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SERIES L: CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Optical access network topologies for broadband services

Recommendation ITU-T L.90

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Summary

Recommendation ITU-T L.90 describes the optical access network to be used in the design and construction of fibre to the home (FTTH). It deals mainly with access network architectures and the upgrading or new deployment of optical fibre to optical access networks.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T L.90	2012-02-13	15

FOREWORD

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Introduction

Progress on multimedia technologies has led to the active development of many kinds of broadband services such as data and video communication using access networks. It is important that high-speed broadband networks be developed economically to provide such services to all subscribers. In order to provide these services in a timely way, it is necessary to construct optical access networks quickly, efficiently and cost-effectively. However, recent progress in the application of optical plant technology in local access networks has provided substantial technical and economical experiences in several countries. Considering this, the network design must take into account planning, construction, maintenance and operation.

The development of optical fibre access networks for broadband services can largely be divided into four stages based on the increasing number of customers; namely the initial stage, the growth stage, the mature stage and the final stage.

Here, an optical access network is defined as a network of optical fibre cables that extend from a carrier's central office to the cabinets, buildings, individual homes, apartment blocks or business offices for broadband services.

Recommendation ITU-T L.90

Optical access network topologies for broadband services

1 Scope

This Recommendation deals mainly with important considerations concerning optical single-mode fibre access network architectures and the ability to upgrade or new deployment of the optical networks, which are the most important items at each stage in terms of designing, constructing, operating and maintaining optical access networks quickly, effectively and economically for broadband services. Moreover, this Recommendation describes the optical transmission performance, the maintenance system and power supply required for the design and construction of an optical access network for broadband services.

Furthermore this Recommendation covers:

– physical network architectures that have been used to meet different system objectives;
– environmental conditions in customer serving areas;
– passive optical components used for construction of the network;
– installation and maintenance issues;
– safety requirements;
– use of standardised material.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.652] Recommendation ITU-T G.652 (2003), *Characteristics of a single-mode optical fibre and cable*.

[ITU-T G.657] Recommendation ITU-T G.657 (2009), *Characteristics of a bending-loss insensitive single-mode optical fibre and cable for the access network*.

[ITU-T G.662] Recommendation ITU-T G.662 (1998), *Generic characteristics of optical amplifier devices and subsystems*.

[ITU-T G.664] Recommendation ITU-T G.664 (2003), *Optical safety procedures and requirements for optical transport systems*.

[ITU-T G.671] Recommendation ITU-T G.671 (2002), *Transmission characteristics of optical components and subsystems*.

[ITU-T G.694.1] Recommendation ITU-T G.694.1 (2002), *Spectral grids for WDM applications: DWDM frequency grid*.

[ITU-T G.694.2] Recommendation ITU-T G.694.2 (2003), *Spectral grids for WDM applications: CWDM wavelength grid*.

[ITU-T G.982] Recommendation ITU-T G.982 (1996), *Optical access networks to support services up to the ISDN primary rate or equivalent bit rates*.

[ITU-T G.983.1] Recommendation ITU-T G.983.1 (1998), *Broadband optical access systems based on Passive Optical Networks (PON)*.

[ITU-T G.983.2] Recommendation ITU-T G.983.2 (2002), *ONT management and control interface specification for B-PON*.

[ITU-T G.983.3] Recommendation ITU-T G.983.3 (2001), *A broadband optical access system with increased service capability by wavelength allocation*.

[ITU-T G.983.4] Recommendation ITU-T G.983.4 (2001), *A broadband optical access system with increased service capability using dynamic bandwidth assignment*.

[ITU-T G.983.5] Recommendation ITU-T G.983.5 (2002), *A broadband optical access system with enhanced survivability*.

[ITU-T G.984.1] Recommendation ITU-T G.984.1 (2003), *Gigabit-capable Passive Optical Networks (GPON): General characteristics*.

[ITU-T G.985] Recommendation ITU-T G.985 (2003), *100 Mbit/s point-to-point Ethernet based optical access system.*

[ITU-T G.986] Recommendation ITU-T G.986 (2010), *1 Gbit/s point-to-point Ethernet-based optical access system.*

[ITU-T G.987.x] Recommendation ITU-T G.987.x-series (in force), *10 Gigabit-capable passive optical network (XG-PON) systems.*

[ITU-T G.987.1] Recommendation ITU-T G.987.1 (2010), *10 Gigabit-capable passive optical network (XG-PON): General requirements.*

[ITU-T G.988] Recommendation ITU-T G.988 (2010), *ONU management and control interface (OMCI) specification.*

[ITU-T K.51] Recommendation ITU-T K.51 (2009), *Safety criteria for telecommunication equipment*.

[ITU-T L.10] Recommendation ITU-T L.10 (2002), *Optical fibre cables for duct and tunnel application*.

[ITU-T L.12] Recommendation ITU-T L.12 (2000), *Optical fibre joints*.

[ITU-T L.13] Recommendation ITU-T L.13 (2003), *Performance requirements for passive optical nodes: Sealed closures for outdoor environments*.

[ITU-T L.26] Recommendation ITU-T L.26 (2002), *Optical fibre cables for aerial application*.

[ITU-T L.31] Recommendation ITU-T L.31 (1996), *Optical fibre attenuators*.

[ITU-T L.36] Recommendation ITU-T L.36 (1998), *Single mode fibre optic connectors*.

[ITU-T L.37] Recommendation ITU-T L.37 (1998), *Fibre optic (non-wavelength selective) branching devices*.

[ITU-T L.40] Recommendation ITU-T L.40 (2000), *Optical fibre outside plant maintenance support, monitoring and testing system*.

[ITU-T L.41] Recommendation ITU-T L.41 (2000), *Maintenance wavelength on fibres carrying signals*.

[ITU-T L.43] Recommendation ITU-T L.43 (2002), *Optical fibre cables for buried application*.

[ITU-T L.44] Recommendation ITU-T L.44 (2000), *Electric power supply for equipment installed as outside plant*.

[ITU-T L.50] Recommendation ITU-TL.50 (2010), *Requirements for passive optical nodes: Optical distribution frames for central office environments*.

[ITU-T L.51] Recommendation ITU-T L.51 (2003), *Passive node elements for fibre optic networks – General principles and definitions for characterization and performance evaluation*.

[ITU-T L.53] Recommendation ITU-T L.53 (2003), *Optical fibre maintenance criteria for access networks*.

[ITU-T L.58] Recommendation ITU-T L.58 (2004), *Optical fibre cables: Special needs for access network.*

[ITU-T X.200] Recommendation ITU-T X.200 (1994) ISO/IEC 7498-1:1994, *Information technology – Open Systems Interconnection – Basic Reference Model: The basic model.*

3 Definitions

3.1 Terms defined elsewhere

For the purpose of this Recommendation, the definitions given in [ITU-T G.652], [ITU-T G.662], [ITU-T G.664], [ITU-T G.671], [ITU-T G.694.1], [ITU-T G.694.2], [ITU-T G.982], [ITU-T G.983.1] to [ITU-T G.983.5], [ITU-T G.984.1], [ITU-T K.51], [ITU-T L.13], [ITU-T L.26] and [ITU-T L.51] apply.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 access point: A drop optical cable from subscriber premises is connected to a distribution cable at this point.

3.2.2 building entry point (BEP): Allows the transition from outdoor to indoor cable. The type of transition may be a splice or a removable connection.

3.2.3 central office area: This area is the section between the optical line terminal (OLT) and the optical distribution frame (ODF) in the central office.

3.2.4 customer premises equipment (CPE): This is any active device, e.g., set-top-box, that provides the end-user with certain services (high-speed data, TV, telephony, etc.). The ONT and CPE may be integrated.

3.2.5 distribution area: The area between the distribution point and the access point.

3.2.6 distribution point: Optical cables from some access points in a distribution area are gathered at this point and connected to the feeder cable from the central office.

3.2.7 feeder area: The area between the ODF and the distribution point.

3.2.8 floor distributor (FD): The floor distributor is an optional element which allows the transition from the vertical to the horizontal indoor cable.

3.2.9 optical network termination (ONT): Terminates the optical network at customer premises. It includes an electro-optical converter. The ONT and CPE may be integrated.

3.2.10 optical telecommunication outlet (OTO): This is a fixed connecting device where the fibre optic indoor cable terminates. The optical telecommunication outlet provides an optical interface to the equipment cord of the ONT/CPE.

3.2.11 user area: The area between the access point and ONU/ONT in subscriber premises.

3.2.12 user equipment: The user equipment, TV, phone, personal computer, etc., allows the user to access the services.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AF	Adaption Function
BEP	Building Entry Point
CATV	Cable Television
CPE	Customer Premises Equipment
CWDM	Coarse Wavelength Division Multiplexing
DWDM	Dense Wavelength Division Multiplexing
FD	Floor Distributor
FTTH	Fibre to the Home
FTTx	Fibre To The x, where 'x' stands for the final location on the end-user side.
OAN	Optical Access Network
ODF	Optical Distribution Frame
OFA	Optical Fibre Amplifier
OLT	Optical Line Terminal
OMDF	Optical Main Distribution Frame
ONT	Optical Network Termination
ONU	Optical Network Unit
OPS	Optical Packet Switching
OTB	Optical Termination Box
OTN	Optical Transport Network
OTO	Optical Telecommunication Outlet
PON	Passive Optical Network
POP	Point of Presence
PRBS	Pseudo-Random Bit Sequence
SDH	Synchronized Digital Hierarchy
WDM	Wavelength Division Multiplexing

5 Concept of layers within a network architecture

The layers are classified according to the [ITU-T X.200] OSI ISO reference model.

This specification refers only to the physical layer (layer 1).

5.1 Optical fibre

A suitable choice of fibre and splicing technology should be made. Single-mode fibre, normally compliant with [ITU-T G.652] and [ITU-T G.657], is the most appropriate for a wide range of telecommunication services in the local distribution network since this fibre benefits from economy of scale and has long-term potential utility for future services. With current usage of single-mode fibre, splicing techniques will allow typical splice losses of less than 0.5 dB to be achieved (see [ITU-T L.12] for further information).

The user should note that only ITU-T G.657 category A fibres are compatible with ITU-T G.652 fibres. Using other fibre types will increase the uncertainty regarding the splice values and compatibility issues.

5.2 Passive components and cables

This requires cable design and fibre types to be determined depending on the network architecture adopted, see clause 6.

Passive components may be used in conjunction with optical fibres and thus are considered as part of the passive elements sub-layer.

Other passive optical plant hardware such as splice closures, cabinets and housing for OPSs, WDMs, OFAs, connectors and patch panels, all of which have specific environmental constraints.

5.3 Structural facility

This optical access network architecture evolved from copper networks in the form of a star radiating from the exchange. Therefore, it will allow the introduction of optical spines to generate network architectures. Hence, the changes required for optical networks concern mainly the manner in which the optical cables and optical fibres are deployed, mainly within the outside plant. However, use of optical plants may lead to the development of new structures and plant layout. For example, a duct installed for the copper network may be sub-divided, compartmented, using appropriately-sized plastic tubes, each to accommodate one of the smaller diameter optical cables. Also, special consideration shall be given to aerial support structures for optical cables.

6 Features of access network architecture

In order to select or design an optical access network for FTTH, telecommunication companies and local service providers should mainly consider:

1) scalability (number of terminated fibres, total fibre length of network, etc.);
2) survivability (security, supervisory system, etc.);
3) functionality (bit rate, transmission distance, etc.);
4) construction and maintenance costs;
5) upgrading the optical network (increase transmission capacity, increase transmission length, increase number of customers including for future demand).

When designing or constructing an optical access network, telecommunication companies should select and use one or more of the following architectures, based on the optical access network requirements in each region.

6.1 Point-to-point architecture

The basic configuration for a point-to-point architecture is shown in Figure 1. This distributes one or more fibres individually from an OLT in a central office to an ONU in buildings, apartment blocks or residential premises. Therefore, a large number of fibres are installed and distributed from a central office to customers. The location of the active node is in a temperature controlled environment. Between a central office and building basement only splices are used in closures or in street cabinets in an outside plant.

This configuration has low optical loss and provides the maximum distance between central offices and customers. The insertion loss of the optical line is a sum of fibre, splice and connector losses. Moreover, this may be suitable for customers requiring large bandwidth and/or high security.

The cabling characteristics for the point-to-point network shall be defined in the following main parts of the network:

– OMDF in POP;
– Feeder cabling between the OMDF and a manhole;
– Drop cabling between a manhole and a BEP;
– BEP;
– Cabling between a BEP and an OTO;
– OTO;
– Equipment cord between an OTO and ONT/ONU/CPE. A specific home cabling can be deployed in the apartment/customer site instead of the equipment cord.

Each customer is connected with one to four fibres from the building entry point to the optical telecommunication outlet. Typically one to four fibres are either collected in one indoor cable or they can also be taken from the multiple fibre cables. At least one fibre is connected between the central office (OMDF) and the customer site (OTO).

