables may invest in more than two shield layers, such as "quad-shield", which uses four alternating layers of foil and braid. Other shield designs sacrifice flexibility for better performance; some shields are a solid metal tube. Those cables cannot be bent sharply, as the shield will kink, causing losses in the cable. For high-power radio-frequency transmission up to about 1 GHz, coaxial cable with a solid copper outer conductor is available in sizes of 0.25 inch upward. The outer conductor is rippled like a bellows to permit flexibility and the inner conductor is held in position by a plastic spiral to approximate an air dielectric.

Coaxial cables require an internal structure of an insulating (dielectric) material to maintain the spacing between the centre conductor and shield. The dielectric losses increase in this order: Ideal dielectric (no loss), vacuum, air, polytetrafluoroethylene (PTFE), polyethylene foam, and solid polyethylene. A low relative permittivity allows for higher-frequency usage. An inhomogeneous dielectric needs to be compensated by a non-circular conductor to avoid current hot-spots.

The insulating jacket can be made from many materials. A common choice is PVC or PE, but some applications may require fire-resistant materials. Outdoor applications may require the jacket resist ultraviolet light, oxidation and rodent damage. Flooded coaxial cables use a water blocking gel to protect the cable from water infiltration through minor cuts in the jacket. For internal chassis connections the insulating jacket may be omitted.

## 5. Aerial cables

Aerial cables are supported on poles or other tower infrastructures and represent one of the more cost-effective methods of deploying drop cables in the final link to the subscriber. The main benefits are the use of existing pole infrastructure to link subscribers, avoiding the need to dig in roads to bury cables or new ducts. Aerial cables are relatively quick and easy to install, using hardware and practices already familiar to local installers.

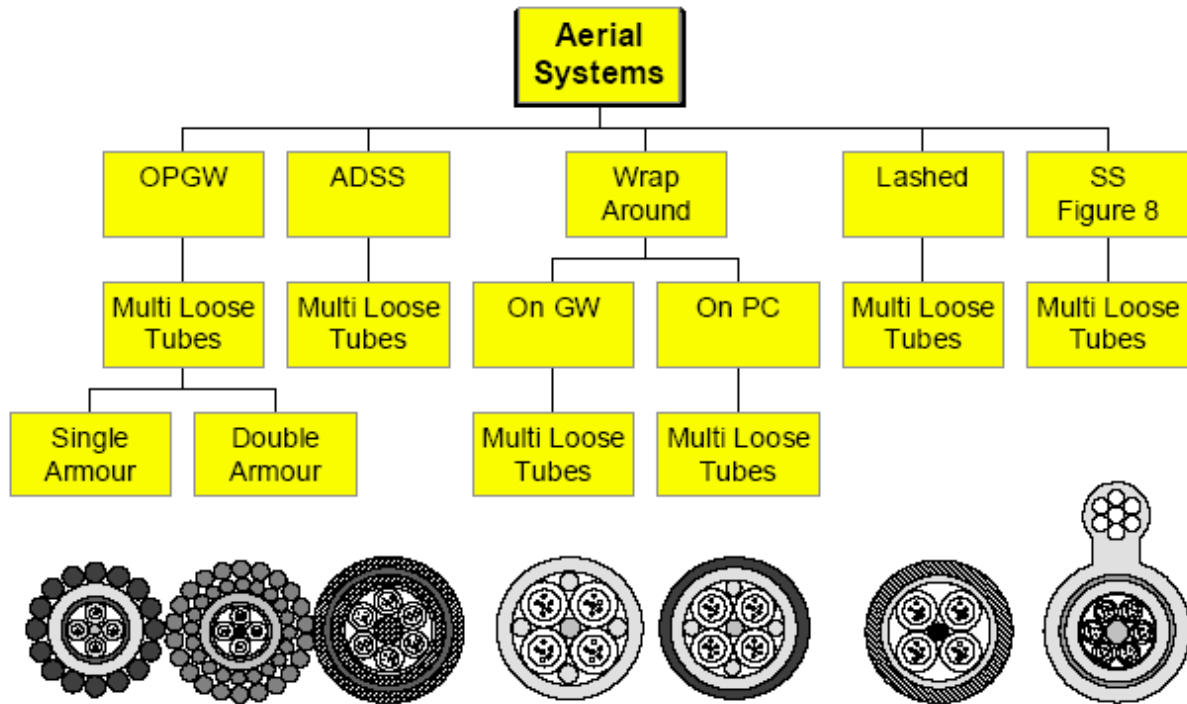
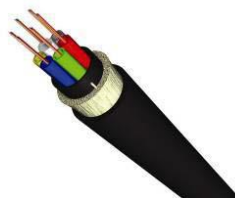


