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

Considerations on the installation site of branching components in passive optical networks for fibre to the home

Recommendation ITU-T L.86

ITU-T

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Considerations on the installation site of branching components in passive optical networks for fibre to the home

Summary

Recommendation ITU-T L.86 describes considerations for determining the installation site of a (fibre optic) branching component for a passive optical network (PON) designed to provide fibre to the home (FTTH).

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T L.86	2010-07-29	15

Keywords

Branching component, capital expenditures (CAPEX), operating expenditures (OPEX), passive optical network (PON).

FOREWORD

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Introduction

PONs are used to provide an FTTH service to subscribers in many regions and countries. The primary feature of a PON is that it realizes FTTH economically by sharing fibre access infrastructures, namely an optical line termination (OLT), fibre cable and branching component, between multiple subscribers. The branching component is one of the most important elements in a PON because its installation site has a powerful effect on both capital expenditures (CAPEX) and operating expenditures (OPEX). Therefore, the branching component installation site is an important consideration in designing this network. Recommendation ITU-T L.86 recommends considerations for selecting the location of the branching component in the network as a function of the scale of the subscriber density and geographical extent.

Recommendation ITU-T L.86

Considerations on the installation site of branching components in passive optical networks for fibre to the home

1 Scope

This Recommendation deals mainly with considerations concerning the installation site of the (fibre optic) branching component for a PON providing FTTH. This Recommendation also deals with consideration for useful PON configuration in urban and rural areas.

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.983.1] Recommendation ITU-T G.983.1 (2005), *Broadband optical access systems based on Passive Optical Networks (PON)*.

[ITU-T G.987] Recommendation ITU-T G.987 (2010), *10-Gigabit-capable passive optical network (XG-PON) systems: Definitions, abbreviations, and acronyms*.

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

[ITU-T L.42] Recommendation ITU-T L.42 (2003), *Extending optical fibre solutions into the access network*.

[ITU-T L.50] Recommendation ITU-T L.50 (2003), *Requirements for passive optical nodes: Optical distribution frames for central office environments*.

[ITU-T L.52] Recommendation ITU-T L.52 (2003), *Deployment of Passive Optical Networks (PON)*.

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

[ITU-T L.65] Recommendation ITU-T L.65 (2006), *Optical fibre distribution of access networks*.

[ITU-T L.72] Recommendation ITU-T L.72 (2008), *Databases for optical access network infrastructure*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 optical distribution frame [ITU-T L.50]

3.1.2 optical line termination [ITU-T G.983.1]

3.1.3 optical network unit [ITU-T G.987]

3.2 Terms defined in this Recommendation

This Recommendation does not define any terms.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CAPEX	Capital Expenditure
FTTH	Fibre to the Home
ODF	Optical Distribution Frame
OLT	Optical Line Termination
ONU	Optical Network Unit
OPEX	Operating Expenditure
PON	Passive Optical Network

5 Conventions

None.

6 Configuration of optical access network and installation site of fibre optic branching component for PON

An optical access network consists of four areas, as described in [ITU-T L.65] (Figure 1). The feeder area is from optical distribution frames (ODFs) in the central office area to a distribution point. The distribution area extends from the distribution point to the access point. In this area, a distribution cable is connected to a feeder and a drop cable at the distribution point and the access point, respectively. In the user area, the drop cable is connected to an optical network unit (ONU) on a subscriber's premises.

There are three main installation sites for the branching component, namely in a central office, an outside plant and on a subscriber's premises, as described in [ITU-T L.52]. In fact, the installation site in the outside plant is separated into two locations, namely a distribution point and an access point. Therefore, telecommunication companies should select one or more of the following four locations for the branching component, as shown in Figure 2.

1) central office;
2) distribution point (outside plant);
3) access point (outside plant);
4) final location on the subscriber side (e.g., subscriber's building, apartment or residential premises).

