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

Extending optical fibre solutions into the access network

ITU-T Recommendation L.42

ITU-T Recommendation L.42

Extending optical fibre solutions into the access network

Summary

This Recommendation 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 of optical networks to optical access networks.

Source

ITU-T Recommendation L.42 was approved on 14 May 2003 by ITU-T Study Group 6 (2001-2004) under the ITU-T Recommendation A.8 procedure.

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1 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 to provide such services economically. In order to provide these services in a timely way, it is necessary to construct fibre to the home (FTTH) optical access networks immediately, efficiently and cost-effectively. To achieve this, the network design must take construction, maintenance and operation into account. Here, an optical access network is defined as a network of optical fibres that extend from a carrier's central office into individual homes, apartment houses and business offices for FTTH.

2 Scope

This Recommendation deals mainly with access network architectures and the ability to upgrade optical networks, which are the most important items in terms of designing and constructing optical access networks. 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 FTTH.

3 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.

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

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

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

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

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

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

[8] ITU-T Recommendation G.983.1 (1998), *Broadband optical access systems based on passive optical networks (PON)*.

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

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

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

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[13] ITU-T Recommendation G.983.6 (2002), *ONT management and control interface specifications for B-PON system with protection features*.

[14] ITU-T Recommendation G.983.7 (2001), *ONT management and control interface specification for dynamic bandwidth assignment (DBA) B-PON system*.

[15] ITU-T Recommendation G.983.8 (2003), *B-PON-OMCI support for IP, ISDN, video, VLAN tagging, VC cross-connections and other select functions*.

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

[17] ITU-T Recommendation K.51 (2000), *Safety criteria for telecommunication equipment*.

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

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

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

[21] ITU-T Recommendation L.15 (1993), *Optical local distribution networks – Factors to be considered for their construction*.

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

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

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

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

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

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

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

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

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

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

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

[33] IEC 60825 (2001), *Safety of laser products*.

[34] IEC 60950 (2001), *Information technology equipment – Safety*.

4 Terms and definitions

For the purpose of this Recommendation, the definitions given in ITU-T Recs G.652, G.662, G.664, G.671, G.694.1, G.694.2, G.982, G.983.1 to G.983.8, G.984.1, K.51, L.13, L.26 and L.51 apply.

5 Abbreviations

This Recommendation uses the following abbreviations:

CATV Cable Television

CWDM Coarse Wavelength Division Multiplexing

DWDM Dense Wavelength Division Multiplexing

FTTH Fibre to the Home

OLT Optical Line Terminal

ONU Optical Network Unit

WDM Wavelength Division Multiplexing

6 Features of access network architecture

In order to select or design an optical access network for FTTH, telecommunication companies 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 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 network

The basic configuration for a point-to-point network 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 houses or residential premises. Therefore, a large number of fibres are installed and distributed from a central office to customers. This configuration has low optical loss and provides the maximum distance between central offices and customers. Moreover, this may be suitable for customers requiring large bandwidth and/or high security.

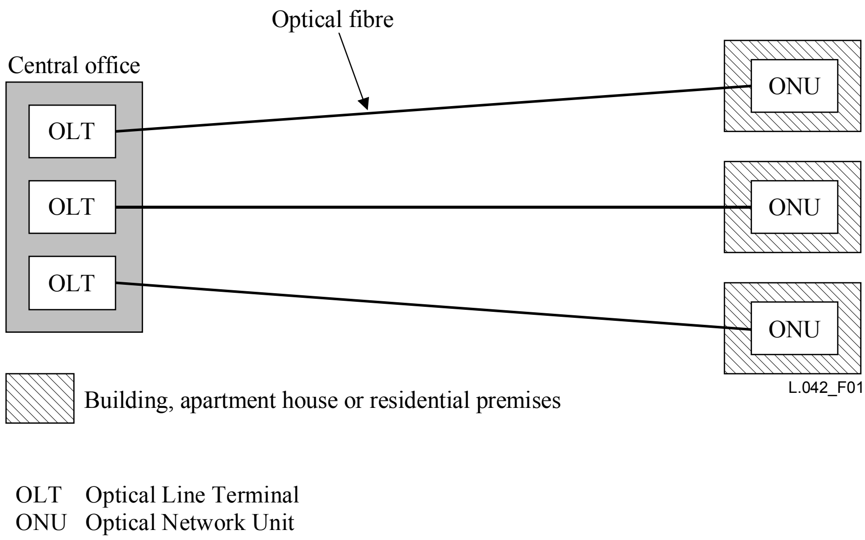
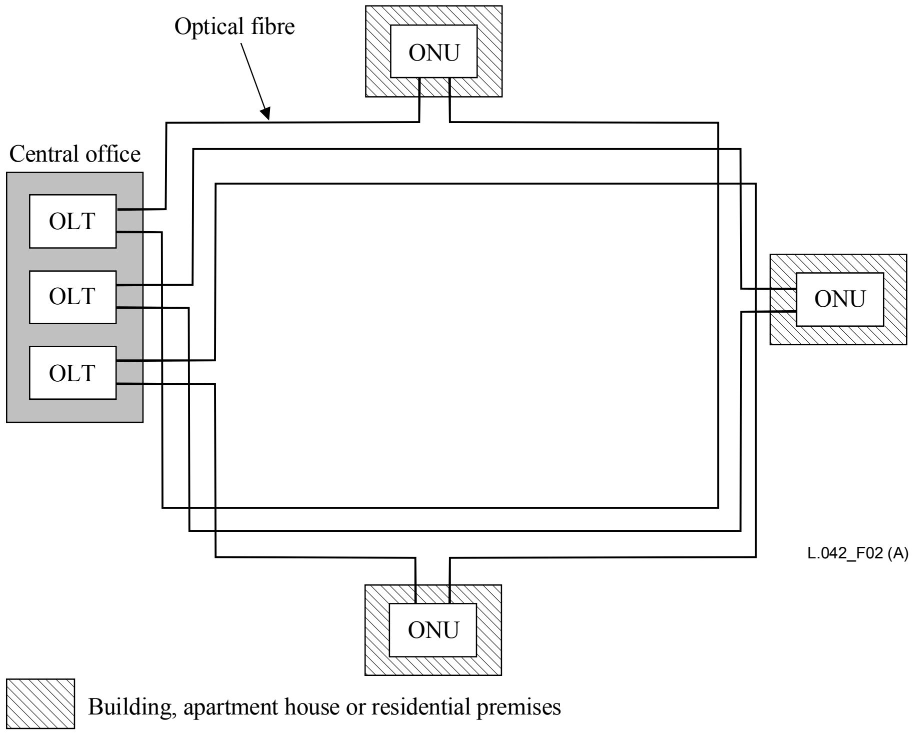