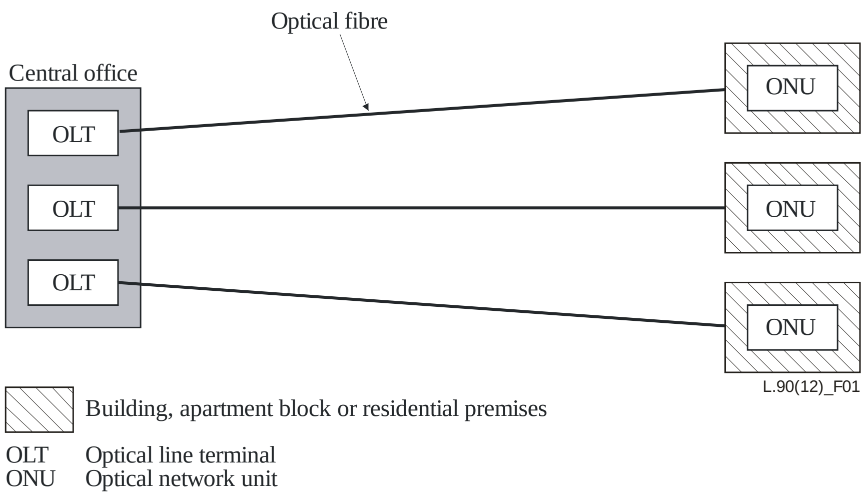


Figure 1 – Point-to-point network, simplified view

A more detailed reference model for point-to-point networks is shown in Figure 2:

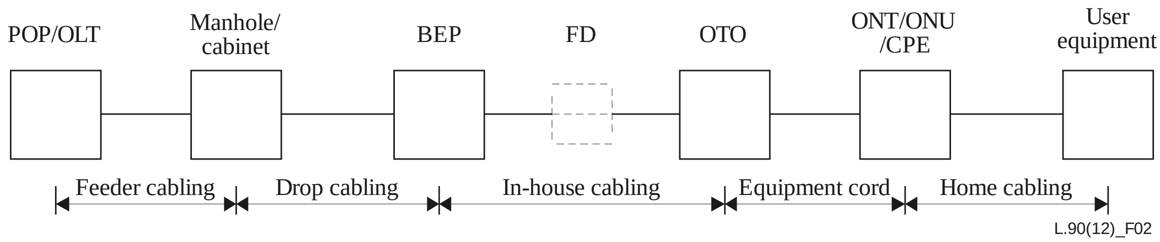


Figure 2 – Detailed reference point-to-point network

6.2 Ring architecture

The basic configuration of a ring network is shown in Figure 3. This starts and ends at the same central office and distributes two or more fibres to ONUs in buildings, apartment blocks or residential premises. Therefore, for point-to-point ring networks as shown in Figure 3a, a very large number of fibres are installed and distributed from central offices to customers. By contrast, for multiple-type ring networks as shown in Figure 3b, the number of distributed fibres can be reduced compared to a point-to-point ring network. The advantages of the ring network are very high reliability and its ease of maintenance for alternative routing.

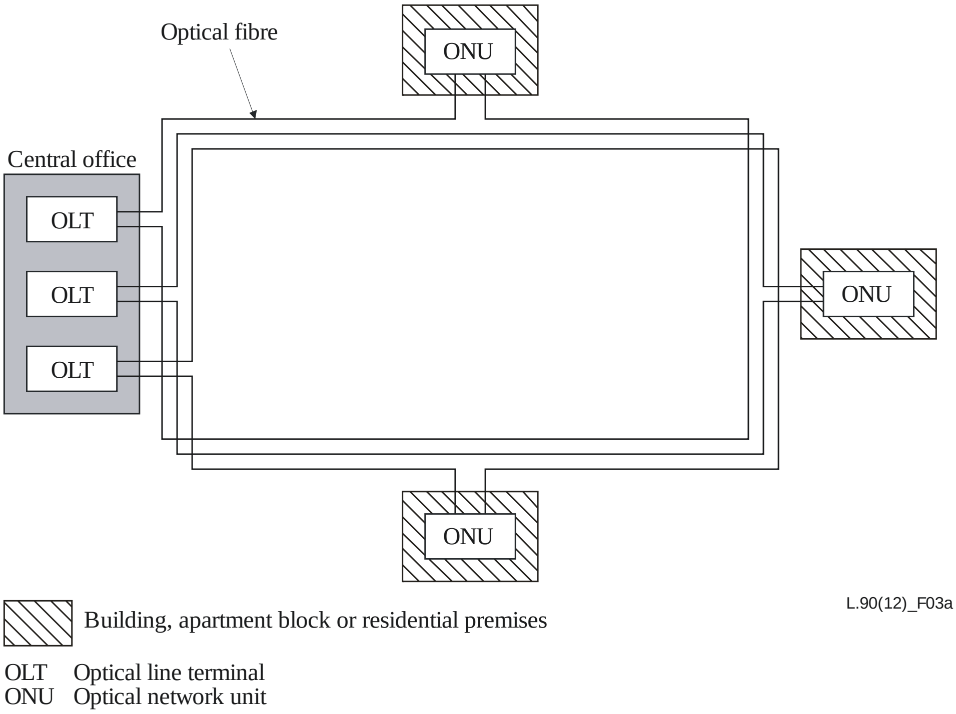


Figure 3a – Ring network (Point-to-point type)

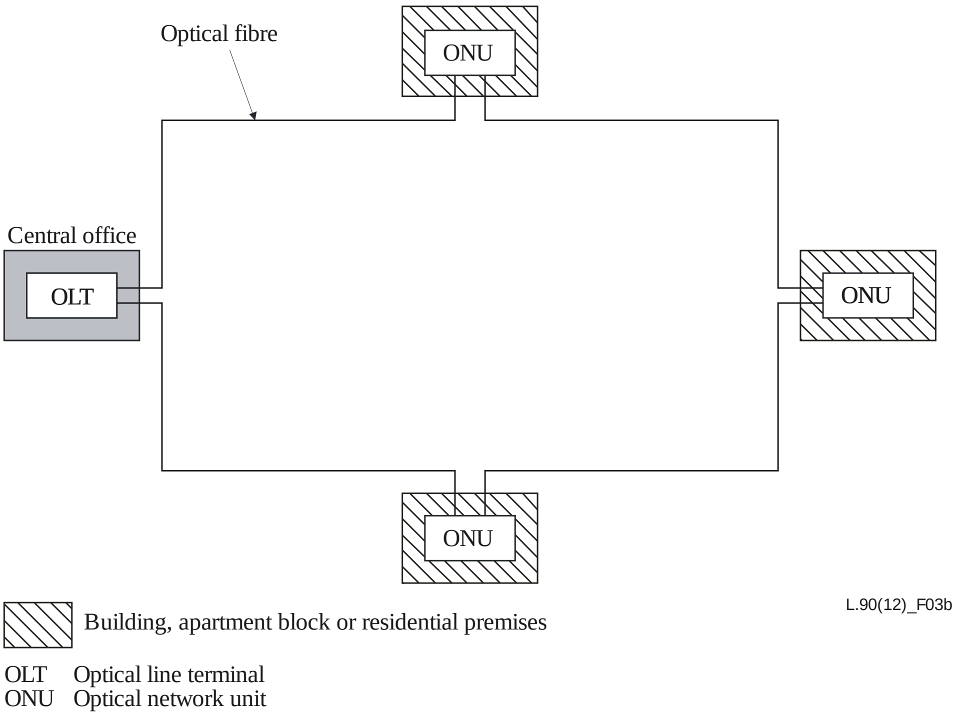


Figure 3b – Ring network (Multiple type)

6.3 Point-to-multipoint architecture

The basic configuration of a point-to-multipoint network is shown in Figure 4 with one branching component per OLT port. Figure 5 would be the configuration with two branching components per OLT port. The feature of the point-to-multipoint network is that a (fibre optic) branching component or an active node is placed between an OLT and several ONUs. The location which is installed for use with (fibre optic) branching components or active nodes is the most important item in terms of this network design and construction. Moreover, two types of (fibre optic) branching components can be used in this network. One type has a wavelength multiplexer and de-multiplexer, the other does not. A (fibre optic) branching component without a wavelength multiplexer and de-multiplexer increases the insertion loss and reduces the transmission distance as the number of branches is increased. By contrast, a (fibre optic) branching component with a wavelength multiplexer and de-multiplexer is mainly used in WDM systems. The insertion loss does not increase greatly but it is difficult to control and manage the wavelength when the number of branches is increased.

When a (fibre optic) branching component is installed in a central office, at least one fibre is connected between the central office and a customer's building, apartment block or residential premises. Therefore, a large number of fibres are installed and distributed from the central office. Moreover, the environmental conditions for the (fibre optic) branching component are mild because it is installed inside a central office.

On the other hand, a (fibre optic) branching component can be installed in a closure or cabinet in the outside plant or inside a customer's building. In such cases, the number of fibres between an OLT and a fibre optic branching component can be reduced. However, the environmental conditions for the (fibre optic) branching component are severe because it is located in the outside plant, or on the outside walls of a building or a house.

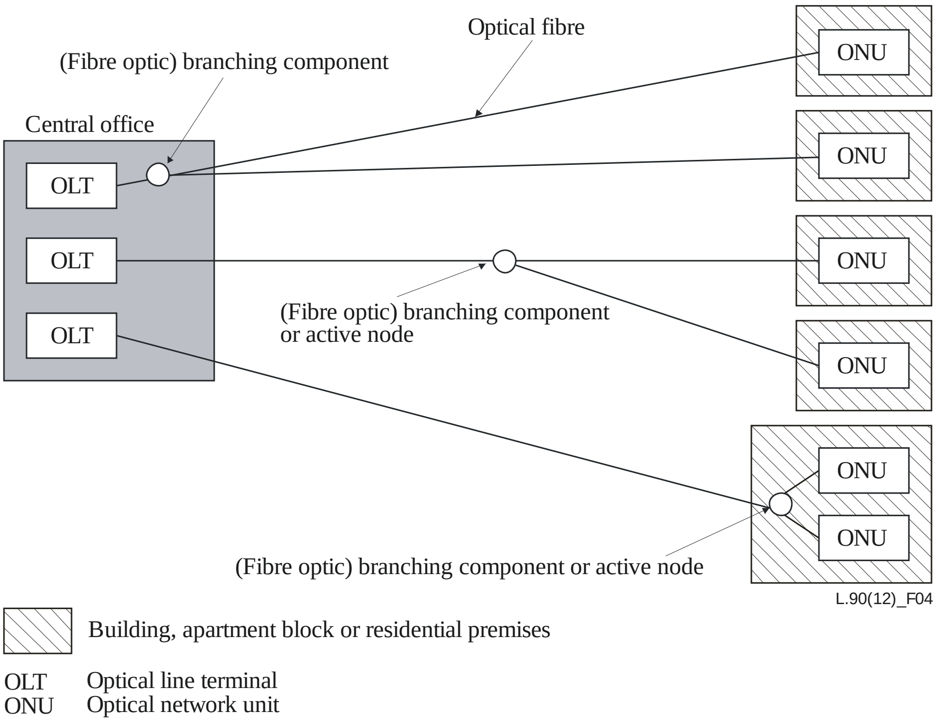


Figure 4 – Point-to-multipoint network (in the case of 2 branches)

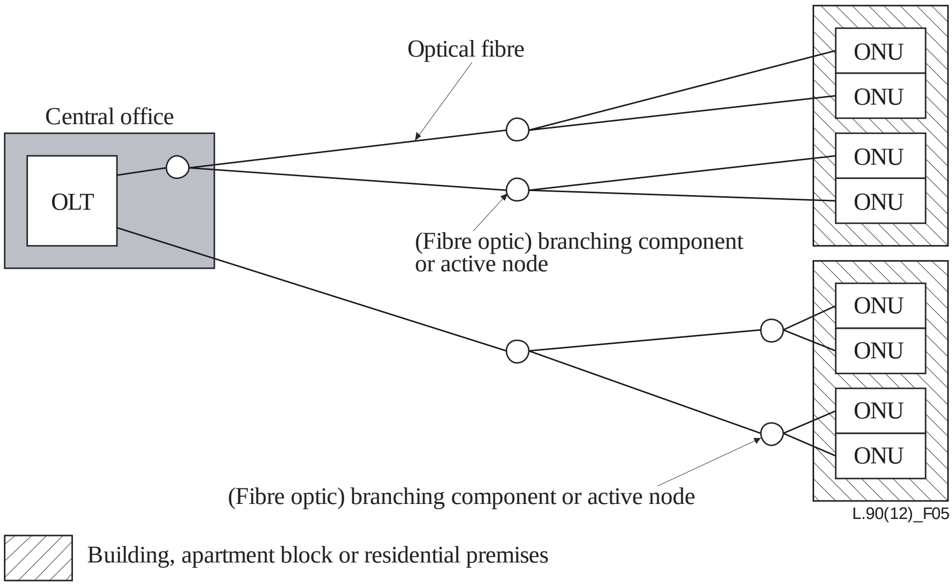


Figure 5 – Point-to-multipoint network (in the case of 4 ONUs and 2 levels of branching components)

7 Optical fibre distribution method in an outside plant

Factors such as geographic conditions, population density, future fibre demand, etc., will differ from region to region. Therefore, telecommunication companies should decide on an economical and effective optical fibre distribution method based on a consideration of these factors.