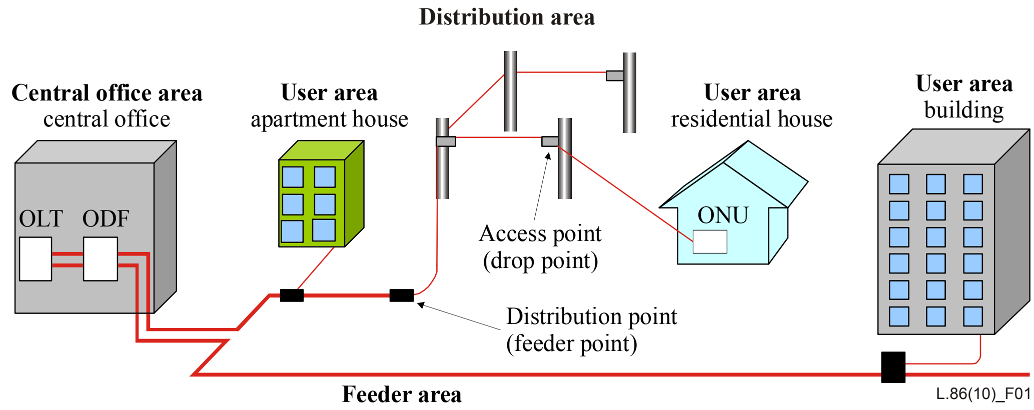


Figure 1 – Basic configuration of optical access network

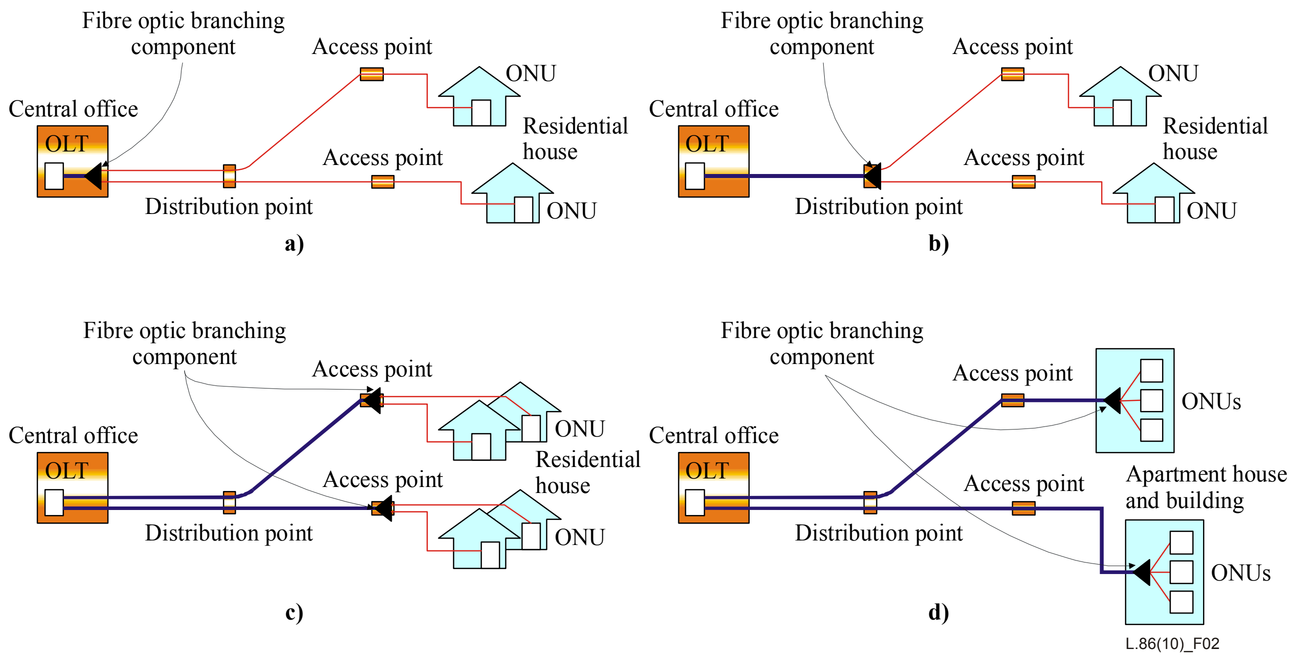


Figure 2 – Installation site of fibre optic branching component for PON:
a) in central office, b) at distribution point (in outside plant),
c) at access point (in outside plant) and d) in final location on subscriber's side

7 Considerations when determining installation site of branching component for PON

7.1 Minimization of CAPEX and OPEX

Telecommunication companies should determine the installation site for the branching component with a view to minimizing the total cost, which consists of the CAPEX and the OPEX, based on increases in demand. The location of one or more fibre branching components and each split ratio may also depend on the engineering plan and the mapping distribution of the premises.

Both the CAPEX and the OPEX are influenced by the installation site of the branching component, the demand and economies-of-scale. Progress with respect to demand, as shown in Figure 3 a), is divided into four stages, as described in [ITU-T L.65]. The ratios of the CAPEX and the OPEX to the total cost for each stage are shown in Figure 3 b). In the initial stage when the demand is small, a reduction in the CAPEX reduces the total cost, excluding any consideration of economy-of-scale. After the mature stage when demand is saturated, the total cost is reduced by reducing the OPEX, excluding any consideration for installation and short-term maintenance. As just described, the dominant factor (i.e., the CAPEX or the OPEX) of the total cost for each stage changes. This may make it difficult to maintain the minimization of the total cost solely by the individual installation site over all the stages. Therefore, it is also necessary to consider combining some installation sites in an access network to respond to the changes of the dominant factor and in demand.

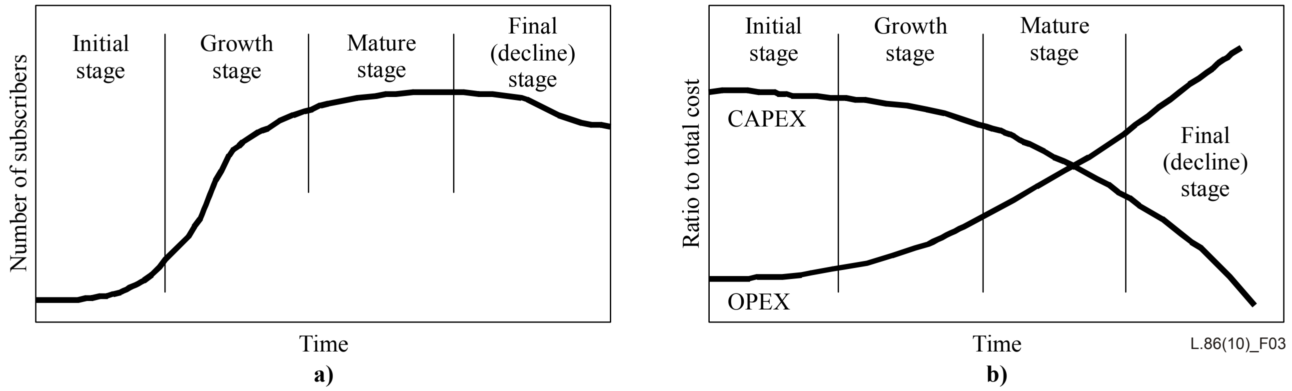


Figure 3 – a) Increase in number of FTTH subscribers and b) ratio of CAPEX and OPEX to total cost for each stage