Figure 1/L.42 – Point-to-point network

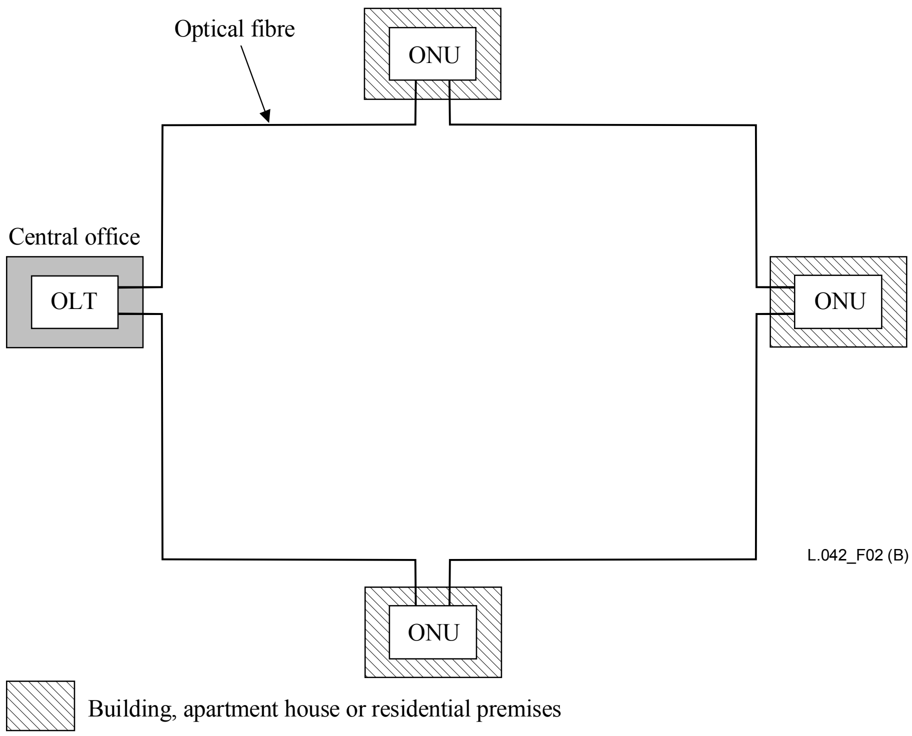
6.2 Ring network

The basic configuration of a ring network is shown in Figure 2. This starts and ends at the same central office and distributes two or more fibres to ONUs in buildings, apartment houses or residential premises. Therefore, for point-to-point ring networks as shown in Figure 2a, 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 2b, 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 ease of maintenance for alternative routing.



OLT Optical Line Terminal
ONU Optical Network Unit

Figure 2a/L.42 – Ring network (Point-to-point type)



OLT Optical Line Terminal
ONU Optical Network Unit

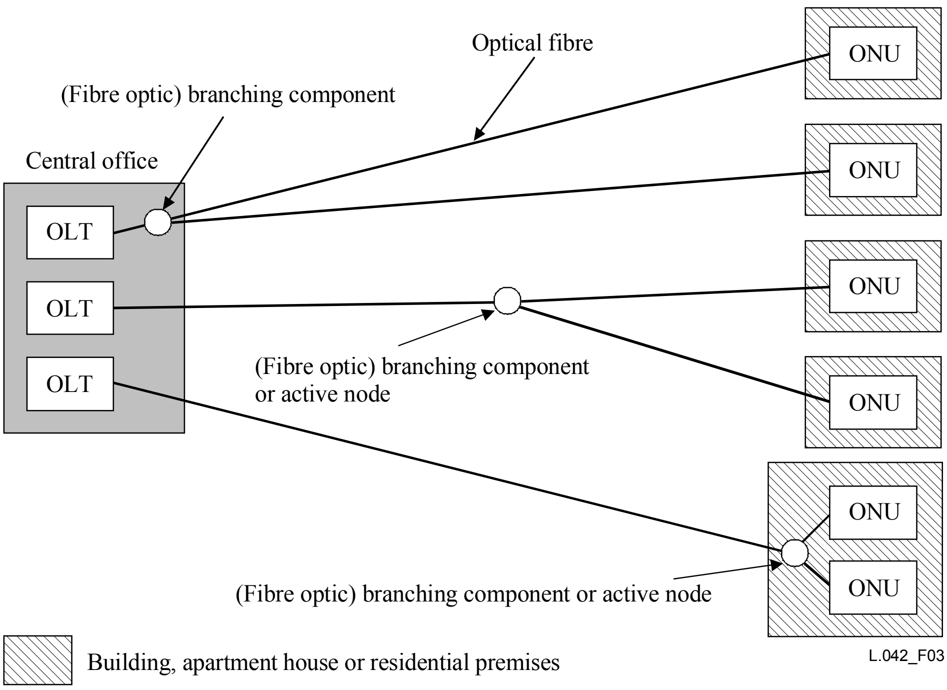
Figure 2b/L.42 – Ring network (Multiple type)