8 Upgrading the optical network

When the transmission capacity, transmission length and/or number of customers increase, it will be necessary to upgrade the optical network. At such a time, telecommunication companies should consider the contents of Table 1 and select the appropriate method for upgrading the network.

Table 1 – Network upgrade methods

	Point-to-point architecture	Ring architecture	Point-to-multipoint architecture
Increase transmission capacity	• Not a problem for P2P and ring architecture		• Use high bit rate systems (PON systems) • Use WDM system (CWDM, DWDM)
Increase transmission length	• Reduce number of optical fibre joints by using, for example, blown fibre technique • Use optical fibre amplifier		• Reduce number of optical fibre joints by using, for example blown fibre technique • Use WDM system (Use (fibre-optic) branching component with wavelength multiplexer and de-multiplexer.) • Reduce number of branches or change to point-to-point network • Use optical fibre amplifier

Table 1 – Network upgrade methods

	Point-to-point architecture	Ring architecture	Point-to-multipoint architecture
Increase number of customers	• Change to point-to-multipoint architecture and increase number of branches • Install new cable	• Install new cable	• Increase number of branches • Install new cable

With a multiple type ring architecture and a point-to-multipoint architecture, when the optical network is upgraded, all the customers connected to one OLT must be upgraded simultaneously.

9 Optical transmission performance for optical access networks

Optical access network routes should be designed to meet the optical access network performances (attenuation range, return loss, dispersion, etc.) described in such system requirements as described in [ITU-T G.982], [ITU-T G.983.1] to [ITU-T G.983.5], [ITU-T G.984.1] to [ITU-T G.984.7], [ITU-T G.985], [ITU-T G.986] and [ITU-T G.987.x].

The calculation of the total network optical loss will take into account [ITU-T G.982].

10 Optical network maintenance support, monitoring and testing system

The optical network maintenance support, monitoring and testing when employing a point-to-point architecture or a point-to-multipoint architecture with a (fibre optic) branching component in a central office is described in [ITU-T L.40]. The maintenance wavelength shall be selected in accordance with [ITU-T L.41].

When using a ring network or a point-to-multipoint network using a (fibre optic) branching component, or an active node in an outside plant or in a building, apartment block or residential premises, the optical network maintenance support, monitoring and testing is as described in [ITU-T L.53]. The maintenance wavelength shall be selected in accordance with [ITU-T L.41].

11 Electrical power supply

The electrical power supply and battery backup to an ONU should be selected by taking into account the outage rate of commercial power suppliers, the cost when using commercial power suppliers and the time to repair a power source failure as described in [ITU-T L.44].

12 Safety

12.1 Electrical safety

Electrical safety should take into account [ITU-T K.51].

12.2 Optical safety

Optical safety should take into account [ITU-T G.664].

13 Optical fibre distribution

An optical access network comprises four areas: a central office area, a feeder area, a distribution area and a user area from a central office to residential premises, as shown in Figure 6. The feeder area extends from optical distribution frames (ODFs) in the central office to a distribution point. In the distribution area, a distribution cable is connected with a feeder cable at the distribution point and led to an access point. In the user area, a drop cable is connected with a distribution cable at the access point and led to an optical network unit (ONU) in an individual home, apartment or business building, etc. It is most important that the optical fibres are distributed in such a way that efficient design, construction, maintenance and operation for FTTx are achieved.

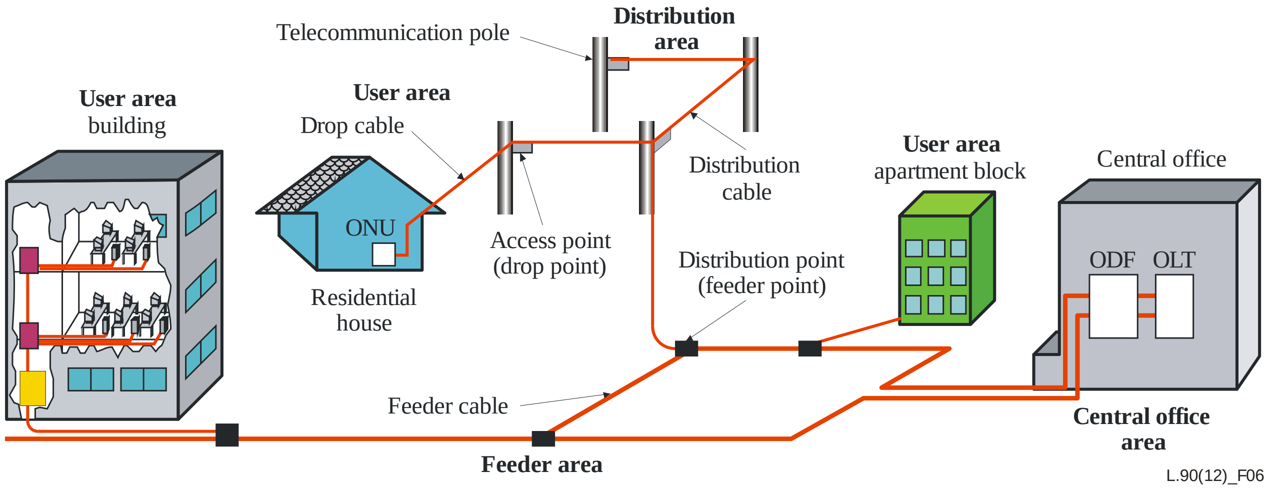


Figure 6 – Configuration of an optical access network

Therefore, in order to determine the network architecture, design, construction, maintenance and operation approach for the optical access network, and to select the optical components for FTTx, telecommunication companies should mainly consider the following:

– Scalability (number of terminated fibres, number of fibre jointing points (joint closures), total fibre length of network, etc.).

– Survivability (security, supervisory system, etc.).

– Functionality (bit rate, transmission distance, etc.).

– Construction and maintenance costs (cost, quality and reliability of components to position in the network, etc.).

– Network upgradeability (increased transmission capacity, transmission length, number of customers (including for future demand) and the potential evolution or migration of architecture).

– Operability and suitability over designed network lifetime.

– Regulatory aspects (co-operation on layer 1).

Telecommunication companies should develop appropriate designs based on the optical access network requirements for each country. In addition, the development of optical fibre access networks can largely be divided into four stages based on the increasing number of subscribers as shown in Figure 7, namely the initial stage, the growth stage, the mature stage and the final stage. Telecommunication companies should focus particularly on the previous items in each stage.

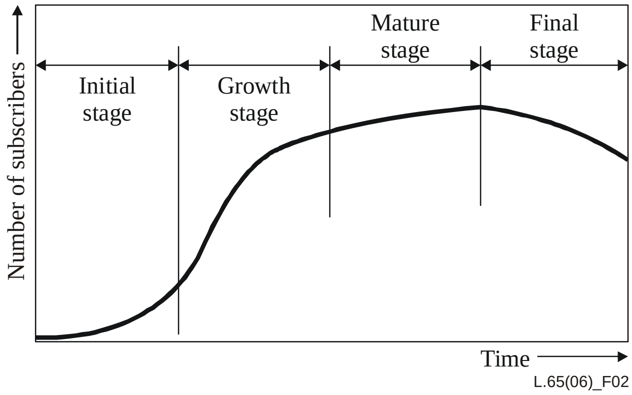


Figure 7 – Progressive increase in number of FTTx subscribers

13.1 Initial stage

13.1.1 Effective and economical optical fibre distribution for demand dispersed over a wide area

In the initial stage, the demand for optical fibre will be dispersed over a wide area. Therefore, telecommunication companies should respond by designing effective and economical approaches to optical fibre distribution. For example, it is important to determine the distribution point and access point allocation, which is closely related to the construction cost and construction workability. Moreover, to flexibly respond to demand, ease of branching and dropping after the initial cable installation should be considered as described in [ITU-T L.58] when selecting the optical fibre cables.

13.1.2 Optical fibre distribution taking future demand into account

In addition to the above, it is important that the optical fibre distribution scheme should take into account potential demand during the growth and mature stages. For example, the number of fibres in the cables and the number of branches for the branching devices in a passive optical network (PON) are important optical fibre distribution parameters with regards to future demand. Technologies that support deferred costs for subsequent up-scaling of fibre capacity could be considered.

13.2 Growth stage

13.2.1 Optical fibre distribution for quick response to demand

In the growth stage, the demand for optical fibre will occur randomly over a wide area. It is therefore very important for the optical fibre distribution scheme to be able to quickly respond to this demand. In particular, it is necessary to design the optical access network with a view to achieving easy optical fibre distribution over the last part of the access network between an access point and individual homes, apartments, business buildings, etc., because the distribution over the last mile is large scale and the demand is random. However, in the growth stage, the demand for optical fibre will be widely dispersed in rural areas. Therefore, an effective and economical optical fibre distribution scheme that responds to this demand will be needed for rural areas.

13.2.2 Optical fibre distribution for easy maintenance and operation

In addition to the above, at this stage there will be a rapid expansion of the optical access network infrastructure, including optical fibre and optical fibre cable. Therefore, it is important to be able to easily maintain and operate the optical access network infrastructure. For example, there will be a need to use the optical fibre network maintenance support, monitoring and testing system described in [ITU-T L.40] and [ITU-T L.53]. In addition, an optical access network infrastructure database will need to be constructed and used to operate and administer the huge expansion of the infrastructure, taking into account other future Recommendations on databases for optical access network infrastructure and system architecture for data transmission, database access and interoperability.

Moreover, it is anticipated that overlay of fibre networks into areas of legacy metallic networks will eventually occur, presenting challenges for both aerial and underground deployment. In addition, it will be important to use existing facilities such as cable ducts for the effective and economical installation of optical fibre cables. For example, several optical fibre cables could be installed in a cable duct. This is because the optical access network infrastructure will increase and the available facilities may become scarce. Consideration could be given to active cable duct management solutions to ensure their future economical usability.

13.3 Mature stage

13.3.1 Optical fibre distribution for easy maintenance and operation

In the mature stage, the demand for new optical fibres will be slow and a huge optical access network infrastructure will already be in place. Therefore, it is of the utmost importance that the optical fibre distribution scheme be easy to maintain and operate. This will require an optical fibre network maintenance support, monitoring and testing system, and a corresponding database.

In addition, customers who require very high reliability should be provided with two or more fibres using a ring network in each stage.

Telecommunication companies should select appropriate architecture and optical components (e.g., optical fibre cable and passive optical components), and design and construct optical access networks taking account the above factors in each stage.

13.4 Final stage

In the final stage, demographic considerations may determine that the demand for optical fibre may decline and the plant and land be re-used for different purposes, e.g., industrial, commercial, retail or residential, or a mix of these uses. Such events may be common in urban areas. It is likely that there will be a threshold at which systems and networks will become uneconomic to operate and need to be decommissioned.

Appendix I

Japanese experience

(This appendix does not form an integral part of this Recommendation.)

I.1 Outline of optical access network structural design technologies

Optical fibre-based communication services in Japan have grown rapidly in recent years. The optical fibre network design method for access networks is important in that it forms the foundation on which the optical fibre network is constructed. To meet the small and dispersed optical demand in the initial stages, we must operate an appropriate number of facilities efficiently. Figure I.1 shows the optical access network configuration in Japan.