7.2 Quick response to demand

The demand will increase rapidly and will occur over a wide area in the growth stage, as shown in Figure 3 a). Therefore, telecommunication companies should determine the installation sites for branching components taking the need for a quick response to demand into consideration. To achieve such a prompt response, ease of deployment over the last mile is important. The installation sites described in Figure 2 b), c) and d) may be effective as regards increasing ease of deployment of the last mile. However, in the initial stage where the demand is small and dispersed over a wide area, the location described in Figure 2 a) may be more effective in terms of the CAPEX than the other locations. Therefore, telecommunication companies should also consider combining some branching component installation sites, as shown in Figure 4.

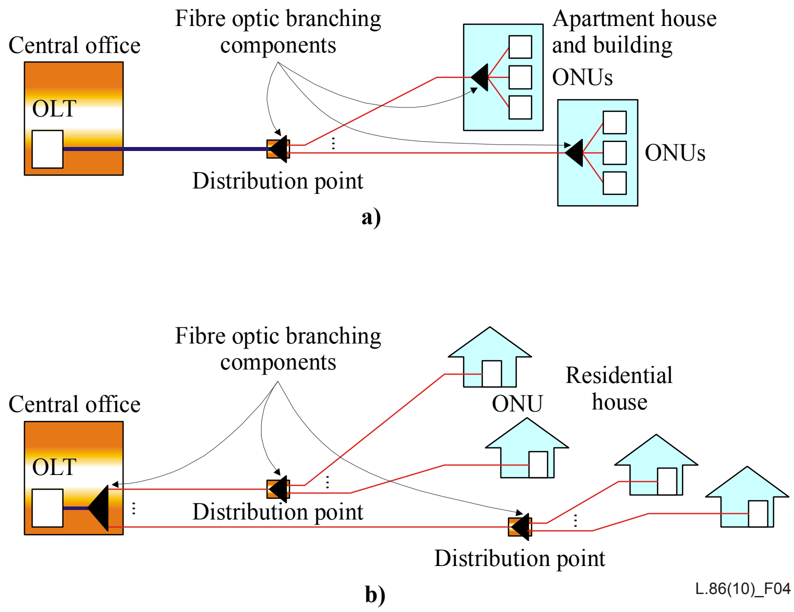


Figure 4 – Examples of PON configuration with combined branching component installation sites which are a) in distribution point and the final location on the subscriber side and b) in central office and distribution point

7.3 Maintenance

It is important to consider ease of maintenance if we are to reduce the OPEX. In particular, a reduction in the OPEX strongly affects the total cost because it is the dominant factor in the total cost after the mature stage when demand is saturated and there are a large number of facilities. The optical network maintenance support, monitoring and testing system described in [ITU-T L.40] and [ITU-T L.53] is useful for reducing the OPEX. However, when using a branching component in an outside plant or the final location on the subscriber side, functions in addition to those indicated in [ITU-T L.40] and [ITU-T L.53], are required when an individual optical fibre from a branching component to an ONU is monitored and tested. Moreover, the database for an optical access network infrastructure described in [ITU-T L.72] and fibre identification technology are also needed for the maintenance of a large number of facilities. Therefore, when telecommunication companies decide the installation site, they should give sufficient consideration to increases in the OPEX imposed by the additional functions.

7.4 Subscriber density

In order to providing effective PON configuration, it is important to consider subscriber density in order to maintain a higher branching component utilization ratio with low cable costs absorbed by a single subscriber for both an urban and a rural area. To meet the requirement, telecommunication companies should consider a distribution area scale covered by single branching component and its installation sites.

In general, subscriber density and distance from a central office to users' demands are different between an urban and a rural area.

In an urban area, the subscriber density is high and the distance to demands is short as shown in Figure 5 a). When adopting a large distribution area scale, a high component utilization ratio is maintained if there is sufficient subscriber density. On the other hand, in this case, a drop cable cost absorbed by a single subscriber is increased because long drop cables are required for subscribers located near the boundary of the area, namely far position from the branching component. When employing a small area scale to an urban area, of course, the high branching component utilization ratio can be maintained and the cost is decreased because of shorter drop cables.

A cable cost absorbed by a single subscriber is reduced by installing the branching component near subscribers because the cable (or fibre) shared by multiple subscribers becomes longer. However, when the installation site is too close to the subscriber, it is difficult to maintain the high branching component utilization ratio depending on subscriber density. Under such a low branching component utilization ratio, the branching component cost per single subscriber is increased. In this case, telecommunication companies can increase the branching component utilization ratio by expanding the area scale or moving the installation site of the branching component toward a central office. In the former case, they can reduce the branching component cost absorbed by single subscriber, but, as mentioned above, this expansion of the area scale causes the increase in the drop cable cost absorbed by a single subscriber. Also in the latter situation, they can reduce the branching component cost absorbed by a single subscriber because its utilization ratio is increased. However, the cable cost absorbed by a single subscriber is increased.