Figure 20: Types of aerial cable include circular self-supporting (ADSS or similar)

ADSS is useful where electrical isolation is important, for example, on a pole shared with power or data cables requiring a high degree of mechanical protection. This type of cable is also favoured by companies used to handling copper cables, since similar hardware and installation techniques can be used. The Figure-8 design allows easy separation of the optical package avoiding contact with the strength member. However, with the ADSS cable design, the strength member bracket is part of the cable. ADSS cables have the advantage of being independent of the power conductors as together with phase-wrap cables they use special anti-tracking sheath materials when used in high electrical fields.



Wrapped aerial cable



Example of ADSS cable



Example of Figure 8 cable

Figure 21: Aerial cable designs (possibly micro bundle instead of multi loose tube)

Lashed or wrapped cables are created by attaching conventional cable to a separate catenary member using specialist equipment; this can simplify the choice of cable. Wrap cables use specialised wrapping machines to deploy cables around the earth or phase conductors.

If fibre is deployed directly on a power line this may involve OPGW (optical ground wire) in the earth. OPGW protects the fibres within a single or double layer of steel armour wires. The grade of armour wire and the cable diameters are normally selected to be compatible with the existing power line infrastructure. OPGW offers excellent reliability but is normally only an option when ground wires also need to be installed or refurbished.

Aerial cables can have similar cable elements and construction to those of duct and buried optical fibre cables described previously. Circular designs, whether self-supporting, wrapped or lashed, may include additional peripheral strength members plus a sheath of polyethylene or special antitracking material (when used in high electrical fields). Figure-8 designs combine a circular cable with a high modulus catenary strength member. If the feeder cable is fed by an aerial route then the cable fibre counts will be similar to the underground version. It should be noted that all of the above considerations are valid for blown fibre systems deployed on poles or other overhead infrastructures. Extra consideration needs to be taken of environmental extremes that aerial cables can be subjected to including ice and wind loading. Cable sheath material should also be suitably stabilised against solar radiation. Installation mediums also need to be seriously considered (e.g. poles, power lines, short or long spans, loading capabilities).

Aerial cables are installed by pulling them over pre-attached pulleys and then securing them with tension and suspension clamps or preformed helical dead-ends and suspension sets to the poles. Installation is usually carried out in reasonably benign weather conditions with installation loading often being referred to as the everyday stress (EDS). As the weather changes, temperature extremes, ice and wind can all affect the stress on the cable. The cable needs to be strong enough to withstand the extra loading. Care also needs to be taken to see that installation and subsequent additional sagging, due to ice loading for example, does not compromise the cable's ground clearance (local authority regulations on road clearance need to be taken into account) or lead to interference with other pole-mounted cables with different coefficients of thermal expansion.

Aerial products may be more susceptible to vandalism than ducted or buried products. Cables can, for example, be used for illegal shot gun practice. This is more likely to be low energy impact, due to the large distance from gun to target. If this is a concern then corrugated steel tape armouring within a Figure-8 construction has been shown to be very effective. For non-metallic designs, thick coverings of aramid yarn, preferably in tape form, can also be effective. OPGW cable probably has the best protection, given that it has steel armour.