6.3 Point-to-multipoint network

The basic configuration of a point-to-multipoint network is shown in Figure 3. 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 component can be used in this network. One type has a wavelength multiplexer and demultiplexer, the other does not. A (fibre optic) branching component without a wavelength multiplexer and demultiplexer 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 demultiplexer 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 house 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 benign 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 an 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 an outside plant, or on the outside walls of a building or house.



OLT Optical Line Terminal
ONU Optical Network Unit

Figure 3/L.42 – Point-to-multipoint network (in case of 2 branches)

7 Optical fibre distribution method in outside plant

Such factors as the geographic conditions, population density, future fibre demand and so on 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/L.42 – Network upgrade method

<table>
<tr><th></th><th>Point-to-point network</th><th>Ring network</th><th>Point-to-multipoint network</th></tr>
<tr><td>Increase transmission capacity</td><td colspan="3">• Use high bit rate system
• Use WDM system (CWDM, DWDM)</td></tr>
<tr><td>Increase transmission length</td><td colspan="2">• Reduce number of optical fibre joints by using, for example, blown fibre technique
• Use optical fibre amplifier</td><td>• 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 demultiplexer.)
• Reduce number of branches or change to point-to-point network
• Use optical fibre amplifier</td></tr>
<tr><td>Increase number of customers</td><td>• Change to point-to-multipoint network and increase number of branches
• Install new cable</td><td>• Install new cable</td><td>• Increase number of branches
• Install new cable</td></tr>
</table>

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

9 Optical transmission performance for optical access network

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 Recs G.982, G.983.1 to G.983.8 or G.984.1.

NOTE – The calculation of the total network optical loss will take into account ITU-T Rec. G.982.

10 Optical components

The network mainly consists of optical components including single-mode optical fibre cable, passive optical components such as (fibre optic) branching component, optical fibre joints (fusion splices, mechanical splices, fibre optic connectors).

The performance of these optical components may be affected by such aspects of the environment as temperature, humidity and mechanical conditions, and the environment will be different in each region. The components should, therefore, be designed and selected to operate under such conditions. Moreover, biological attack may cause component failure. Therefore, components should be protected from the potential damage related to a particular environmental situation.

Moreover, each component should be in accordance with the recommendations mentioned below.

10.1 Optical fibre cable

As regards single-mode optical fibre cable, the cable should conform with ITU-T Recs L.10, L.26 or L.43, and the fibre should normally conform with ITU-T Rec. G.652.

10.2 Optical fibre joint

Three different methods are normally used for joining optical fibres, these involve the use of fusion splices, mechanical splices and fibre optic connectors. The characteristics of fusion and mechanical splices should comply with ITU-T Recs G.671 and L.12. Fibre optic connectors should be selected taking ITU-T Recs G.671 and L.36 into account.

With analogue CATV transmission, the optical connector return loss needs to be carefully considered in order to meet system requirements.

When the transmission distance is limited by the total optical loss of a network with many optical fibre joints, the design should reduce the number of optical fibre joints by using, for example, the blown fibre technique.

10.3 Other optical components

1) *(Fibre-optic) branching component*

   When a point-to-multipoint network is designed, a (fibre optic) branching component with or without a wavelength multiplexer and demultiplexer is used. The (fibre optic) branching component splits the optical signal from the input fibres to one or more output fibres. The optical performance of the (fibre optic) branching component should be in accordance with ITU-T Recs G.671 and L.37.

   When the (fibre optic) branching component has an unused port and the return loss from this port is small, it is necessary to increase the return loss by using a suitable termination method for the port in order to meet system requirements.

2) *Optical amplifier*

   An optical amplifier may provide compensation for optical loss such as that of a (fibre optic) branching component. The optical amplifier performance should take into account ITU-T Recs G.662 and L.50.

3) *Optical attenuator*

   An optical attenuator with either fixed or variable attenuation is necessary to adjust the optical power budgets to the required ranges. The (fibre optic) attenuator performance should take into account ITU-T Recs G.671 and L.31.

4) *Passive dispersion compensator*

   A passive dispersion compensator may be necessary to compensate for the chromatic dispersion of an optical path using very broad wavelength regions and high speed, and long distance transmission. The passive dispersion compensator performance should take ITU-T Rec. G.671 into account.

5) *Optical filter*

An optical filter may be necessary to allow the required wavelength region of a service to pass and to reject other service wavelengths or optical test wavelengths within a network. The spectral response of the filter may be in very narrow or very broad wavelength regions depending upon the application. The optical filter performance should take ITU-T Rec. G.671 into account.

6) *Optical distribution frames (ODF)*

An optical distribution frame, which can both contain and protect the optical fibres, passive optical components and route and store the pigtail in an indoor environment, is necessary to attach the cables at the end of the cable sheath. The performance of the optical distribution frame should take into account ITU-T Rec. L.50.

11 Optical network maintenance support, monitoring and testing system

The optical network maintenance support, monitoring and testing when employing a point-to-point network or a point-to-multipoint network with a (fibre optic) branching component in a central office, is described in ITU-T Rec. L.40. The maintenance wavelength shall be selected in accordance to ITU-T Rec. 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 house or residential premises, the optical network maintenance support, monitoring and testing is as described in ITU-T Rec. L.53. The maintenance wavelength shall be selected in accordance to ITU-T Rec. L.41.