In a rural area, subscriber density is low and the distance to demands is long as shown in Figure 5 b). The large distribution area scale gives us higher branching component utilization ratio than that for the case of the small scale area. In the case of the large area scale, the branching component cost adopted by a single subscriber can be suppressed because of its high ratio although the drop cable cost is higher than that for the small area scale. If the branching component cost is more dominant than the drop cable cost, the large area scale may provide the suitable PON configuration in a rural area.

A cable cost absorbed by a single subscriber is reduced by installing the branching component near subscribers for not only the urban area but also the rural area. Note that when the installation site is too close to the subscriber, the branching component utilization ratio becomes enormously low because of the low subscriber density, even if the large area scale is adopted. Moreover, the influence of the branching component installation site on the cable cost per single subscriber is bigger than that for the case of the urban area because the distance from the central office to the subscriber is longer in the rural area.

As a result, in general, the cost trend corresponding to subscriber density and the distribution area size is as shown in Figure 6. Therefore, telecommunication companies should consider specific features of both the urban and the rural area. Based on those features, it is recommended to determine the distribution area scale and the installation site of the branching component with an appropriately balanced branching component utilization ratio and the cable cost.

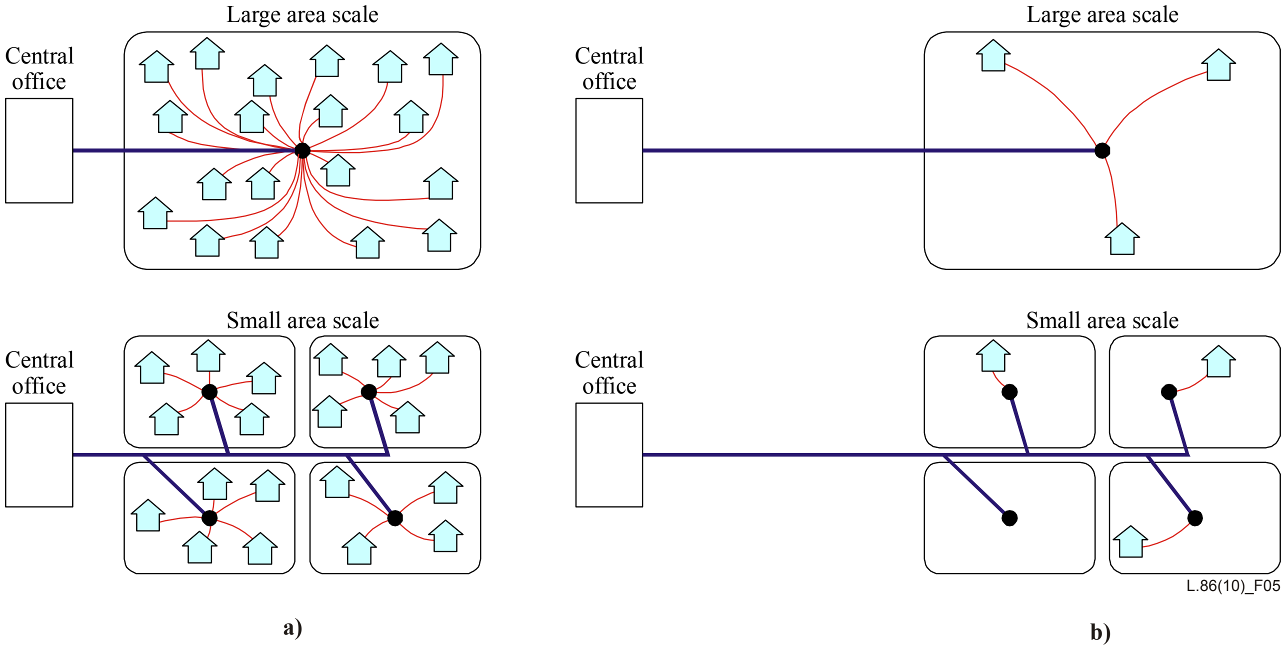


Figure 5 – Examples for facility architectures and area scales in a) urban and b) rural area

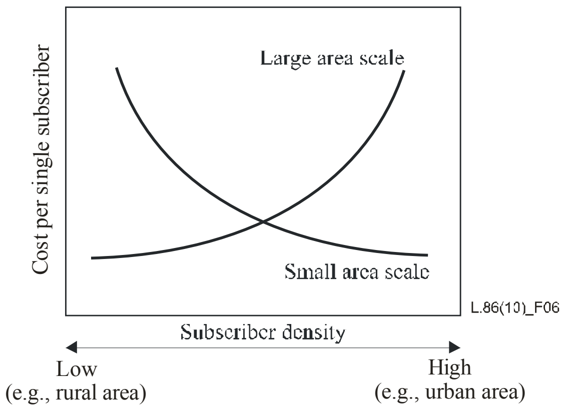


Figure 6 – Typical cost trend corresponding to subscriber density and distribution area size

Appendix I

OFS's experience – Examples of FTTx networks in United States

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

I.1 Introduction

Developing an evolution plan for a fibre optic network first requires determining expected usage over the expected lifetime of the network. OFS has put together the following chart which shows the expected bandwidth at an individual household in the United States over time. We realize that the actual data rate vs year may vary country to country but have seen that growth rates near 42% are universal. The key message that can be taken from this graph is that any network evolution path will lead, in the relative near term, to data rates exceeding 100 Mbit/s. Further, a fibre connection to each household is required to meet that need.