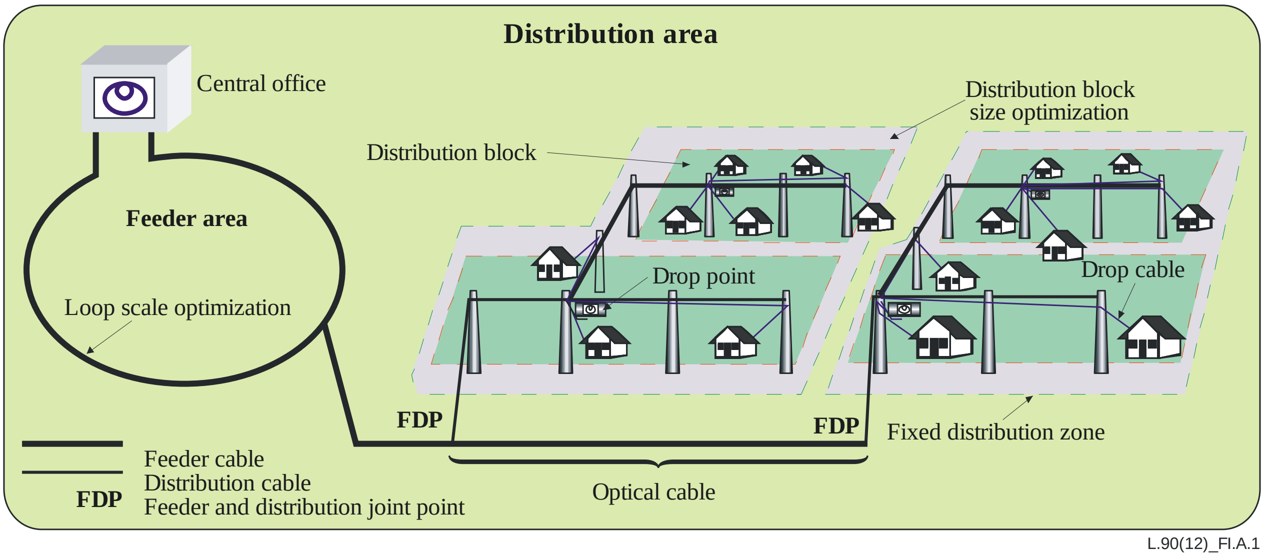


Figure I.1 – Optical access network configuration

Feeder cables are installed in a cable tunnel or duct, located between a central office and a feeder and distribution joint point (FDP), in a feeder area. The distribution cable, which is mainly installed between telecommunication poles, is connected to the feeder cable and distributed from an FDP to drop points close to residential premises. A central office covers a certain area, which is divided into a number of fixed distribution zones of an appropriate size. Each fixed distribution zone is divided into several distribution blocks based on service demand using optical fibres.

Two items must be examined in relation to optical access network structural design in the feeder and distribution areas:

1) Loop scale optimization;

2) Distribution block size optimization.

I.1.1 Loop scale optimization (feeder area)

"Loop distribution" describes cable that leaves a central office, takes a circular route, and returns to the point of origin. This kind of configuration can provide fibre optics from two different directions to respond to fluctuations in demand, making it more flexible than the "star distribution". However, not only does loop distribution respond better to changes in demand, it also enables breakdowns to be repaired more quickly by switching to routes in the opposite direction, even in lines that require a high degree of reliability. Thus, loop distribution has been employed for feeder area routes in, for example, large metropolitan areas, where there are many major lines.

This type of distribution is currently being established to connect customer routes efficiently in areas that have been, or will be, upgraded to fibre optics. As a result, loops of various sizes have been constructed. Notwithstanding, one cannot project that the current loop architecture will always form the most economical configuration of future optical fibre-based distribution networks. Therefore, looking at the entire area served by a central office, we are investigating optimum loop distribution configurations for use well into the future, and testing their effectiveness using models and simulations on actual networks.

I.1.2 Customer drop area size optimization (distribution area)

A distribution zone is divided into several distribution blocks based on service demand using optical fibres. A drop point is established in a distribution block. The subscribers in the same block are dropped from the same drop point as shown in Figure I.2.

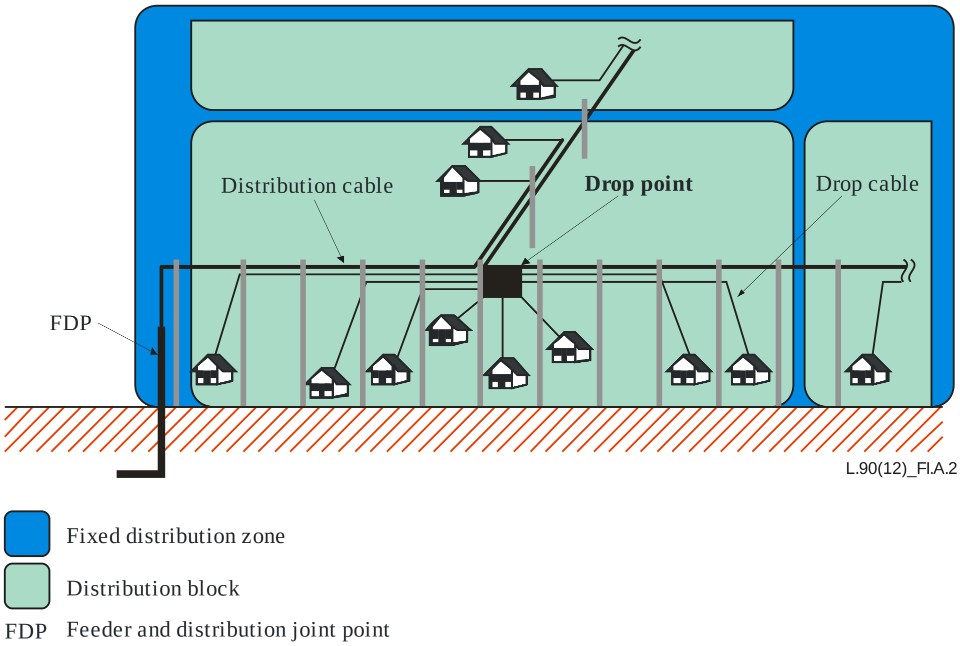
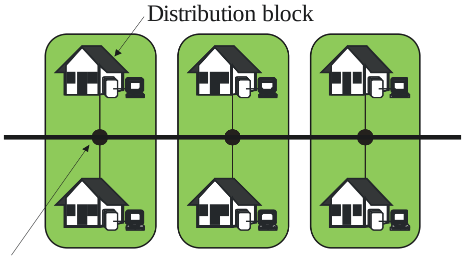
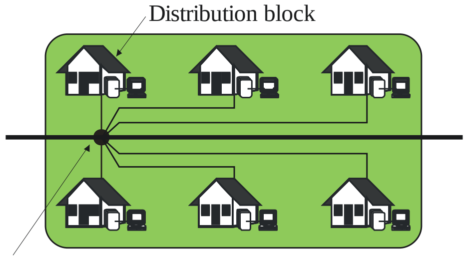


Figure I.2 – Distribution block configuration

The optimum size of the distribution block should be obtained in terms of the minimum cost of construction between a feeder point and a subscriber. When there are many distribution blocks and the number of drop points increase, the cost of construction between the feeder point and the subscriber is too high to allow us to use many closures for drop and high count distribution cable. However, when there are few distribution blocks and the number of drop points decrease, the cost of construction between a feeder point and a customer is also too high to allow us to install many long drop cables as shown in Table I.1. Therefore, we are investigating the number of distribution blocks in the distribution zone to minimize the cost of construction between the feeder point and the subscriber.

Table I.1 – Difference due to distribution block size

		Large	**Small**
Number of distribution blocks			
Cost	a) Drop cable	Low	High
	b) Drop closure	High	Low
	c) Distribution cable	High	Low

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I.2 Optical fibre distribution of access networks

I.2.1 Introduction

Fibre to the home (FTTH) in Japan has grown rapidly in recent years. The number of FTTH subscribers had exceeded 20 million at the end of 2011. It seems that FTTH has moved from the initial stage to the growth stage. Some design techniques have been developed in order to construct the access network effectively for the growth stage. This appendix describes the optical fibre network design method in Japan for the coming growth stage.

I.2.2 Design of optimum margin for demand fluctuation for the feeder area

The total number of fibres for a feeder area depends on the number of fibres required for each distribution area. In this case, the number of fibres for each distribution area must be more than the expected user demand in order to be able to cope with demand fluctuations. However, it is less cost effective if additional fibres are distributed for every distribution area. On the other hand, cost effectiveness is also reduced by the additional construction time and cost required if the fibres in a feeder cable are distributed and connected to the fibres in a distribution cable to meet every new user demand. Thus, optimizing the margin for demand fluctuation is important for feeder areas.

A design method that overcomes the above problem is shown in Figure I.3. In the feeder area, the fibres are divided into two groups. In the first group, the number of fibres corresponds to the expected user demand for each distribution area. In the second group, some fibres are used in common for the whole distribution area. This design is cost effective and highly reliable with a minimum number of fibres using the common fibre when there is demand fluctuation.

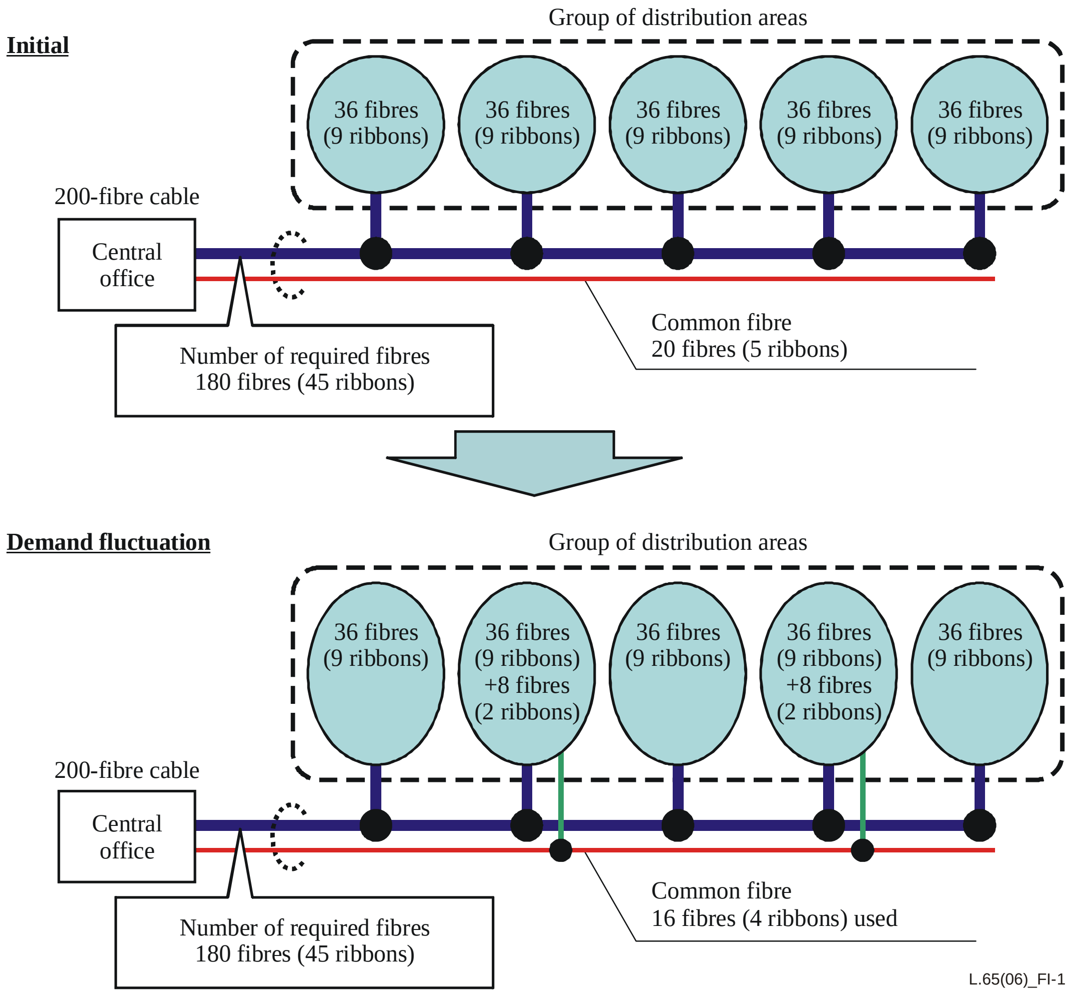


Figure I.3 – Configuration of the fibre distribution method for demand fluctuation (with 200-fibre cable (4-fibre ribbons × 50 ribbons))

For example, 10 to 20% of the total distributed fibre is provided to meet demand fluctuations, although the number of fibres (or fibre ribbons) that are required depends on factors such as the size of each distribution area.

I.2.3 Balanced use of distributed fibre to each drop area in aerial distribution areas

An aerial distribution area is divided into several drop areas based on user demand of the growth stage. Since the user demand is large in the growth stage, it is effective to distribute the optical fibre ribbons to every drop area. However, it is not effective to distribute the optical fibre ribbons to every drop area in the initial stage, when user demand is not great. Thus, in order to prevent the excessive distribution of optical fibres, each optical fibre ribbon is distributed to a limited number of drop points serving each specific drop area. An example distribution area is shown in Figure I.4. Distribution cables branch to some drop areas and fibre ribbons must be distributed to each drop point. In this case, the fibre ribbons are distributed to drop areas D, E and F through drop areas A, B and C. Therefore, if the user demand rises and additional fibres are needed, any of the fibres in the fibre ribbon that passes through these areas can be used. The effective use of fibres is achieved by first selecting the fibre in a distributed fibre ribbon with a low use rate. This can prevent the need for reconstruction due to a shortage of fibres.