12 Electrical power supply

The electrical power supply and battery backup to an ONU should be selected taking account of 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 Rec. L.44.

13 Safety

13.1 Electrical safety

Electrical safety should take into account ITU-T Rec. K.51 and IEC 60950.

13.2 Optical safety

Optical safety should take into account of ITU-T Rec. G.664 and IEC 60825.

Appendix I

Brazil experience

Example of architecture of optical access network

I.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.

I.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 the 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.

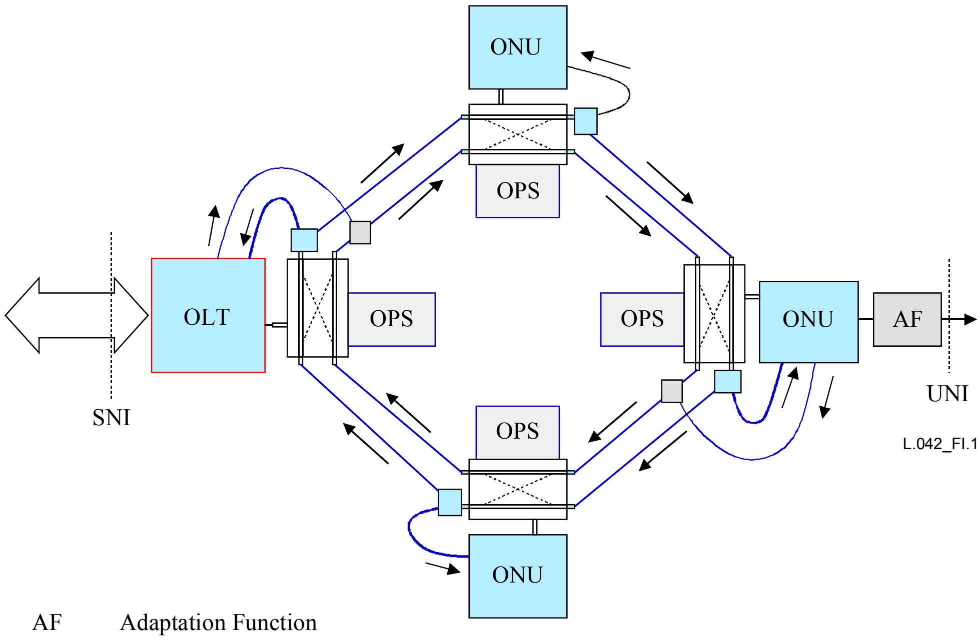
I.3 Proposed model

In Figure I.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 addressees 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 (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 solution is intended for high-capacity networks, with at least 1 Gbit/s digital bandwidth per node. It is characteristic of packet/burst switching very low latency and extremely low packet loss, in accordance with requirements in high-capacity networks. Further details may be found in the listed references, and in references therein.

Protection of traffic and service survivability will, however, require overlay architecture for bidirectionality, taking in 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 I.1/L.42 – Ring topology OAN with all-optical add, drop, and route functions

I.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 bufferless 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.

I.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.

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Appendix II

Japanese experience

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 II.1 shows the optical access network configuration in Japan.

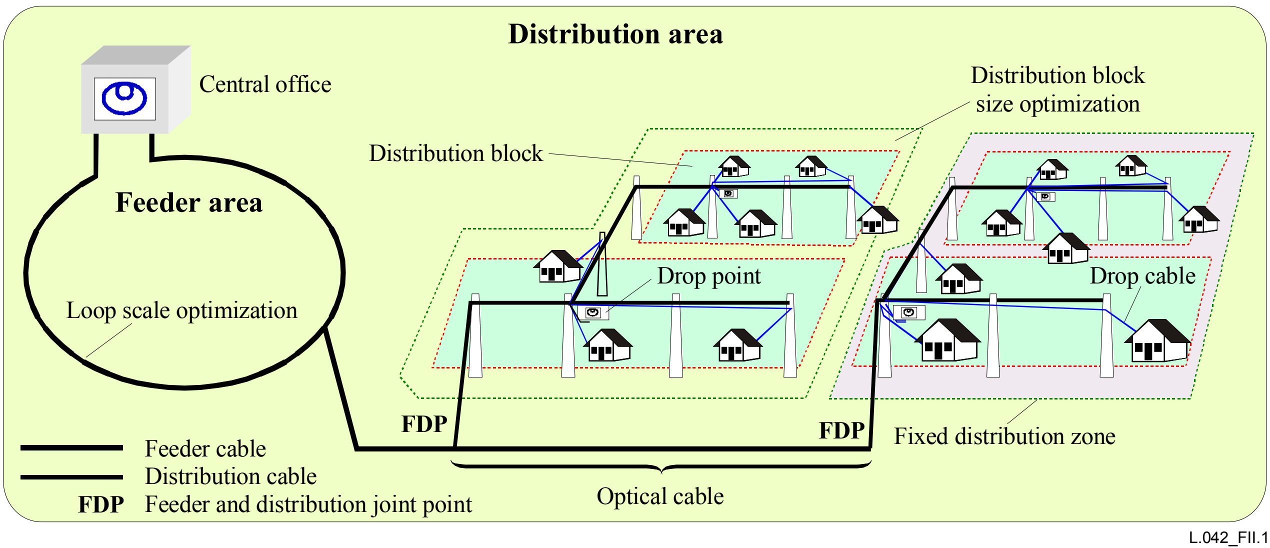


Figure II.1/L.42 – Optical access network configuration

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. 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 fibre.