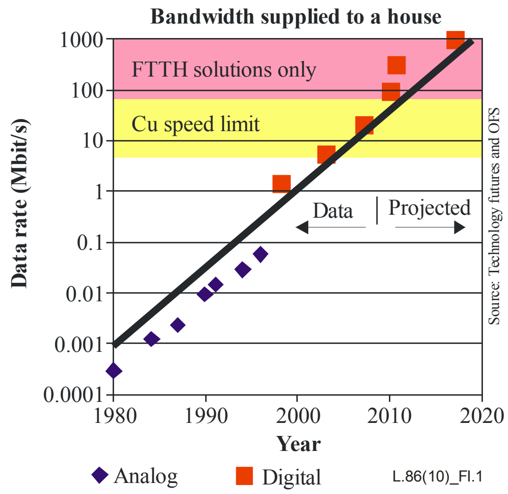


Figure I.1 – Bandwidth supplied to a house

I.2 Overall network configurations

There are a number of architectures that are currently being deployed to connect subscribers using optical fibre. They include:

– P2P (point-to-point) – Direct fibre from central office to each household.

– PON (passive optical network) using a distribution fibre with an optical splitter. Current split ratios are typically 1X32 and systems up to 1X128 have been considered.

– ESON (Ethernet switched optical network) – This deployment can be all fibre but has active electronics in the field to support the Ethernet switch.

– FTTN (fibre to the node) – Fibre is deployed to a switch, then twisted pair of Cu wire is used for the final ~1.5 km. Bandwidth is limited by the length of the twisted pair of wires.

– HFC (hybrid fibre coax) – It uses a combination of optical fibre and coaxial cable. This deployment is well suited for broadcast technology where the majority of the data is from the central office to individual subscribers. Reducing the number of subscribers increases the bandwidth per subscriber. Currently, RFoG (radio frequency over glass) is being used as an evolution path from HFC to an all fibre network.

Each of these networks can evolve to either a P2P or a PON architecture. Splits, when used in the passive plant, may be a single or distributed splitter through the network. The path forward depends on executing a plan that cost-effectively develops the network currently being used by the service provider to their desired final network configuration.