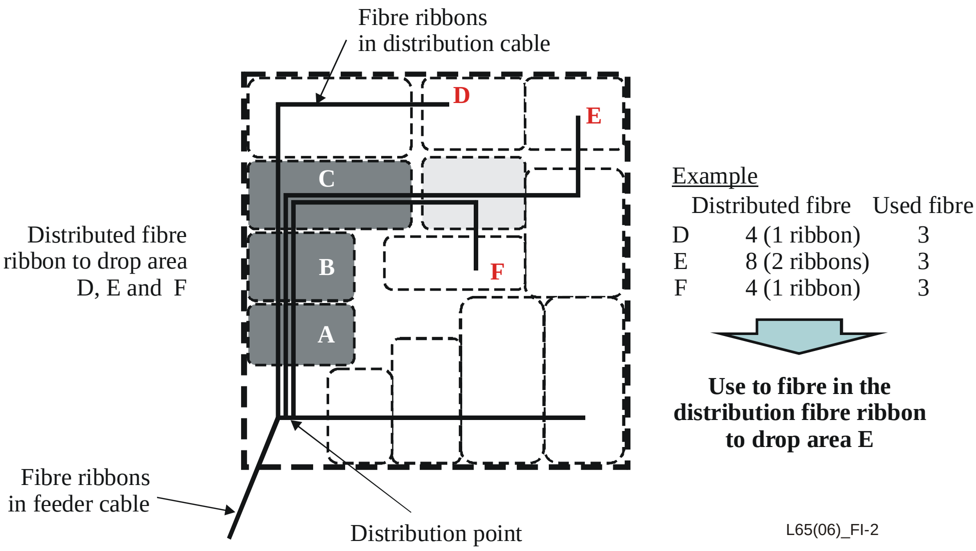


Figure I.4 – Configuration of balanced use in aerial distribution area

If the above technique is used, it is very important to establish an operation database and a management system. In addition, a fibre ribbon separation technique at mid-span without cutting the fibre ribbon is required.

Appendix II

Brazilian experience

Example of architecture of optical access network

(This appendix does not form an integral part of this Recommendation.)

II.1 Introduction

This appendix contains an example showing a possible ring network architecture for optical nodes and is intended as supplementary material to this Recommendation.

II.2 Scope

Optical access networks (OANs) are moving closer to the end-user, with installed legacy networks architecture very much based on SDH systems. Packet-based solutions are gaining momentum, driven by Ethernet in first mile technologies, as opposed to ATM PONs. It is even expected in the near future that optical packet technology will become commercial, based on the fact that several laboratory and field trials are under way.

The present proposal for innovative node and network architecture for OANs wishes to establish a bridge between existing fibre ring topologies and upcoming optical packet systems, allowing for an economically attractive transition.

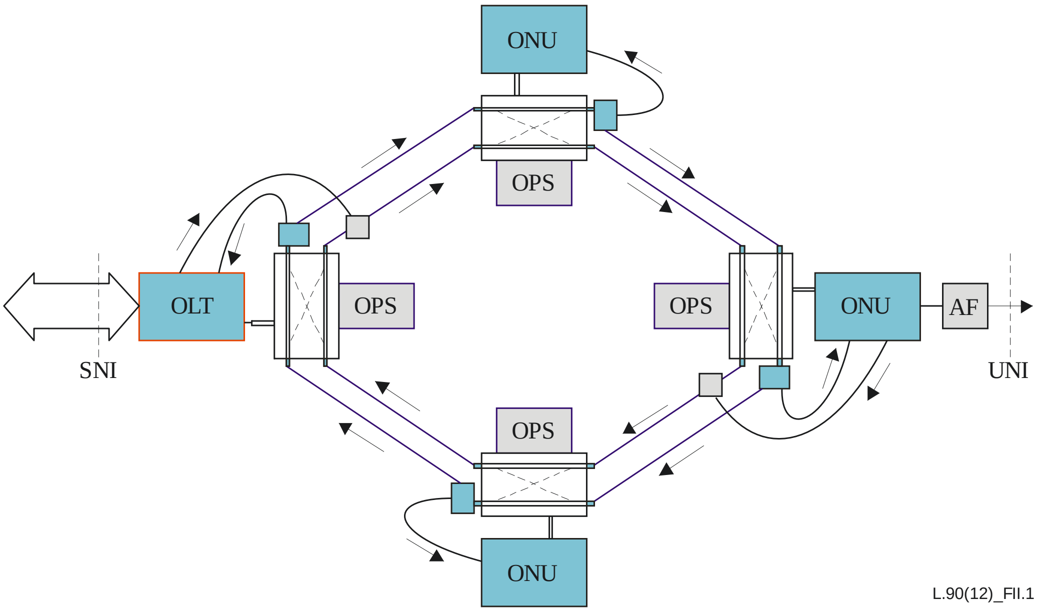
II.3 Proposed model

In Figure II.1, a schematic model is presented. It is assumed that optical packet switching (OPS) is present in the network nodes, but it is not necessary. The solution is also applicable to burst switching. Network traffic is generated in any node, being addressed to any other node; traffic may be dropped at any node. Node addresses are provided by packet or burst headers, in time code or frequency domains. From this viewpoint, the OLT is equivalent to any ONU.

On the other hand, interconnection to a service network is exclusively through an OLT node which, in this respect, will be considered of higher hierarchy, and may have OTN ([ITU-T G.872]) functions.

The nodes are constituted by fast optical switches (operation in µs, or less, time base), and electronic circuitry for header recognition, switch control and packet/burst routing. These all-optical nodes deliver optical packets/bursts to the ONUs, which will convert and process the payload contents, in conjunction with the appropriate adaptation function (AF). The AF is what renders the network transparent to different user's rates and formats. It is understood that such a solution is intended for high-capacity networks, with at least 1 Gbit/s digital bandwidth per node. It is characteristic of packet/burst switching's very low latency and extremely low packet loss, in accordance with the requirements in high-capacity networks. Further details may be found in the bibliography.

Protection of traffic and service survivability will, however, require overlay architecture for bi-directionality, taking into consideration the intrinsically unidirectional packet/burst traffic flow necessary for proper optical switch operation.



AF Adaptation function
OLT Optical line termination
ONU Optical network unit
OPS Optical packet switching
SNI Service network interface
UNI User network interface

Figure II.1 – Ring topology OAN with all-optical add, drop, and route functions

II.4 Further discussion and results

The present proposal has been partially tested in laboratory prototypes and computer simulation, with consistent and scalable results. A network node with add/drop, switch and route functions was implemented with lossless packet switching and routing performance; BER measurements on payload integrity has yielded results better than 10^{-12} using PRBS $(2^{23} - 1)$ words. Network traffic simulation, using both packets and burst, and 2×2 buffer-less optical nodes, and using deflection routing to avoid packet collisions has yielded very low packet loss ($<10^{-6}$) in 4, 8, and 16 node networks.

These results should be interpreted as a basis on which to proceed with perfecting and improving optical network functionalities, and fostering new concepts in network design to increase cost effectiveness and service flexibility.

II.5 Conclusions

Furthermore, by anticipating optical packet switching and routing, new paradigms for network design are taken into consideration. By extension, the enormous potential of optical fibres and WDM systems in the access network is better explored.

Appendix III

Korean experience

Distribution methods for the design of optical networks in access areas

(This appendix does not form an integral part of this Recommendation.)

We dealt with five distribution methods including conventional distribution methods: tree distribution, loop distribution, cross-connect distribution, link distribution and non-reduced tree distribution. Each has its own characteristics and useful applications, and they are the result of Korea Telecom (KT) simulation design and trials.

1) *Tree distribution method*

With this method, distribution cables are simply installed when and where they are required or expected to be required. This means reduced material and installation costs. However, with this method, it is difficult to adapt to unexpected demands and it is not easy to restore services when breakdowns occur. This makes this application very effective in developed or stabilized areas such as areas with apartment complexes, especially when these demands are dispersed linearly along the distribution routes.

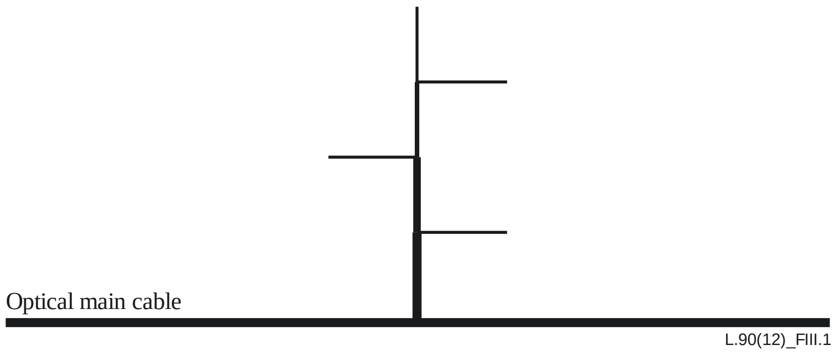


Figure III.1 – Tree distribution method

2) *Loop distribution method*

The loop distribution method is cost effective for optical distribution networks, especially in residential areas with a high population density as well as in optical feeder networks. This method can be employed in residential blocks consisting of rows of houses and detached dwellings that are dispersed uniformly in terms of demand. The demand for high-speed services, such as Internet, from users in residential areas is increasing rapidly, and this method has the advantage of being flexible in response to these demands in optical distribution networks, although its material and installation costs are high.

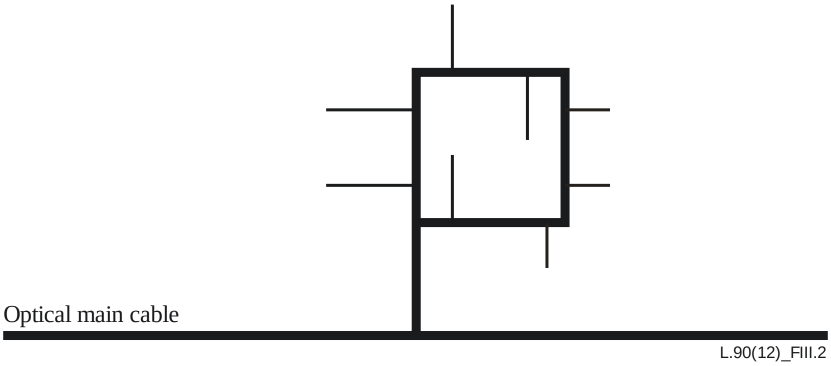


Figure III.2 – Loop distribution method

3) *Cross-connect distribution method*

The cross-connect distribution method is very useful regarding reliability and can operate using cross-connect cabinets. When new cables must be installed to meet increasing demand, installation work is convenient and efficient because it can be undertaken above ground in a cross-connect cabinet. However, it has become difficult to secure space for cross-connect cabinets in distribution areas and to keep the cabinets safe from vandalism. When this method is employed in residential blocks far from feeder networks, it may also achieve cost effectiveness.

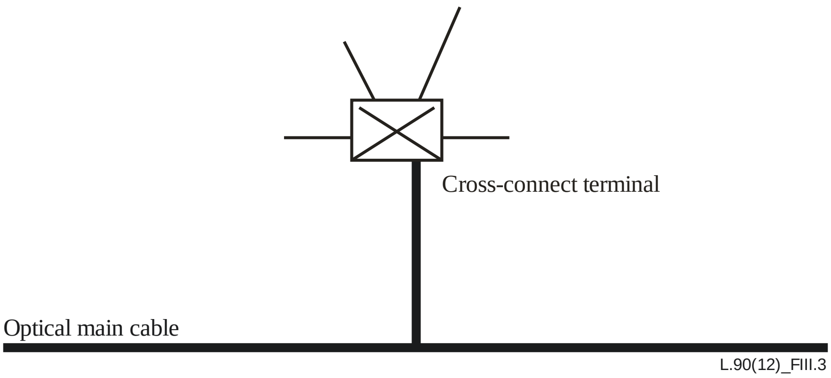


Figure III.3 – Cross-connect distribution method

4) *Link distribution method*

Common cores can be used when unexpected demands arise at any distribution points at which they are linked. However, if the number of linked distribution cables is increased, the material cost of, for example, distribution cables will increase. Thus, cost analysis indicates that 3 to 5 is the economical number of linked distribution cables. Cost analysis also suggests that this method could be 15% more economical for distances less than 1 km from the feeder network than the tree distribution or the cross-connect distribution. While it is related to the number of optical fibre cores managed in a distribution point, it is more economical when the number of cores increases. So, this method is applicable when it is difficult to install a cross-connect cabinet, or the distribution areas are at a distance of less than about 1 km from the feeder networks.

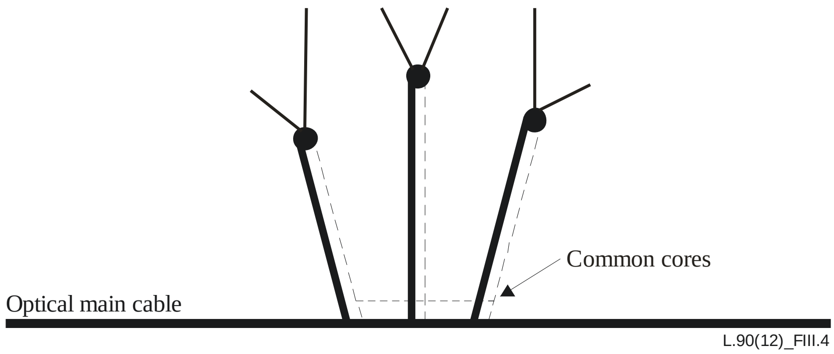


Figure III.4 – Link distribution method

5) *Non-reduced tree distribution method*

The non-reduced tree distribution method can respond more flexibly to demand than the tree distribution. Also, it can be expanded into loop distribution if necessary. It is, therefore, applicable to developing areas where the demand has not stabilized. Loop distribution and non-reduced tree distribution are very flexible in terms of meeting unexpected user demands without cross-connect cabinets.