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.

II.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 "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, we cannot say that loops will always form the most economical total equipment configuration for future opticalization. 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 are testing their effectiveness using models and simulations on actual networks.

II.2 Customer drop area size optimization (Distribution area)

A distribution zone is divided into several distribution blocks based on service demand using optical fibre. 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 II.2.

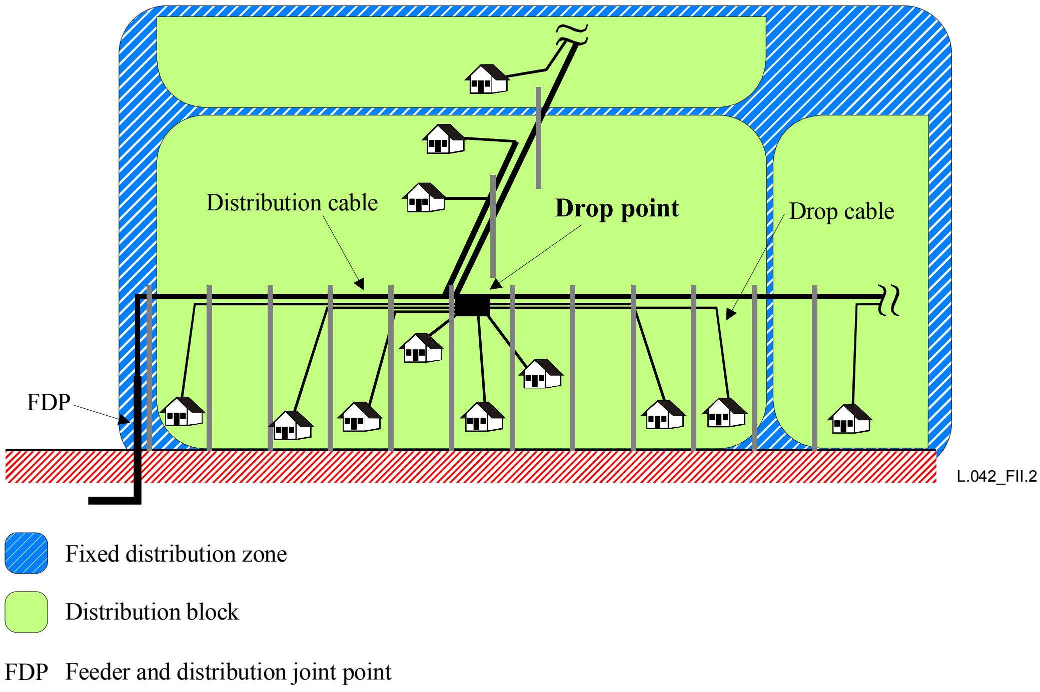
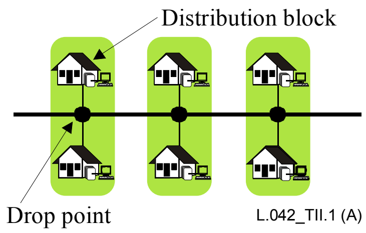
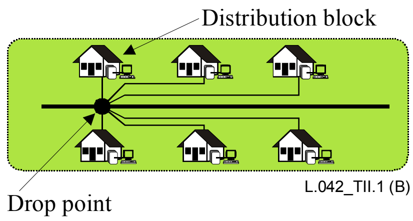


Figure II.2/L.42 – Distribution block configuration

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 increases, 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 decreases, 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 II.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 II.1/L.42 – 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

Appendix III

Korea experience

Distribution methods for the design of optical networks in access areas

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 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.

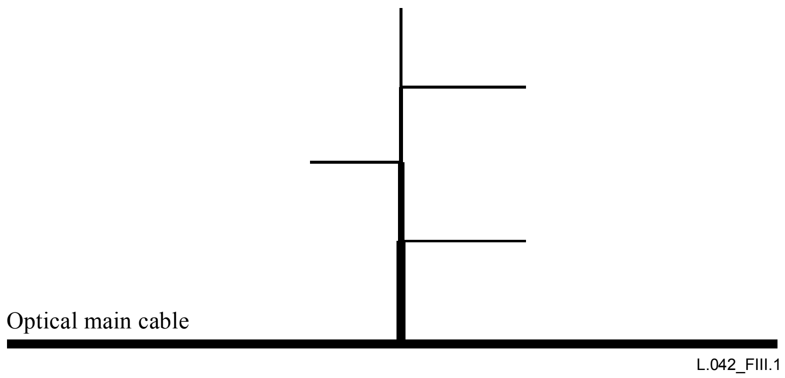


Figure III.1/L.42 – Tree distribution method

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.

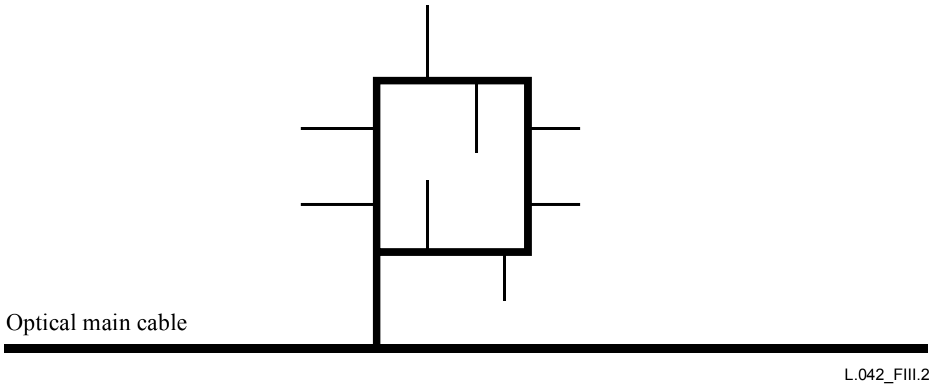


Figure III.2/L.42 – Loop distribution method

3) *Cross-connect distribution method*

The cross-connect distribution method is very useful as regards 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 is also to achieve cost effectiveness.