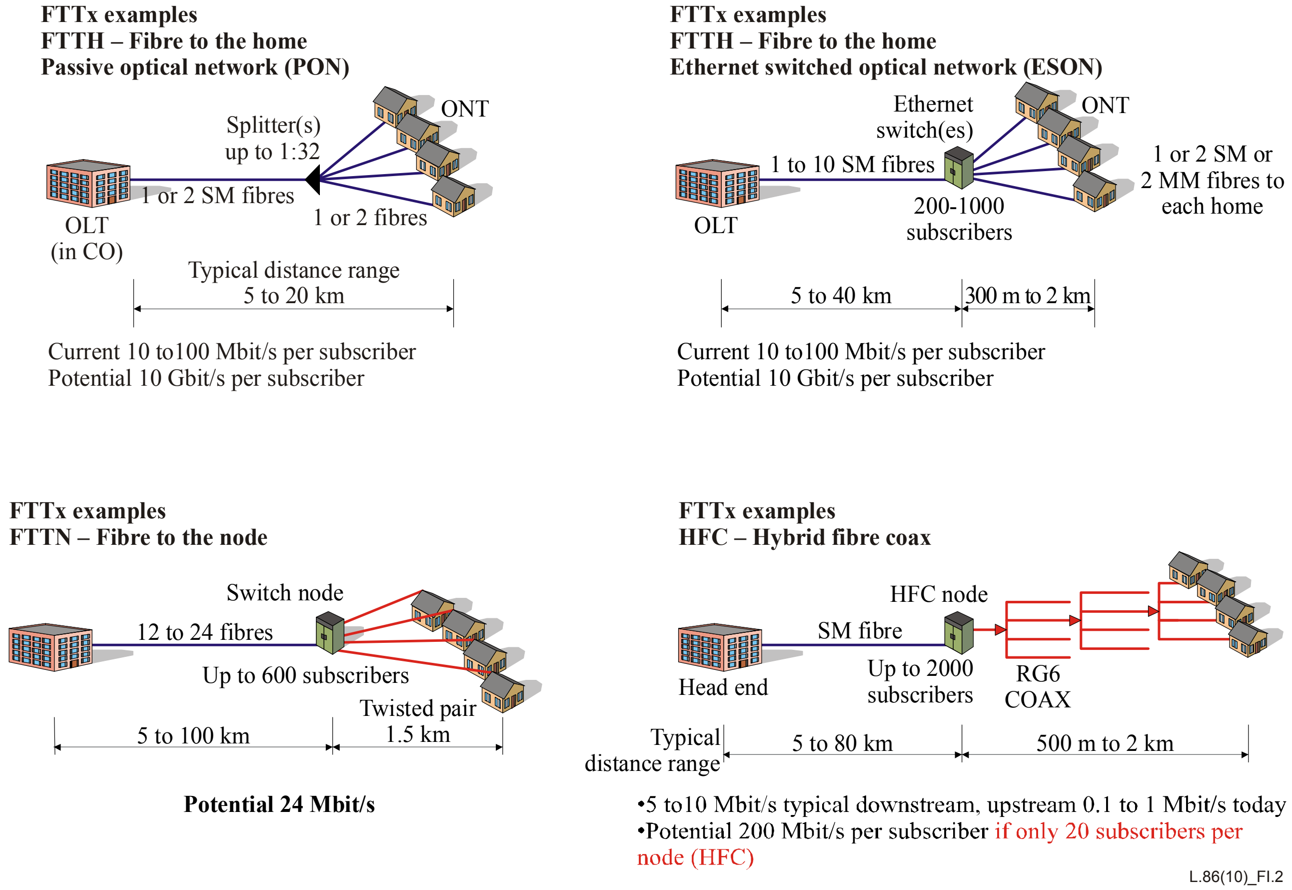


Figure I.2 – Examples of some architectures for FTTx

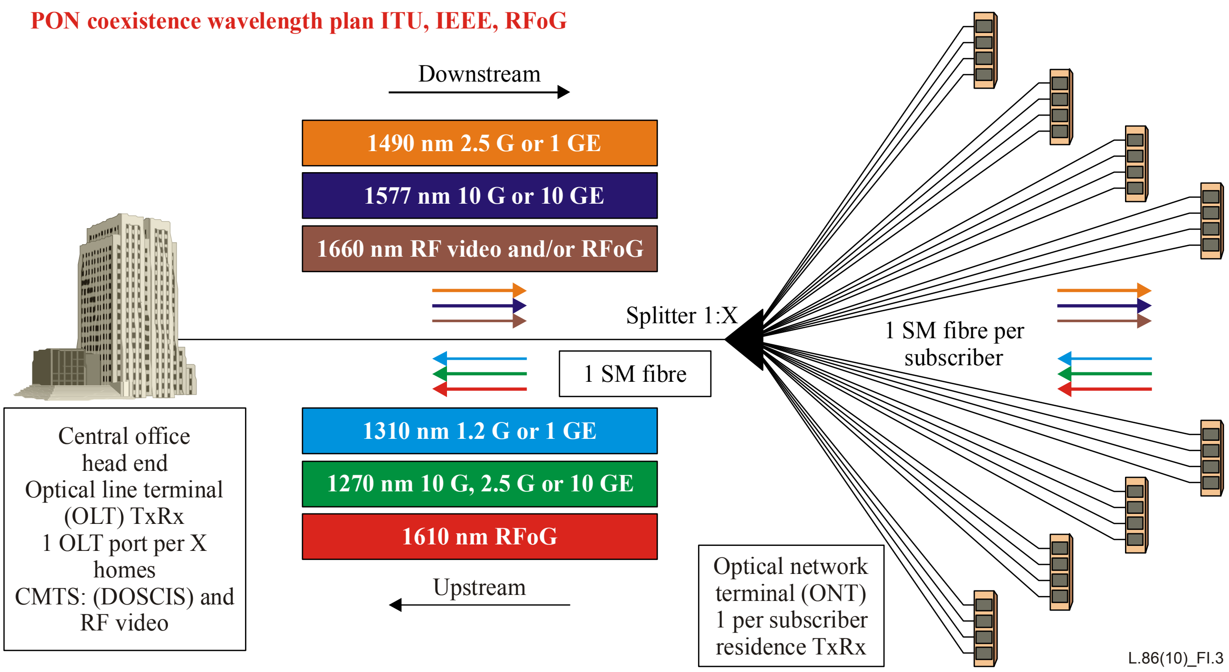


Figure I.3 – Coexistence wavelength plan for PON

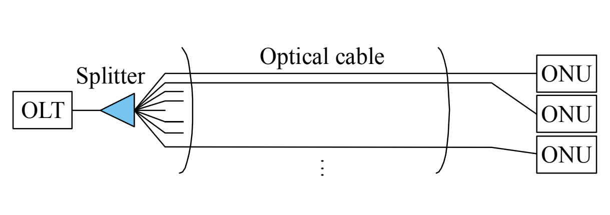
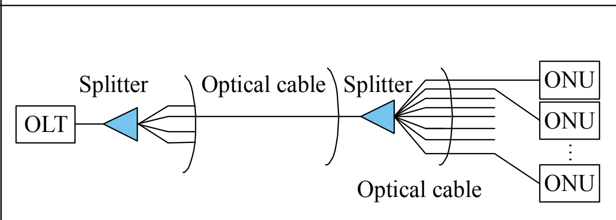
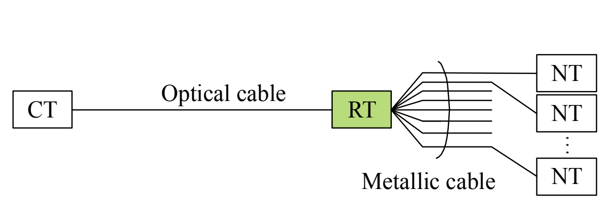
Appendix II

Japanese experience – Examples of PON architectures in Japan

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

II.1 Introduction

An optical access network can be implemented with various topologies as shown in Figure II.1. With the passive double star, optical splitters are used to connect multiple subscribers via a single optical fibre, and passive optical elements are used to configure the optical access network. Hence, it is also referred to as a passive optical network (PON). In Japan, the initial construction costs have been reduced by using a PON configuration with four-branch splitters in central offices and eight-branch splitters outside. To respond promptly to the growing demand for optical services, it is essential to establish optimum optical access network design technologies so that networks develop more efficiently based on economical planning.