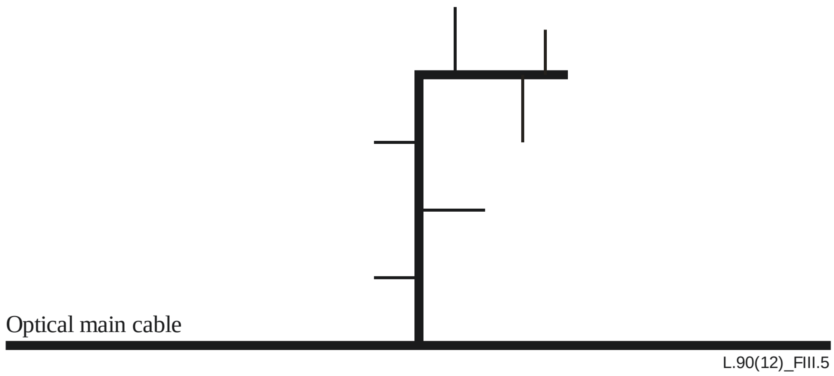


Figure III.5 – Non-reduced tree distribution method

In addition, if we select and apply the distribution method suitable for the local environment, optical fibre cores can quickly be provided and used efficiently when requested. Finally, the described distribution methods and guidelines for these optical distribution networks can be applied to the design of optical networks for access areas such as FTTH.

III.1 Number and size of loops in the feeder network

An access network consists of a feeder network and a distribution network. The construction cost of an access network is the total cost of the combined construction costs of the feeder and distribution networks. It is assumed that the number and size of loops in the feeder network are optimized in order to minimize the construction costs of the access network. Simulations on the different models shown in Figure III.6 and Table III.1 allowed the establishment of relationships between the number and size of loops in the feeder network and the construction costs of the access network. Table III.1 indicates the possibility of a trade-off between the construction cost of a feeder network and the construction cost of a distribution network.

We assume that the Central Office's (CO) serving area and feeder loop are square, and that the CO is centred in the serving area. In the model, K is defined as the ratio of the side length of the feeder loop (d) divided by the side length (D) of the CO's serving area. Figure III.8 shows the calculated construction costs for some selected models and K values.

When K increases, construction costs of the feeder network increase and those of the distribution network decrease. Korean experience concluded that optimal K could be about 0.188 to 0.25 and that the optimal number of loops could be up to 5 or 6 in the CO's serving area. For information, average serving area is 16 km^2 in Korean urban areas. In that case, the optimal length of one feeder loop may be about 3 to 4 km.

Table III.1 – Cost variation on the numbers and size of loops in feeder network

		Size of loop		Number of loops	
		Small (Model A)	**Large (Model B)**	**Few (Model C)**	**Many (Model D)**
Cost	Feeder network	Low	High	Number and size of loops in feeder network	High
	Distribution network	High	Low	High	Low

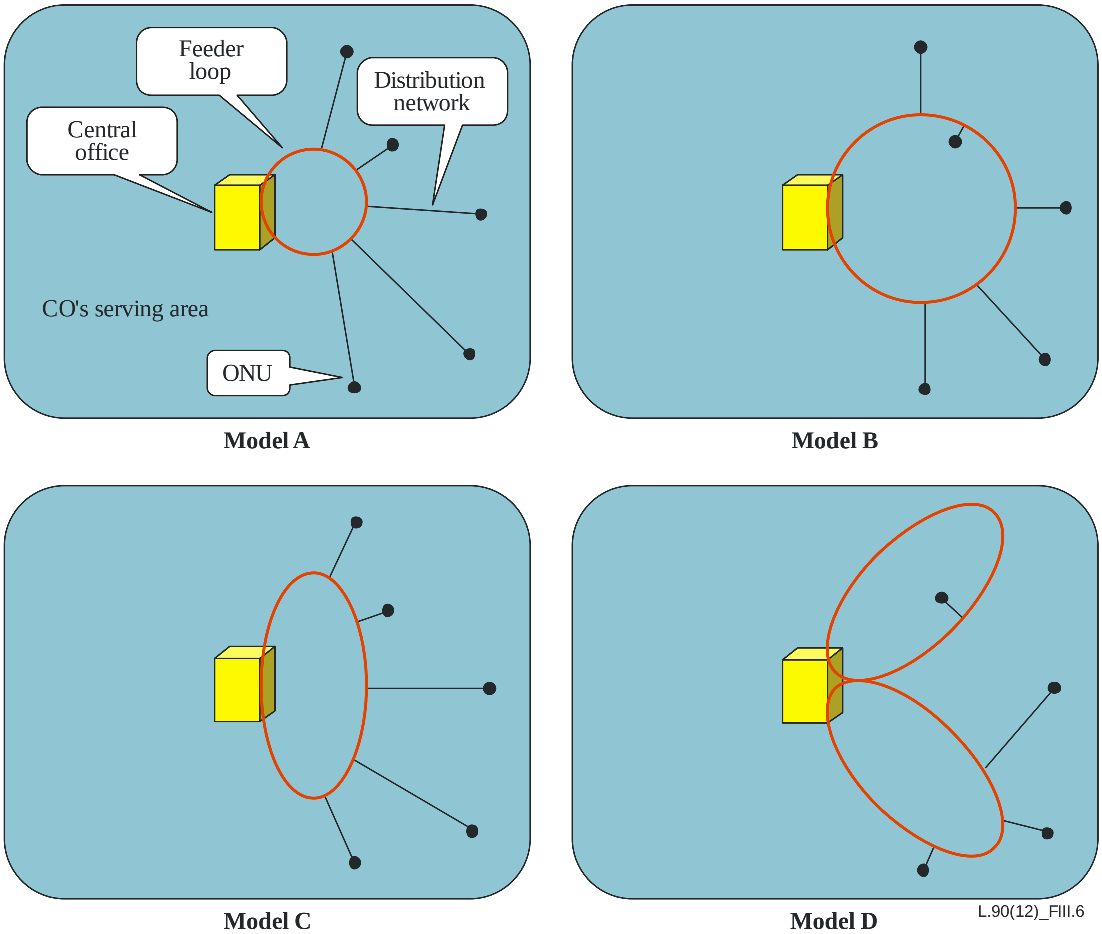


Figure III.6 – Some models of feeder loop configuration

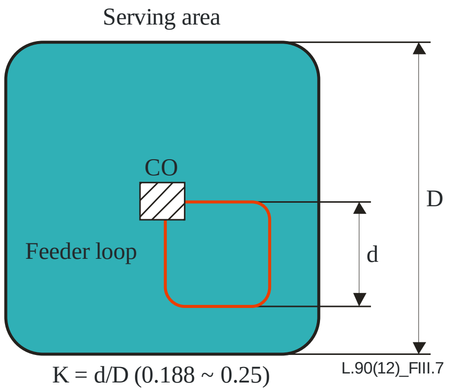


Figure III.7 – K, one side length ratio of feeder loop (d) versus the boundary (D) of CO's serving area

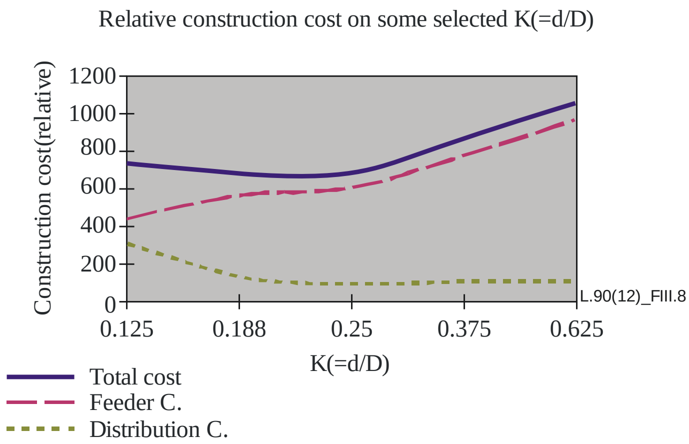


Figure III.8 – Relative construction cost on some selected K(=d/D)

Appendix IV

Dutch experience

(This appendix does not form an integral part of this Recommendation.)

IV.1 Introduction

Today, optical fibre is on its way towards use in local loops. Traditional optical cabling technology does not meet the requirements for access networks. A large number of splices and branches have to be passed for a connection from a local exchange to a customer (not a problem in copper networks). New generation cabling techniques, based on micro-cables, blown fibres and mini-tube (or guide-tube) systems, overcome these limitations. They offer the possibility of branching off without making splices. They are extremely flexible and make it possible to grow with demand. Moreover (limited) duct space is used far more effectively. Usually only a small portion of the installed fibres is used directly. Here timing is money. Also, state-of-the-art fibre technology can be chosen. This appendix introduces access network cabling solutions and provides an overview of duct installation techniques that can be used with these solutions.

IV.2 Mini-tube system configurations

The described techniques consist of bundles, loose or tight, of small-size guide-tubes (see, e.g., Figure IV.1) running through a network of protective ducts (polyethylene, from 25 to 63 mm in diameter). A trunk duct runs through the streets and smaller ducts branch off to subscribers (see Figure IV.2). Low-cost "clip-on" branching connections (see Figure IV.3) or tube-manipulation boxes are used that can be installed any time and at any place. Once the chosen guide-tubes have been connected to each other by means of simple push/pull connectors, individual paths are created from the local exchange or point of presence (e.g., the primary nodes from Figure IV.5) to the customers. In these paths, miniaturized optical cables or fibre units can be blown in without a splice. This can also be undertaken at a later date, when a customer asks for connection.

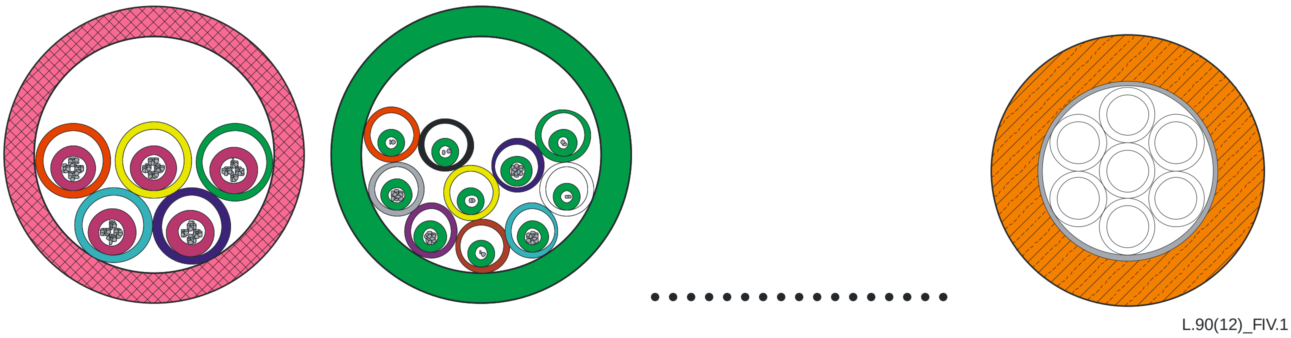


Figure IV.1 – Examples of loose bundles of mini-tubes (left and middle, for microcables with 24-60 and 2-24 optical fibres per mini-tube, respectively) and tight bundle of mini-tubes (right, for fibre members)

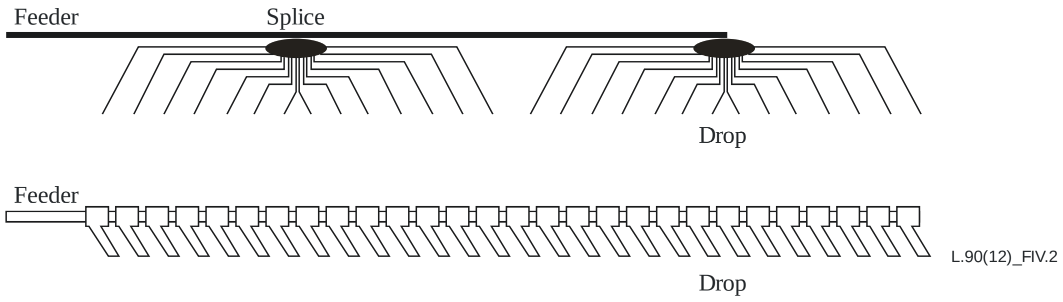


Figure IV.2 – Network structure with traditional cabling (above) and with mini-tubes (below)

Figure IV.3 – Branching connector for mini-tubes

IV.3 Access networks using mini-tube system

When building optical access networks with traditional technology, one is faced with shortcomings in flexibility. To splice a branch cable to a feeder cable it is required to reserve overlength (window cut) in the feeder cable (see Figure IV.4). This is done at predetermined fixed positions, preferably close to the customer. But, most customers are not known in advance. In practice, new customers are generally far away from overlength locations. To avoid digging again along the feeder route, extra tubes are laid parallel. A lot of trench space is consumed and much money is spent. To avoid digging again, and to avoid excessive splicing for each extension, the traditional technology also requires the initial installation of the whole feeder length of cable, beyond the first customer asking for connection.