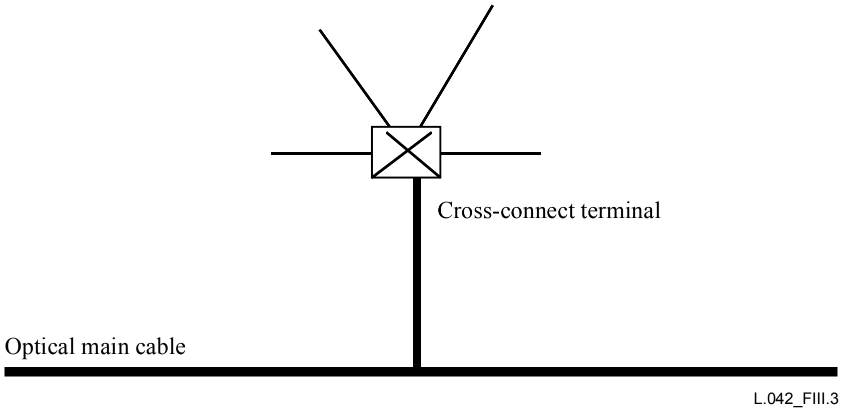


Figure III.3/L.42 – Cross-connect distribution method

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.

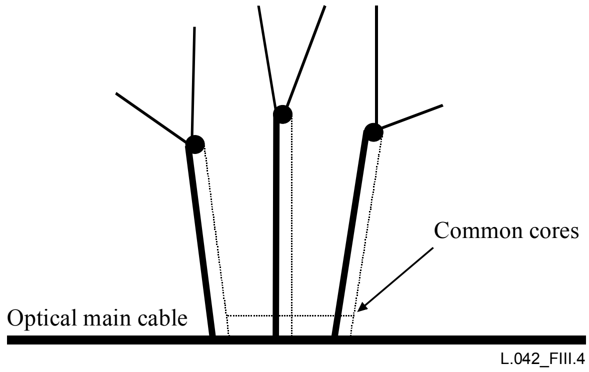


Figure III.4/L.42 – Link distribution method

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.

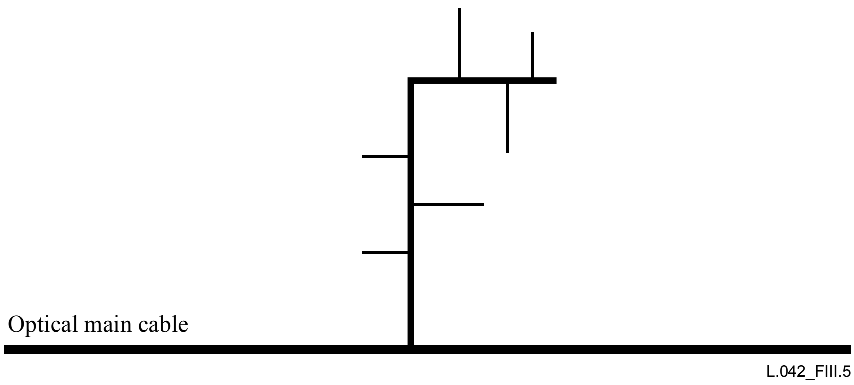


Figure III.5/L.42 – Non-reduced tree distribution method

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. We assume that the number and size of loops in the feeder network are optimized in order to minimize the construction cost 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 cost 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.7). 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/L.42 – 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