Topology	Optical access networks			Characteristics		
	Central office	Access section	Customer premises	Initial construction cost	Multiple services	Testing
Single star[a]				Fair Optical fibre is needed for each subscriber.	Good Multiple services can be provided.	Good End-to-end testing is possible.
Passive double star[a]				Excellent More efficient access sections and equipment in central office.	Fair Splitter must be changed.	Fair Difficult management between splitter and customer's premises.
Active double star[a]				Good More efficient access sections.	Fair Can provide only low-speed services.	Fair Nodes (O/E conversion) require maintenance.

[a] These are also called centralized splitting, distributed splitting and switched Ethernet, respectively.

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CT Central terminal
MC Media converter
NT Network termination
O/E Optical-to-electrical
ONU Optical network unit
RT Remote terminal

Figure II.1 – Optical access network topologies

II.2 Passive optical network architectures in Japan

Here, architecture means the design technologies used to accommodate increasing demand efficiently and economically in central offices. When demand is low, it is cost-effective to establish individual connections between each customer and central office for cable installation. However, as demand increases, this could lead to the overcrowding of facilities, more difficult facility management and the need to perform the same engineering work for each customer. The efficient construction, operation and management of optical access network facilities are realized by establishing optimum management units as shown in Figure II.2.

II.2.1 Distribution area

The distribution area means the area covered by an 8-branch optical splitter outside a central office. When demand is low, larger distribution areas yield a higher splitter utilization rate. On the other hand, when demand is high, smaller distribution areas are more economical because they result in shorter lengths of drop cable between the optical splitter and the customers' premises.

II.2.2 Fibre structure

Aerial optical cables include single-fibre cables and four-fibre ribbon cables. When we use a four-fibre ribbon cable, we need to separate the ribbon's fibres at the point where a fibre is needed. The remaining fibres in the ribbon can be used only to serve homes in that immediate area. So when demand is low, it is inefficient to use four-fibre ribbon cables. However, four-fibre ribbon cables have the advantage of providing simpler multi-fibre connections. When demand is high, four-fibre ribbon cables are economical because they do not need as many connections as single-fibre cables. Therefore, single-fibre cables are more economical in low demand regions and four-fibre ribbon cables are more economical in high demand regions as shown in Figure II.3.

II.2.3 Distribution area configuration

Optical cables tend to cost less per fibre as the number of fibres in the cable increases. Accordingly, although it is more economical to distribute optical fibres individually from an optical splitter to each customer's premises when demand is low, it is more economical to distribute the optical fibres from the nearest telephone pole via cables when demand is high.