With the system based on mini-tubes, the above-described situation is solved using only one protective duct (same size as for traditional cabling) with several small-size guide-tubes, and hence trench space is saved. Customers can be connected any time and, when using "clip-on" branching-connectors, also at any place. No window-cuts are needed and one level of splice-points has been eliminated (see Figure IV.5) from the network. Furthermore, only those fibres, which have been paid for, need to be installed and when new customers appear beyond the installed section, a new section is simply clicked on, allowing the passage of a new cable without making a splice.

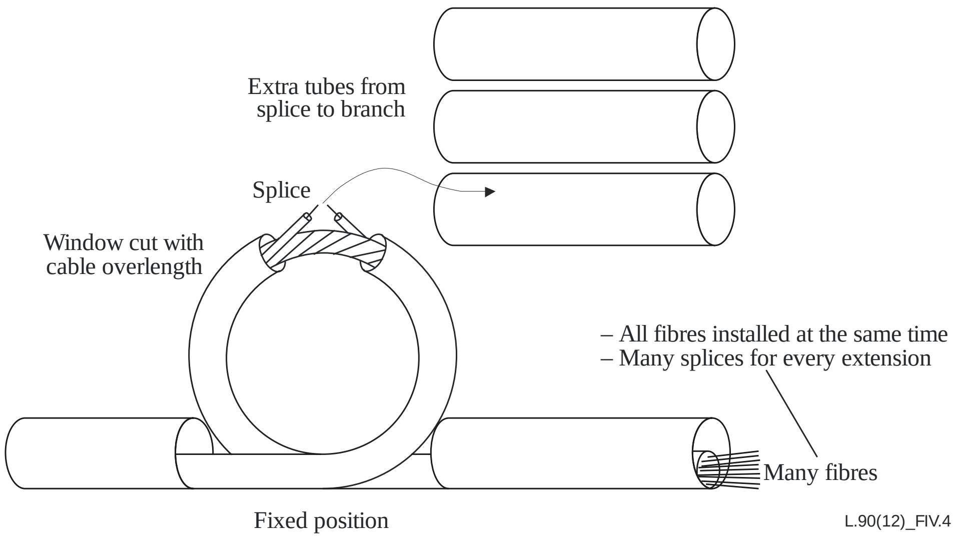


Figure IV.4 – A splice-point with cable-overlength when using traditional optical cabling

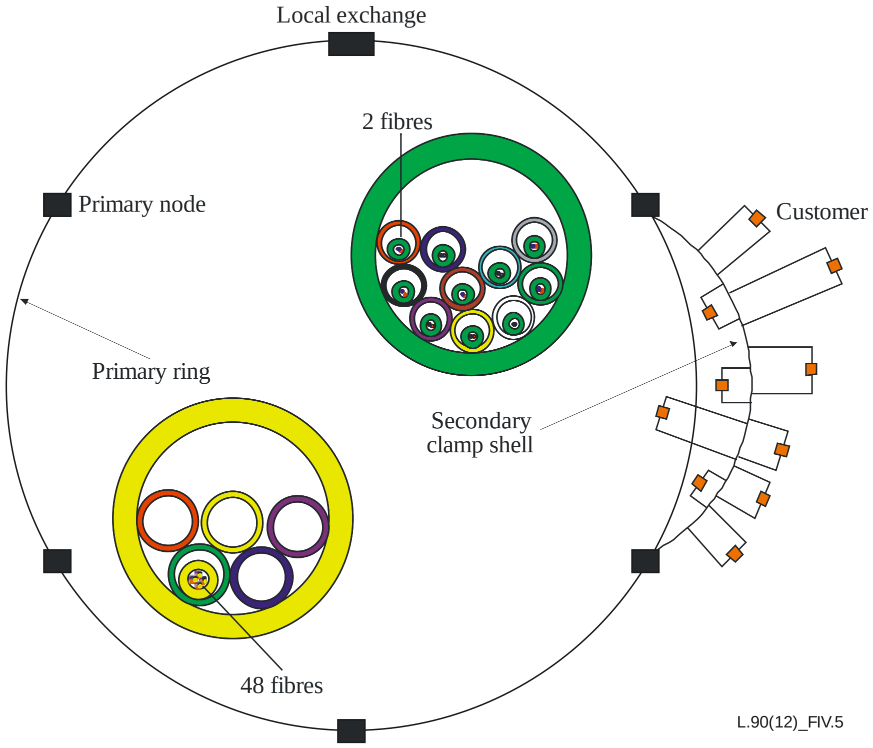


Figure IV.5 – Example of a redundant network with mini-tube cabling for business customers

Appendix V

Swiss experience

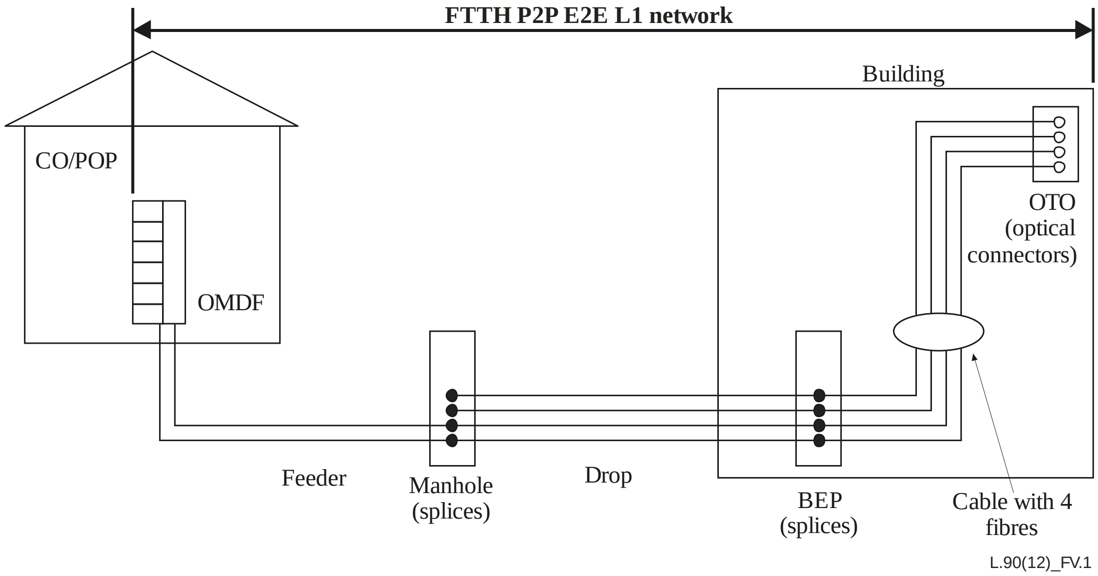
Point-to-Point FTTH access network

(This appendix does not form an integral part of this Recommendation.)

The Swiss national carrier started in 2008 an ambitious FTTH project, offering symmetrical 100 Mbps at the first stage, covering the usual triple-play services (high-speed internet, voice and HDTV).

The layer 1 infrastructure deployment will be carried out where possible together with co-operation partners (municipalities, electricity suppliers, etc.) in order to optimize the costs, speed-up the roll-out and avoid parallel construction work. Telecommunication service providers have access to the network at different levels including layer 1. The aim is to give customers a choice of service-providers.

The main concept and functionalities that allow co-operation between the CO, manhole and BEP is presented below. Simplified models are also possible.



- Between the manhole and the OTO four fibres are deployed for each subscriber:
  - two fibres for the provider (OTO-POP)
  - one active
  - one reserve
  - two fibres as reserve for other co-operation models are left in the closure (manhole)
- Between BEP-OTO is deployed one cable with four fibres for each subscriber (diameter app. 2.8 mm).
- The Swiss regulator recommends a layer 1 cooperation in the CO, manhole or BEP for two carriers.
- Between the POP and manhole outdoor cables (feeder) – up to 576 fibres (loose-tube construction) are used.
- Between the manhole and BEP outdoor cables (drop) – up to 144 fibres (loose-tube construction) are used.

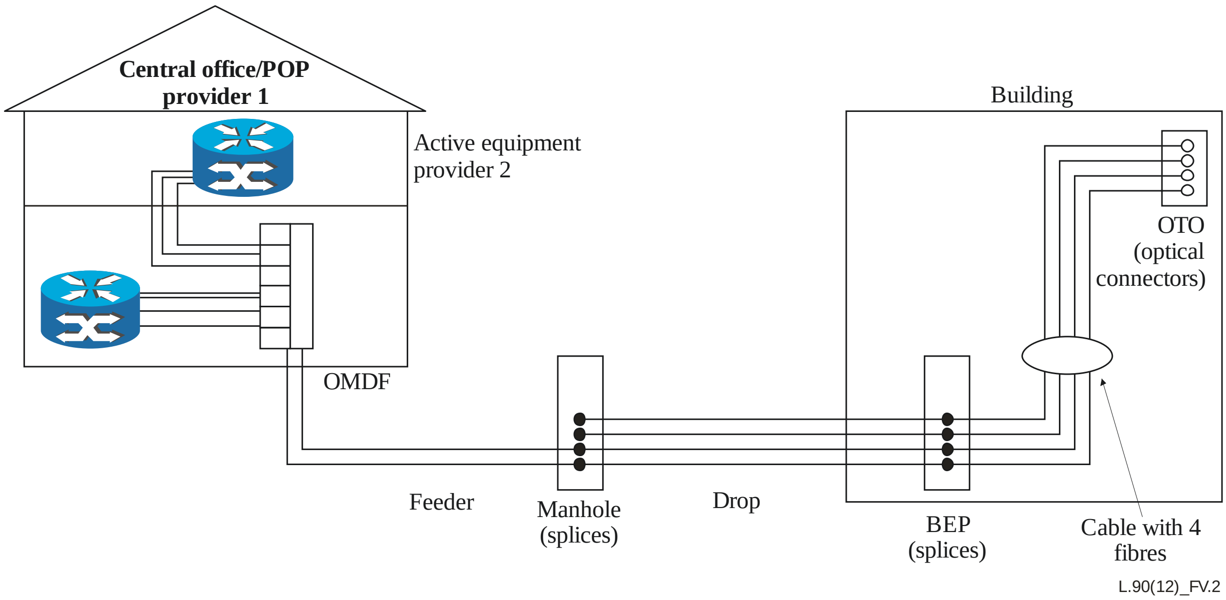
Scenario 1:

– Provider 1 builds the P2P FTTH network and rents out a technical room in its CO (collocation) for the active equipment of a second provider.

– Provider 1 uses one optical fibre between OMDF-OTO.

– Provider 2 uses on a rental basis a different fibre between OMDF-OTO.

– Two fibres are left in the closure (manhole).



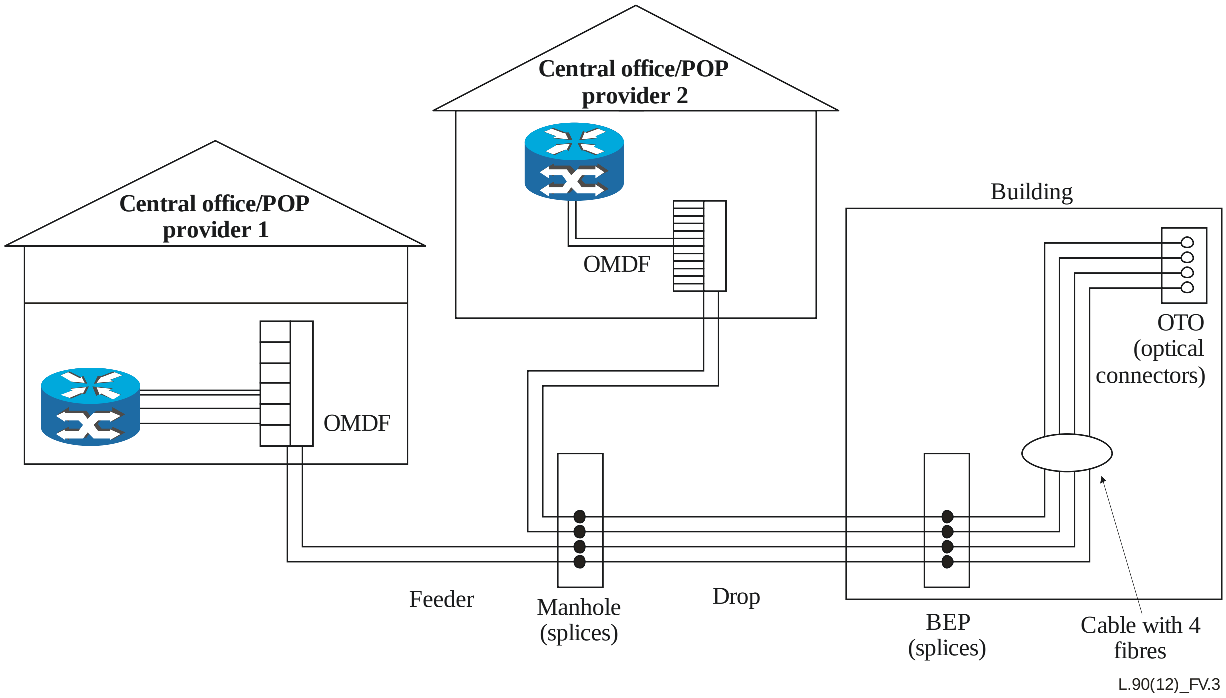
Scenario 2:

– Service provider 1 uses two optical fibres (one active, one reserve).