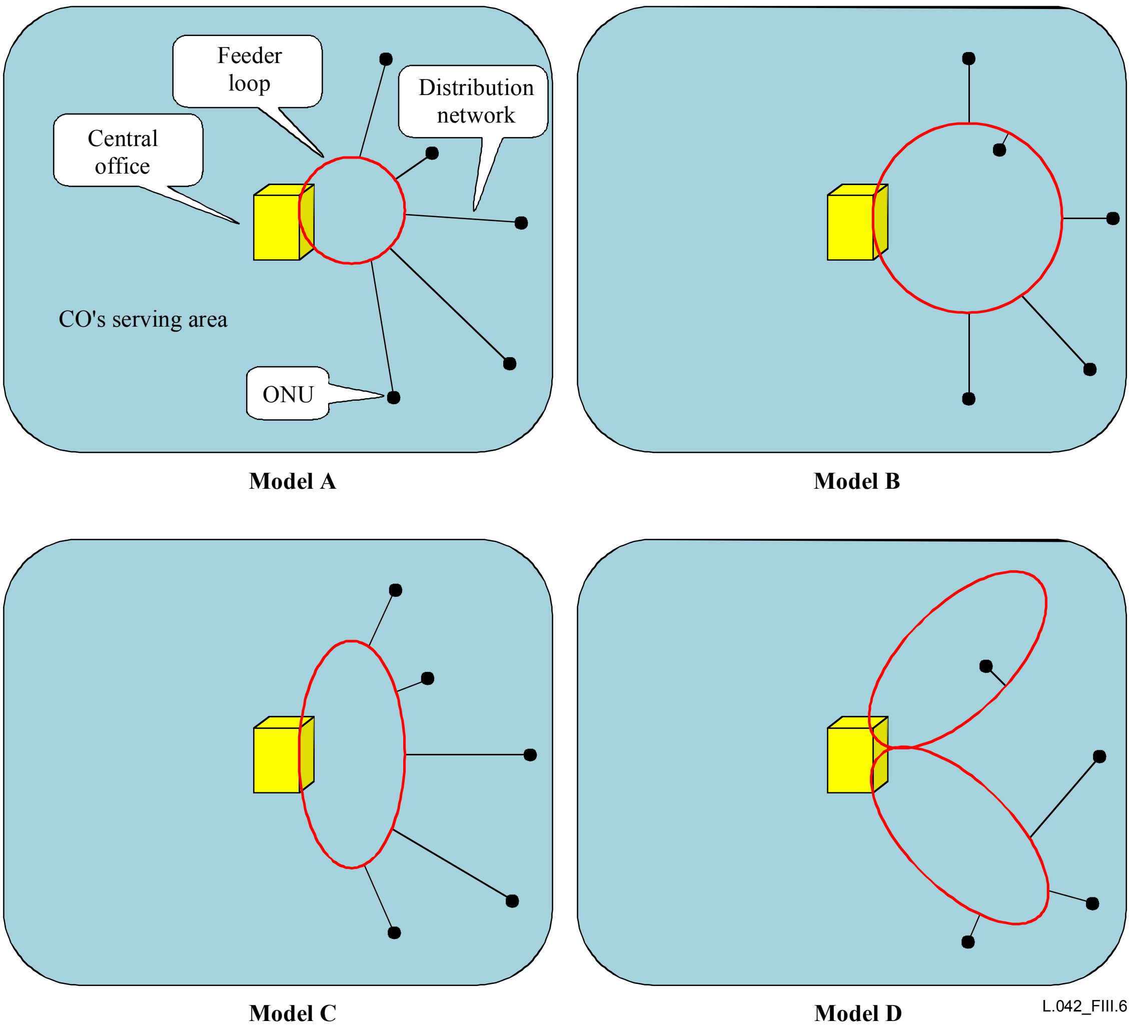


Figure III.6/L.42 – Some models of feeder loop configuration

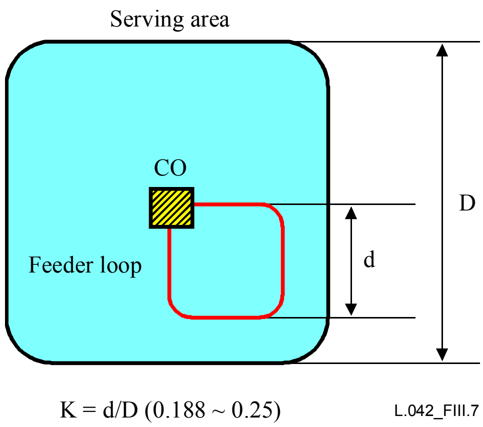


Figure III.7/L.42 – K, one side length ratio of feeder loop (d) versus the boundary (D) of CO's serving area

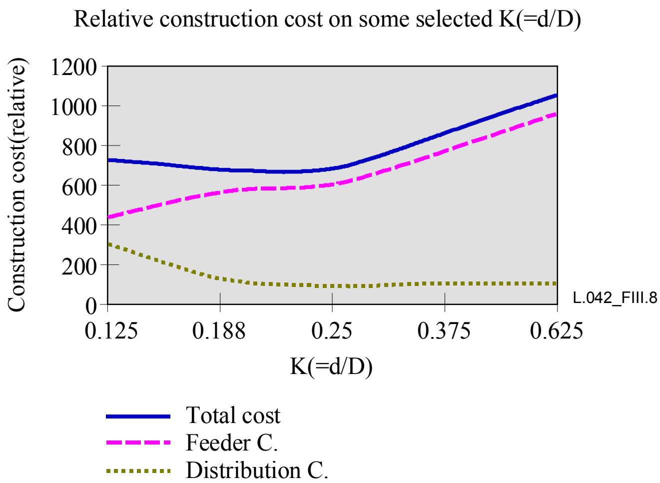


Figure III.8/L.42 – Relative construction cost on some selected K(=d/D)

Appendix IV

Netherlands experience

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.

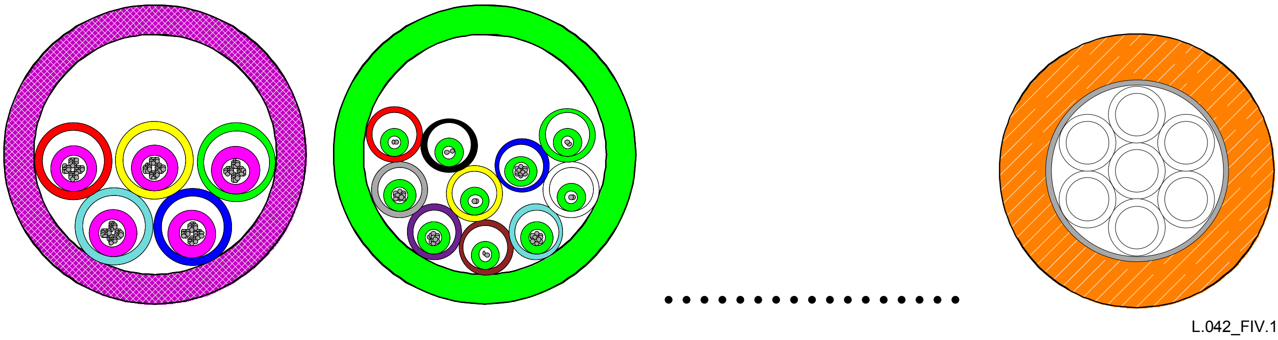


Figure IV.1/L.42 – Examples of loose bundles of mini-tubes (left and middle, for microcables with 24-60 and 2-24 optical fibres per mini-tube, respectively) and tight bundle of mini-tubes (right, for fibre members)