Alternative optical fibre aerial cable, also copper twisted pair cable is installed in aerial networks (see section 4.2 for more details on twisted pair):

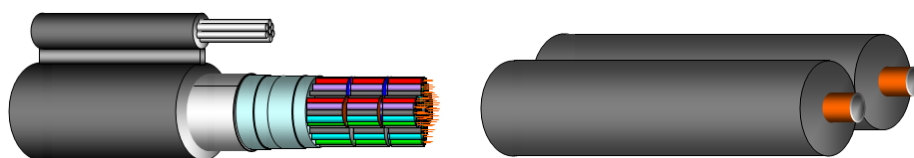


Figure 22: Aerial copper multi twisted pair and aerial copper drop cable



## 6. In house cabling

In this chapter, cabling from building entry point to customer telecommunication outlet is discussed. There are a couple of in building network typologies:

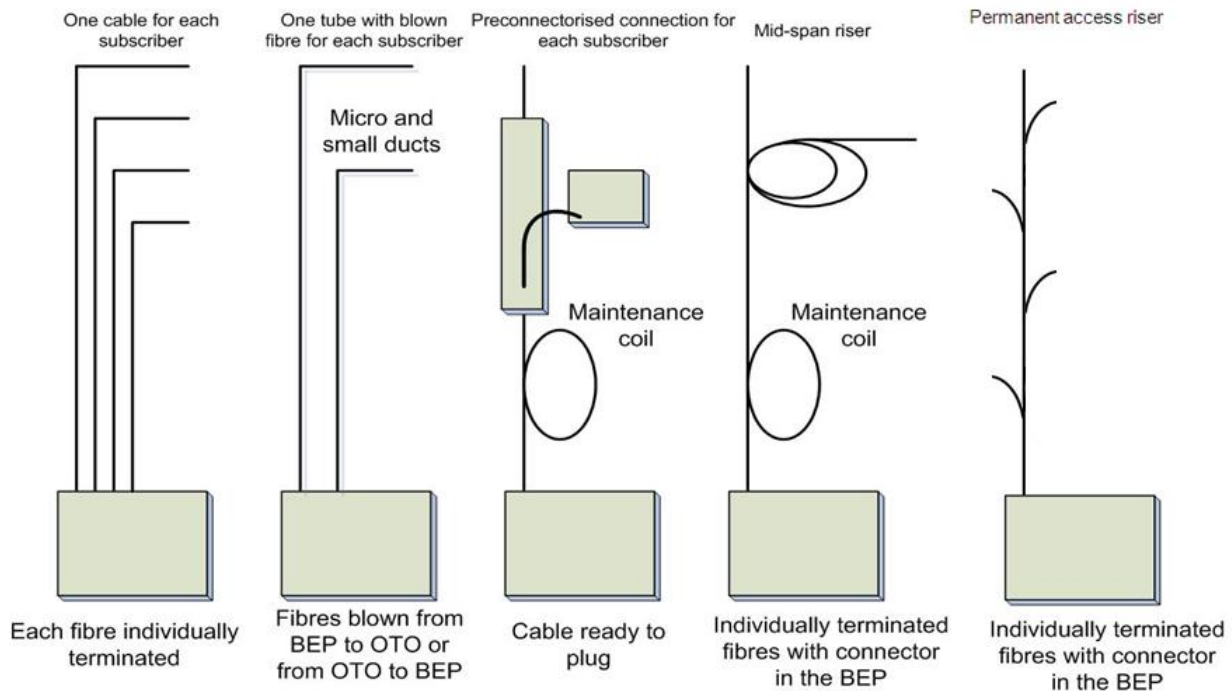


Figure 23: Indoor network typologies

The cable designs are more or less the same for these 4 configurations. In principle, the following cable parts are inside a building:

### 6.2 Riser cables

The vertical part is often referred to as riser cable. Riser fibre cables or ducts fed with fibres are normally installed in existing cable conduits e.g. electrical installations or individually installed cable conduits for the FTTH network. It is common to install a vertical riser from the basement or the top floor of the building. The vertical riser represents the most time consuming installation part of in-house cabling, especially in the section where local fire regulations need to be taken into account as they often pass stairways used as escape routes. The fire performance of indoor and outdoor cables should comply with the requirements of the IEC 60332, IEC 60754 and IEC 61034 series.