– Service provider 2 uses two other optical fibres.

– Service provider 2 deploys its own feeder cable until the manhole.

– The drop cable may be deployed by Provider 1 or Provider 2; this is also similar for the indoor cable BEP-OTO.


Central office/POP
provider 2
OMDF
Building
Central office/POP
provider 1
OTO
(optical
connectors)
OMDF
Feeder
Manhole
(splices)
Drop
BEP
(splices)
Cable with 4
fibres
L.90(12)_FV.3

Appendix VI

Spanish experience

Point-to-multipoint FTTH access network

(This appendix does not form an integral part of this Recommendation.)

VI.1 Introduction

FTTH deployment started in Spain in 2007, based on the GPON architecture. In 2010, began an ambitious plan for a big deployment which had covered more than 1 million homes at the end of 2011.

Two branching components are used per OLT port. The first splitter is usually installed in the manhole or hand-hole closest to the customer, and the second splitter is usually installed in the optical termination box.

Figure VI.1 describes the main concepts of the network.

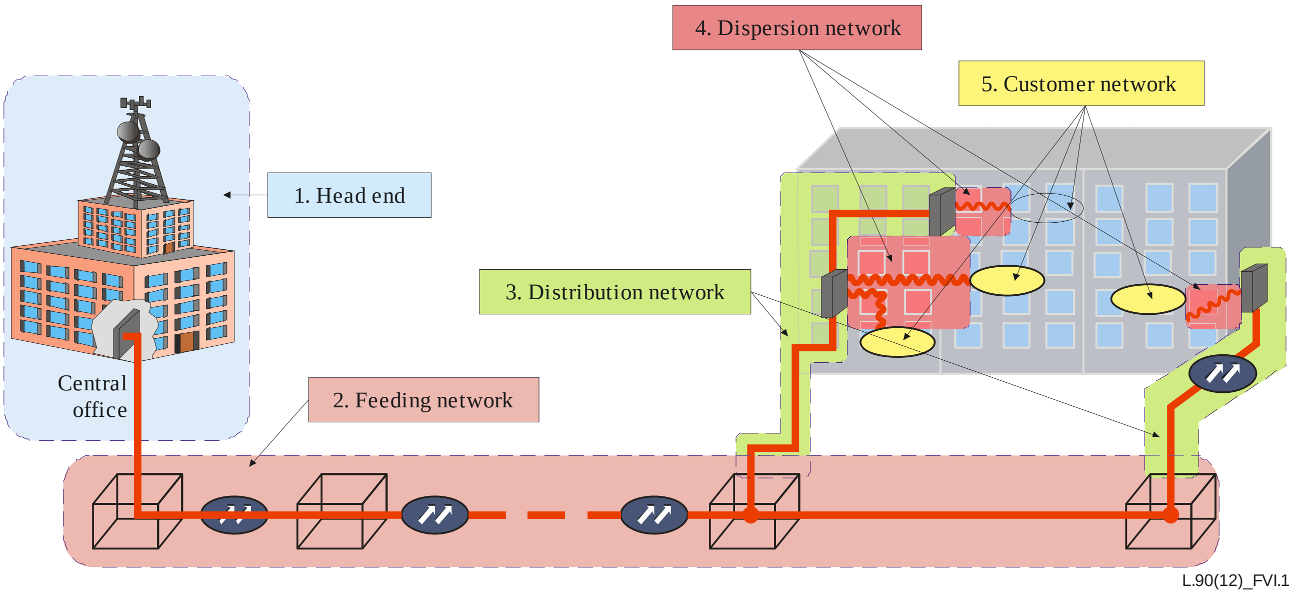


Figure VI.1 – Parts of the FTTH network

FTTH head-end – Local exchange where GPON devices (OLT and fibre frame) will be installed. An FTTH area includes one or more copper areas.

Feeder network – Part of the network, between the fibre frame and the last manhole, where the fibre has been installed underground.

Distribution network – Part of the network between the first splitter and the optical termination box (OTB). Splitters will be installed in the manhole and the optical termination box into the buildings or on the facade.

Dispersion network – This is the final part of the FTTH network. It includes everything from the OTB to the ONT (optical network termination). This part will be installed only when a customer wants to enjoy the benefits of an FTTH network (connected home).

Customer network – A network for the distribution of services at customer premises. This part of the network is after the ONT.

VI.2 Scenarios

In Figure VI.2, the main scenarios (indoor and facade) are shown.

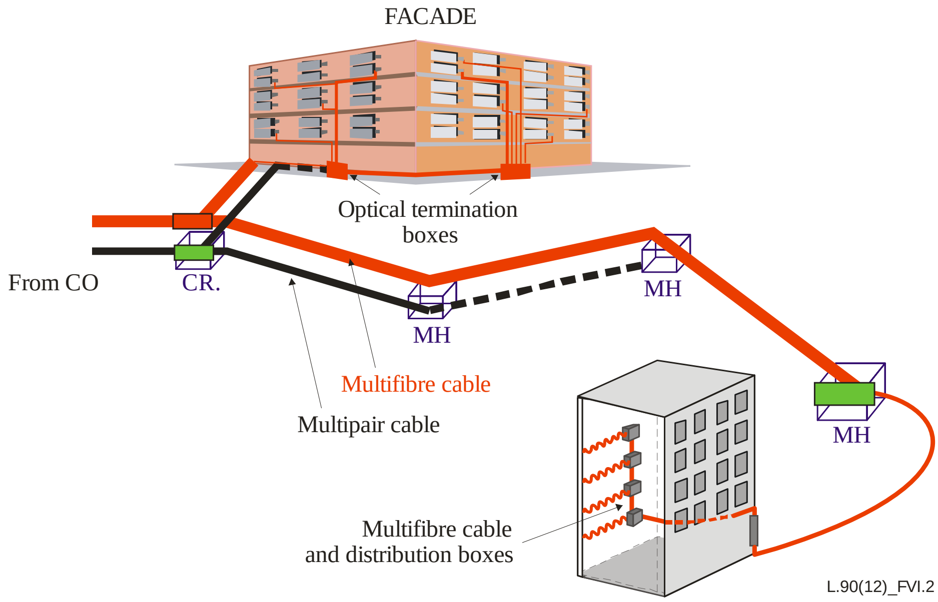


Figure VI.2 – Main scenarios for FTTH

Indoor

For an indoor scenario, optical termination boxes (OTB) are located inside the building. It is mandatory for newer buildings to have a common telecommunication infrastructure, with a room to accommodate these.

It is necessary to find space for the OTBs in older buildings. Depending on the number of potential customers, the cabling from the OTB can be done in two different ways:

- High density: a structural cabling is installed in the vertical, with several floor boxes. For connecting a new customer, an optical drop must be installed from the floor box to the outlet.

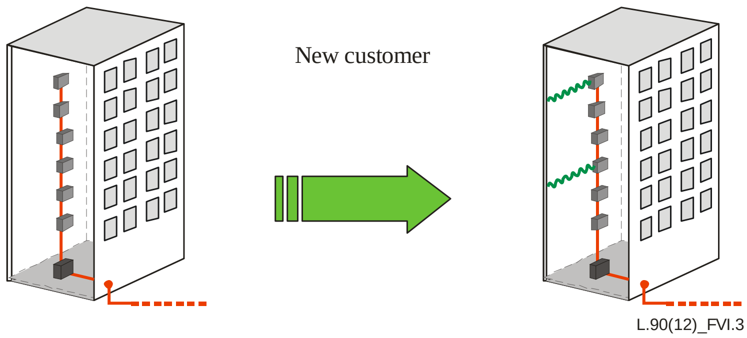


Figure VI.3 – Connecting a customer for high density buildings in indoor

- Low density: all drops are installed on demand from the OTB.

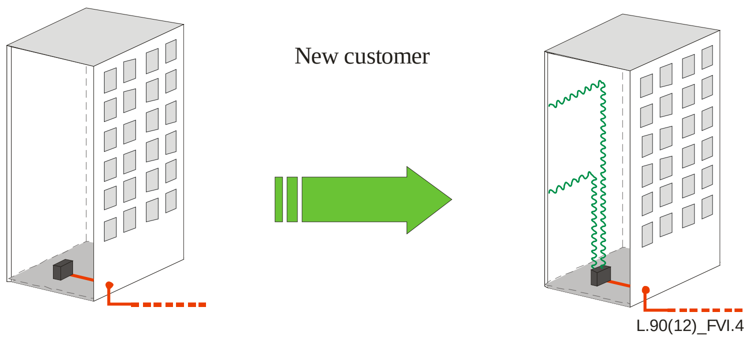


Figure VI.4 – Connecting a customer for low density buildings: indoor

Outdoor

For an outdoor scenario, an OTB is installed in the facade of the building. Due to environmental conditions, robust materials must be used for outdoor equipment. Drop cables are installed on demand.

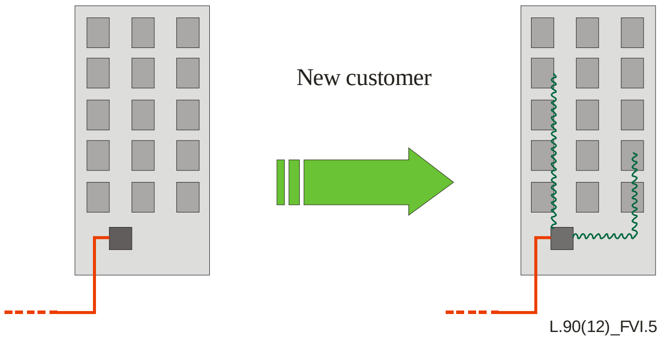


Figure VI.5 – Connecting a customer: outdoor

Single family units can be considered for this scenario, because OTBs are installed outside. The last drop is installed from a manhole/hand-hole or a pole as shown in the next figure.

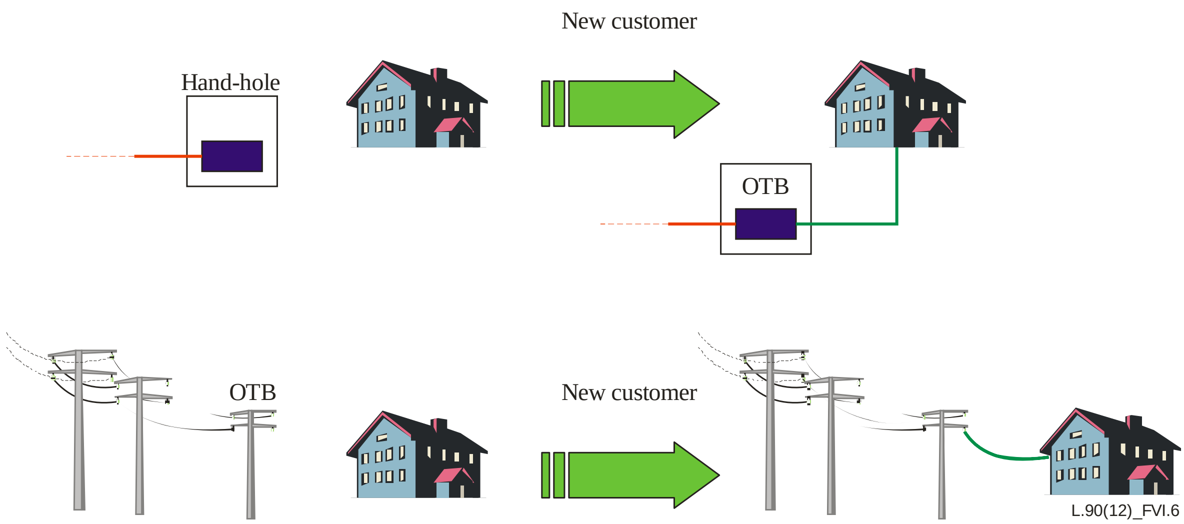


Figure VI.6 – Connecting an SFU customer

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