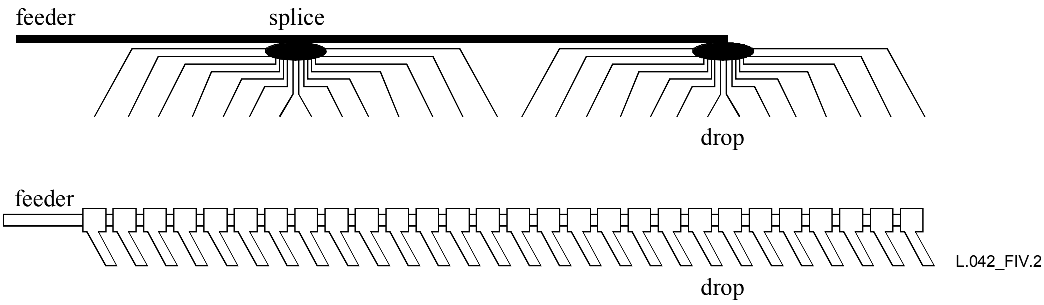


Figure IV.2/L.42 – Network structure with traditional cabling (above) and with mini-tubes (below)

Figure IV.3/L.42 – 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 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 passage of a new cable without making a splice.

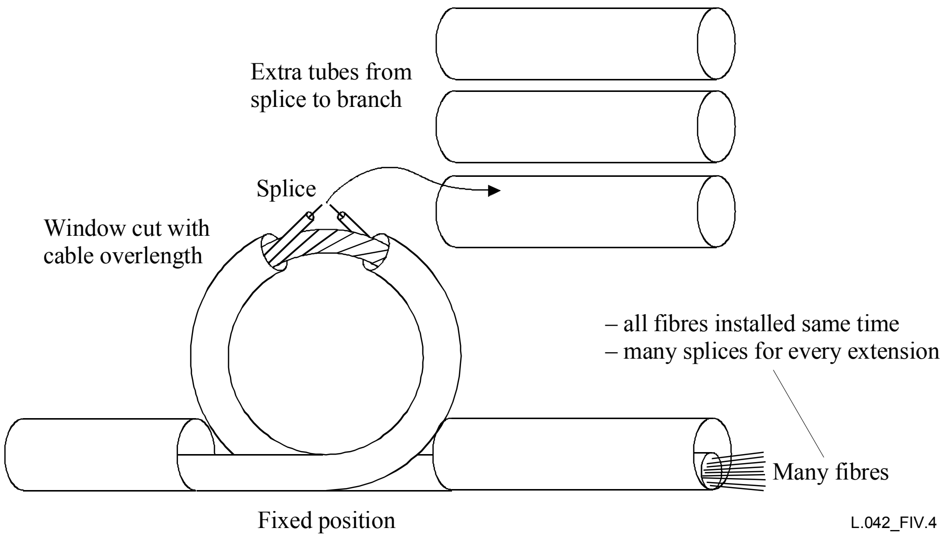


Figure IV.4/L.42 – A splice-point with cable-overlength when using traditional optical cabling

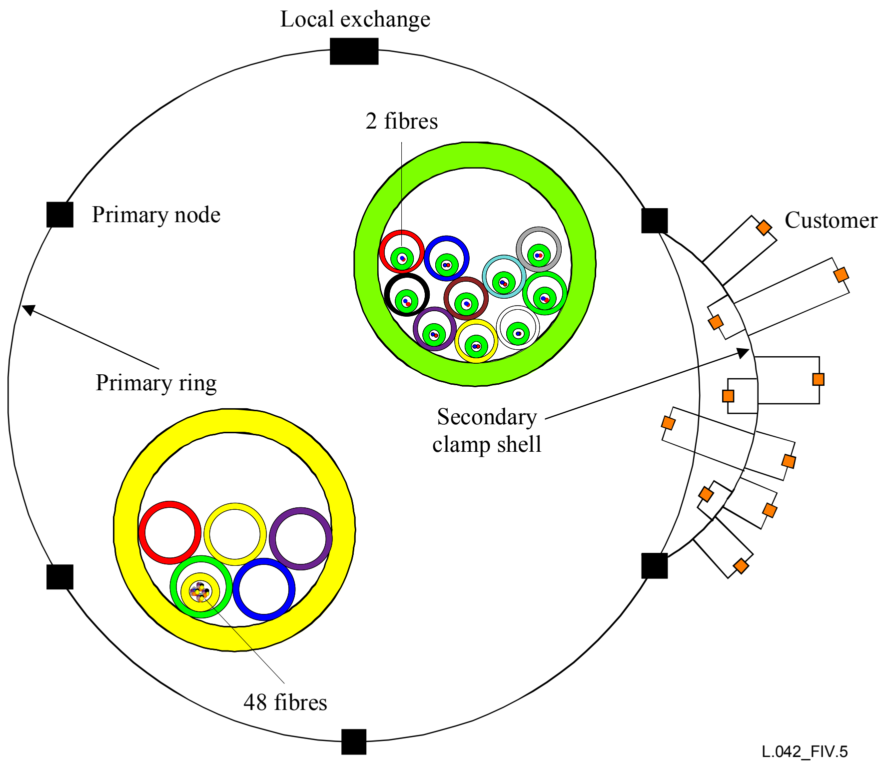


Figure IV.5/L.42 – Example of redundant network with mini-tube cabling for business customers

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