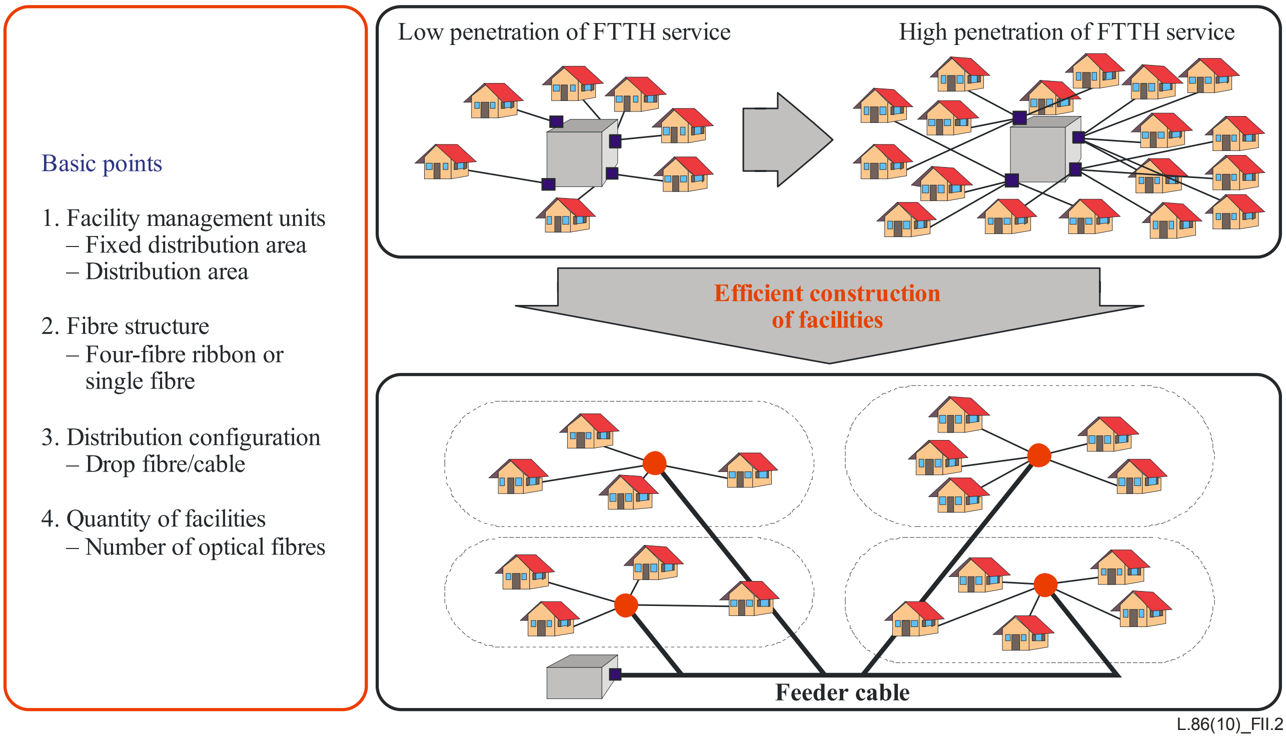

Figure II.2 – Basic concept based on distribution areas

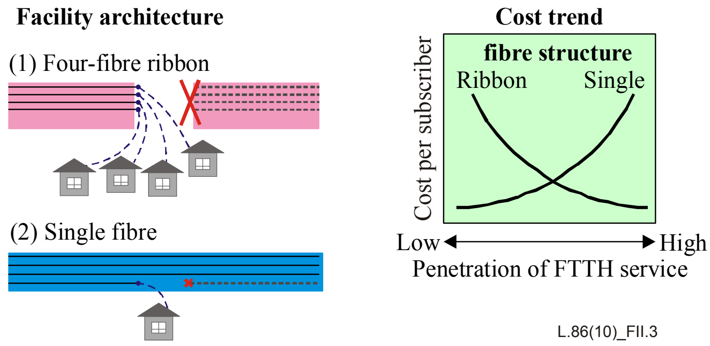

Figure II.3 – Fibre structures: comparison of four-fibre ribbon and single fibre

II.2.4 Number of fibres required in a fixed distribution area

The number of optical fibres that must be installed depends on the target penetration of fibre to the home (FTTH) and the complexity of the distribution network. As the distribution network becomes more complex, the required number of fibres becomes larger. When four-fibre ribbons are used, even more fibres are required; therefore, the utilization rate of four-fibre ribbon is inefficient when demand is low.

II.3 Consideration for more effective optical access network architectures

When the demand for FTTH reaches a substantial level, it is important that optical networks are constructed promptly to meet the growing demand. Figure II.4 shows a distribution that combines a distribution cable and a drop cable. Here, the distribution point, where the optical splitter is installed, is located between the feeder point and the dropping point. This configuration is based on the following two considerations:

– Optical splitter utilization rate

  When demand is low, the number of subscribers accommodated in an eight-branch optical splitter is also low, resulting in a low splitter utilization rate. In a PON configuration, the service's systems and optical splitters are closely related to each other, so new optical splitters have to be added separately when services are added or modified. Consequently, when new services are provided in a short period of time, the cost of the facilities becomes relatively high without any increase in the optical splitter utilization rate. An effective method of increasing the optical splitter utilization rate is to expand the area covered by the optical splitter, i.e., the scale of the distribution area. However, an increase in the scale of the distribution area results in a longer length of drop cable from the optical splitter to the customer's premises.

– Service demand work

  With the current distribution configuration, where direct drop cables are distributed to customers' premises from optical splitters, the drop cables must span several telephone poles, which means that service demand work will become a considerable burden as demand grows. This service demand work can be reduced if the drop cable length is reduced by using an architecture where cables are pre-routed from the optical splitters so that drop cables have to be installed only in the section between the telephone pole nearest to the customer and the customer's premises.

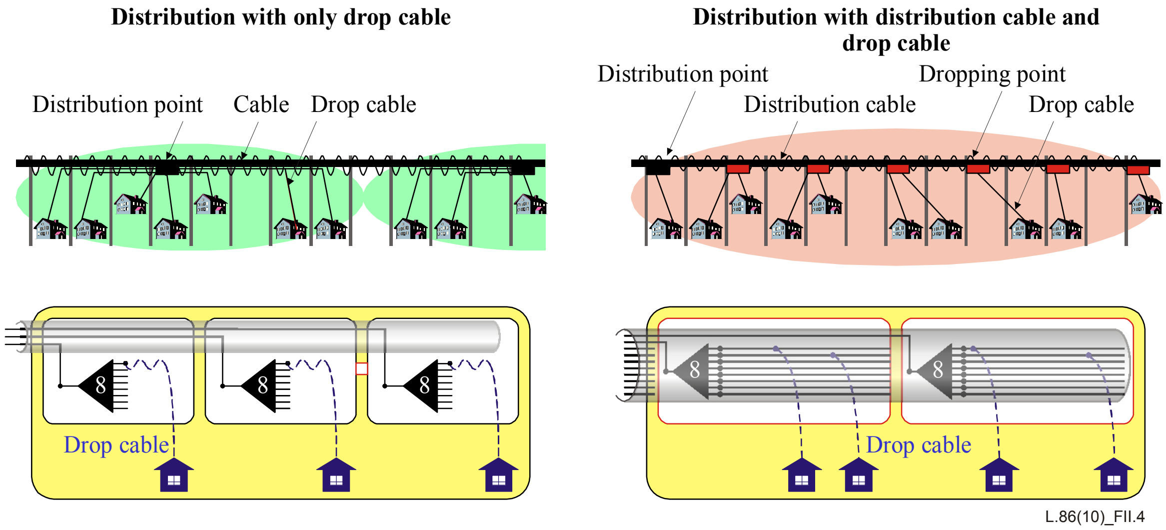

Figure II.4 – Distribution with distribution cables and drop cables

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