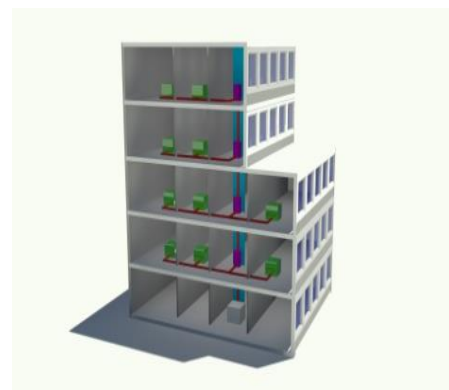


Figure 24: Vertical riser cable and horizontal drop cable

The number of fibres per subscriber and the number of apartments depend on the architecture. In the building, the riser cables can have various structures: mono fibre, bundles of mono fibre, or bundles of multiple fibres.

The bundling of fibres is done by tight buffer, extractable micro modules or loose tube. As these cables are installed in difficult conditions (e.g. low bending radius across edges) use of the new bend-insensitive fibres should be considered.



Figure 25: Example of riser cables, tight buffer and extractable micro module.

## 6.2 Horizontal drop cables

The horizontal part is referred to as drop cable. The cable requirements and cable installation are more or less the same as for riser cable but typically the number of fibres is from 1 to 4, depending on legislation and network owner standards. In order to speed up installation of drop cables, riser and drop cables can be pre-terminated, i.e. connectors are factory mounted in advance.

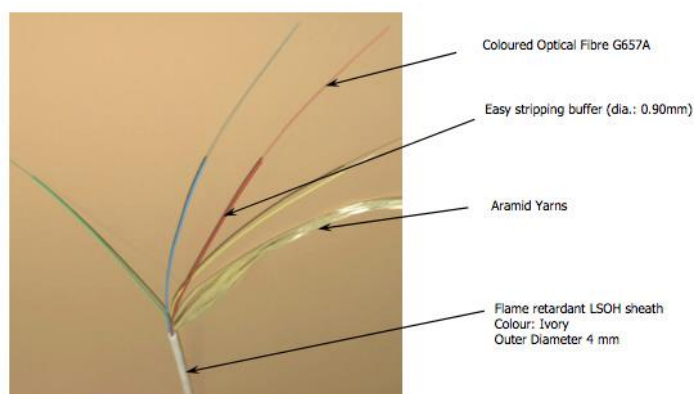


Figure 26 Example of a 4 fibre indoor drop cable

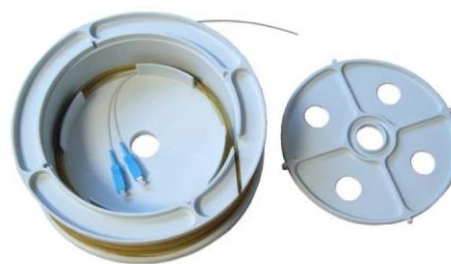


Figure 27: Example of pre-terminated drop cable

## 6.3 Consideration of fibre choice

Inside buildings, fibers face installation practices with sharper bends. All indoor cables are recommended to use so called bend insensitive optical fiber as per ITU G.657.A /B in accordance to the fiber ITU 657 standard for FTTx applications/solutions.

## 6.4 Copper indoor data cables

Optical fibre cable can be substituted by copper twisted pair cable. For indoor applications these are often referred to as category cable.

Generic cabling systems are defined in the series of EN 50173 and allow 100m channel length (incl. patch cords) as standard implementation in offices premises, homes, etc. The applicable standard for data cables are:

- EN50288 series which cover unscreened cables up to 500 MHz and screened cables up to 1000 MHz. These cables are used in horizontal floor and building backbone wiring for information technology, such as generic-cabling systems carrying protocols from 100 Mbit/s to 10 gigabit/s.

- EN50441 series which cover the same transmission protocols as EN50288 but are designed to match the specific constraints of home cabling such as multimedia analog transmission up to 1200 MHz and particular type of laying as stapling or in wall laying.

Twisted pair cables are often shielded in an attempt to prevent electromagnetic interference. Because the shielding is made of metal, it may also serve as a ground. This shielding can be applied to individual pairs, or to the collection of pairs. When shielding is applied to the collection of pairs, this is referred to as screening.

Shielding provides an electric conductive barrier to attenuate electromagnetic waves external to the shield and provides conduction path by which induced currents can be circulated and returned to the source, via ground reference connection. This is particularly important in home cabling where the electromagnetic environment is unpredictable and noises from nearby electrical device or external random noises may occur.

All shielded cables must be grounded for safety and effectiveness and a continuous shield connection maintained from end to end.

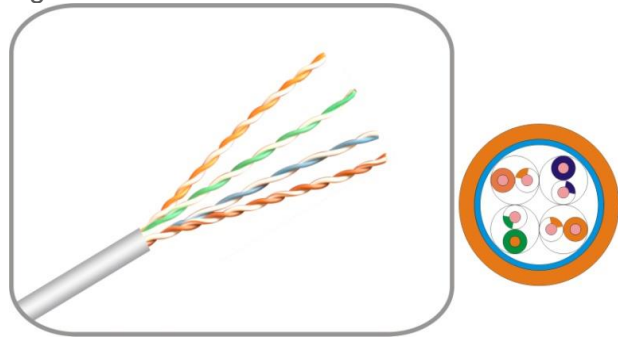


Figure 28: Example of Category 6 UTP

Figure 29: Example of Category 7 S/FTP

## 7. Combining copper and fiber technologies – VDSL2 Vectoring

Combining copper and fibre optical technologies currently is a widely used form of deployment. Many incumbent operators currently deploy FTTC/FTTN networks (as described in Figure 3) and then combine fiber optic cables from the Access Nodes (also central Office) to the Fibre Concentration Point (also referred as street cabinet) while xDSL cables (multi pair copper) are used from street cabinet to premises. The optical signal is converted to electrical signal in the street cabinet.

Today, service providers have three main options to drive higher speeds on copper:

- Deploy VDSL2 with its broadened frequency band;
- Shorten the copper loops; or
- Use multiple copper pairs (known as bonding).

While the above options shorten VDSL2 loop lengths and improve the bandwidth considerably, crosstalk between copper pairs prevents maximum performance and is typically the largest impairment reducing the bandwidth.

VDSL2 Vectoring is a technique to remove this crosstalk: VDSL2 Vectoring is standardized in the International Telecommunication Union– Telecommunication Standardization Sector (ITU-T) G Vector standard<sup>11</sup>. It is a noise-cancellation technology, comparable in concept to the technology found in noise cancelling headphones. With VDSL2 Vectoring, the crosstalk on each line in a DSL binder, or cable, is measured, and an anti-phase signal is applied to each line to remove the crosstalk. With VDSL2 Vectoring, every line in a binder can operate at peak performance, as if there were no other VDSL2 lines in that binder. Vectoring can deliver today up to 100 Mb/s downstream and 40 Mb/s upstream over max 400 meter distance.

The main advantage of VDSL vectoring is the reduction of CAPEX: FTTH is 3 times more expensive than FTTH and 2 times more expensive than FTTB.<sup>1</sup> For incumbent operators with falling revenues, the extension of economic lifecycle of existing copper cable access networks is very attractive. See figure below:

## TI's 2-step strategy on NGAN

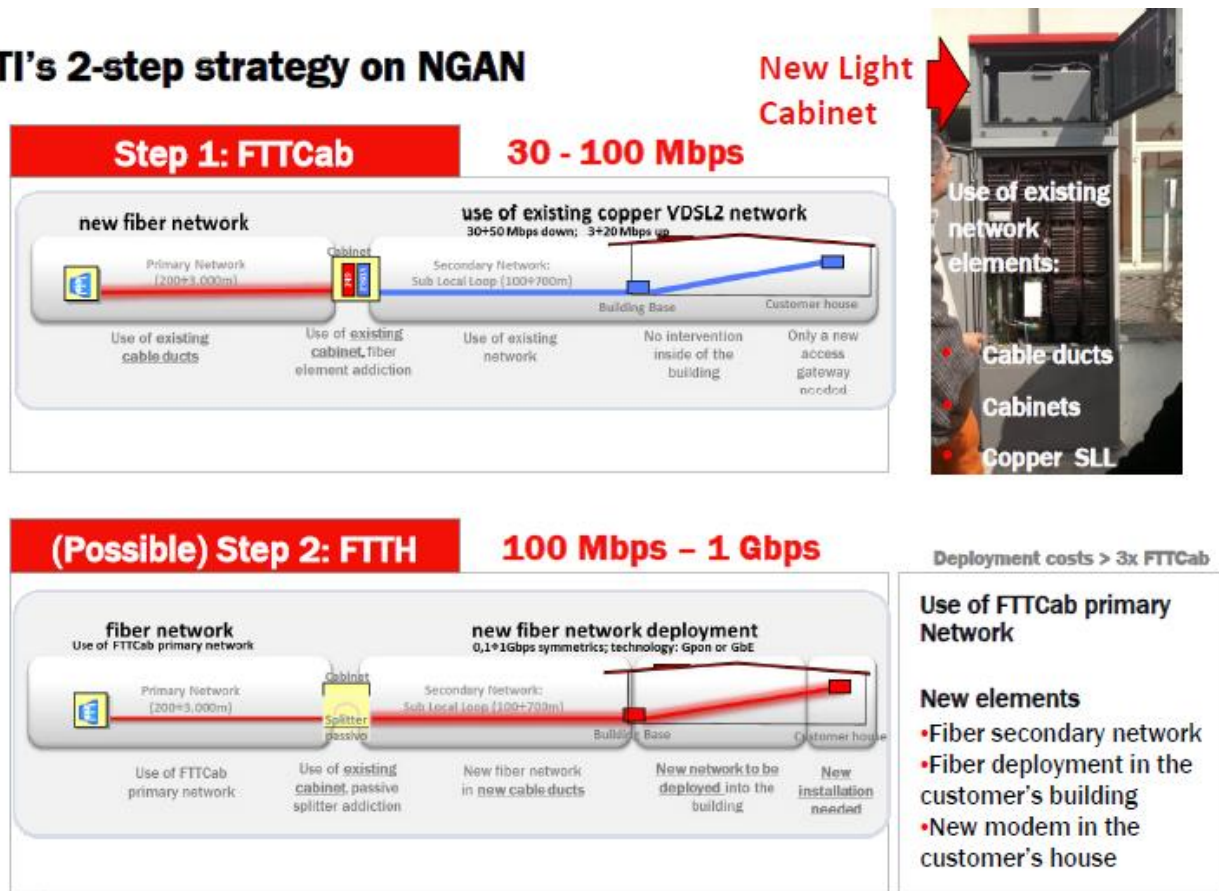


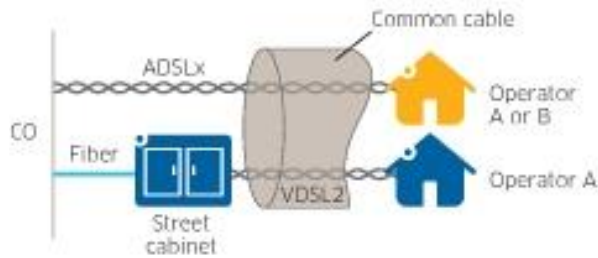
Figure 30: Telecom Italia Capex of FTTC vs FTTH

The main disadvantage of VDSL vectoring is that performance is not future proof and eliminates competition between network operators and service providers. Although speeds of 100 Mb/s can be achieved, actual performance depends strongly on many factors:

- Limited distance between street cabinet and customer premises: not suited for more rural areas;
- Quality of the copper access network (wire diameter);
- Number of operators/service providers on the access network: Vectoring inhibits effective unbundling of physical infrastructure. Unbundling of services is only possible at the central office. The incumbent operator would operate on vectoring but the alternative operator can only operate standard DSL without vectoring. When multiple operators would both want to operate VDSL2 with vectoring, this would mean co-location of street cabinets to host VDSL2 equipment leading to unattractive business cases. See figure below:

<sup>1</sup> Source Alcatel-Lucent and Telecom Italia: main savings in civil works as no cable installation is needed from street cabinet to customer

### CO - ADSLx UNBUNDLING

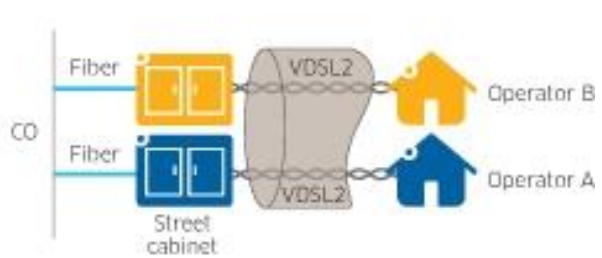


#### ADSLx local loop unbundling

- ADSLx LLU from CO
- Lines controlled by different operators
- Common practice

Small impact on vectoring gain

### FTTx - VDSL2 UNBUNDLING



#### VDSL2 sub-loop unbundling

- VDSL2 SLU from cabinet
- Lines controlled by different operators
- Uncommon: practical issues, unattractive business case

High impact on vectoring gain

Figure 31: Unbundling DSL services and impact on performance

## 8. Cost of cables

### Overall considerations

Respecting EU competition requirements, Europacable can only provide general statements regarding cost factors of telecommunication cables.

Also each project is unique and a full macroeconomic assessment of the cable system should be made that takes into consideration installation costs, life costs, maintenance costs, impact on land / property, environmental protection etc.

Europacable would like to highlight that the cost of high quality cables represent only a marginal part of the total cost of deployment. In the case of optical fibres the cost of cables reverts to approximately 15%.

The highest cost factor results from the cost of installations. Often telecommunication cables need to be installed alongside other existing infrastructure. This complicates deployment and therefore raises installation costs significantly. Notably the final access to home can entails high installation costs.

Europacable take the view that reducing the installation costs of high speed communication infrastructures in Europe will be crucial to ensure Europe's competitiveness in the 21<sup>st</sup> century, will generate socio-economic as well as environmental benefits and last but not least will secure and create employment in a future oriented sector.

Europacable believes that the core objective for reducing the cost of high speed communication infrastructure should be to make Europe's digital networks "future proof". With this we mean:

1. *Stimulating and coordinating civil and building works deployment* notably with regard to the final access to the home;
2. *Ensure using existing rights of ways and infrastructures* whenever possible to reduce environmental impact and cost;
3. *Systematically installing future proof infrastructure* which can be easily upgraded, easily maintained and easily expanded
4. *Deploying only high quality fibre technology* that will provide reliable service for decades;



Europacable member companies are committed to support this development through sustained R&D investments and the production of high speed communication cables in Europe.<sup>2</sup>

**For further information please visit our website [www.europacable.com](http://www.europacable.com) or contact:**

Dr. Volker Wendt, Director Public Affairs, Europacable, [v.wendt@europacable.com](mailto:v.wendt@europacable.com)

Page | 22

### **About Europacable**

Founded in 1991, Europacable represents about 85% of the European wire and cable industry. Our member companies include European multinationals providing global technology leadership, as well as highly specialized small- and medium sized producers of energy, telecommunication and data cables. In 2009, the industry had a total consumption of €20 billion in wire & cables resulting in the manufacture in Europe alone of some 38 million km of cables. Europacable is listed in the European Commission's transparency register under: 453103789-92.

---

<sup>2</sup> For further information please see: Europacable Contribution to Public Consultation on an EU Initiative to Reduce the Cost of Rolling out High Speed Communication Infrastructure in Europe, Brussels, 14 July 2012, [www.europacable.com](http://www.europacable.com)