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Recommendation

ITU-T L.250 (01/2024)

SERIES L: Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant

Optical infrastructures – General aspects and network design

Topologies for optical access network

ITU-T L-SERIES RECOMMENDATIONS

Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant

OPTICAL FIBRE CABLES	L.100-L.199
OPTICAL INFRASTRUCTURES	L.200-L.299
Infrastructure including node elements (except cables)	L.200-L.249
General aspects and network design	**L.250-L.299**
MAINTENANCE AND OPERATION	L.300-L.399
PASSIVE OPTICAL DEVICES	L.400-L.429
MARINIZED TERRESTRIAL CABLES	L.430-L.449
E-WASTE AND CIRCULAR ECONOMY	L.1000-L.1199
POWER FEEDING AND ENERGY STORAGE	L.1200-L.1299
ENERGY EFFICIENCY, SMART ENERGY AND GREEN DATA CENTRES	L.1300-L.1399
ASSESSMENT METHODOLOGIES OF ICTS AND CO2 TRAJECTORIES	L.1400-L.1499
ADAPTATION TO CLIMATE CHANGE	L.1500-L.1599
CIRCULAR AND SUSTAINABLE CITIES AND COMMUNITIES	L.1600-L.1699
LOW COST SUSTAINABLE INFRASTRUCTURE	L.1700-L.1799

For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T L.250

Topologies for optical access network

Summary

Recommendation ITU-T L.250 describes the optical access network to be used in the design and construction of fibre to the x (FTTx), centralized – radio access networks (C-RAN) for mobile communications, and other network services. It deals mainly with access network architectures and the upgrading or new deployment of optical fibre to optical access networks.

History *

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Table of Contents

		Page
1	Scope	1
2	References	1
3	Definitions	4
3.1	Terms defined elsewhere	4
3.2	Terms defined in this Recommendation	4
4	Abbreviations and acronyms	5
5	Conventions	6
6	Concept of layers within a network architecture	6
6.1	Optical fibre	6
6.2	Cables, passive components and passive nodes	7
6.3	Structural facility	7
7	Access network architectures	8
7.1	General	8
7.2	Optical fibre level architecture	8
7.3	Cable level architecture	11
7.4	Convergence architecture	13
8	Cabling characteristics	14
9	Deployment method for high reliability	15
10	Upgrading the optical network	16
11	Optical transmission performance for optical access networks	17
12	Optical safety	17
13	Installation of optical access network	17
13.1	Initial stage	18
13.2	Growth stage	18
13.3	Mature stage	18
13.4	Final stage	19
Appendix I – Installation and maintenance issues		20
I.1	Optical network maintenance support, monitoring and testing system	20
I.2	Digitized management of physical infrastructures in optical access network	20
I.3	Electrical power supply	20
I.4	Electrical safety	20
Bibliography		21

Introduction

Progress in telecommunications 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 optical access networks be developed economically to provide services directly to subscribers, connected things and mobile communication devices. To provide these services in a timely manner, it is necessary to construct optical access networks quickly, efficiently and cost-effectively.

In the past decade, progress in the application of optical fibre technology in local access networks for fibre to the home (FTTH) has provided substantial technical and economic benefits in several countries. The development of "smart city", "Internet of things" (IoT) and "industrial Internet" has broadened the scope of areas by which the optical network can access the services. 5G mobile communication network construction is in progress in many countries and centralized – radio access networks (C-RAN) could save costs on base station sites, equipment, room rent and energy compared with traditional distributed – radio access network (D-RAN).

Here, an optical access network contains a network of optical fibre cables that extend from a carrier's central office to cabinets, buildings, individual homes, apartment blocks, business offices, workshops, smart city equipment boxes, smart poles or mobile telecommunication base stations.

Recommendation ITU-T L.250

Topologies for optical access network

1 Scope

This Recommendation defines optical single-mode fibre access network architectures and provides information on planning new deployments and upgrading existing networks. Moreover, this Recommendation considers optical transmission performance and optical safety which depends on the architecture design of an optical access network.

This Recommendation covers:

– definitions and general features of fibre level and cable level architectures that have been used to meet different system objectives;

– convergence architectures for upgrading the performance of the optical access network;

– physical components within the network architectures;

– optical safety requirements;

– installation issues.

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.

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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] to [ITU-T G.984.7], [ITU-T G.987], [ITU-T L.105], [ITU-T L.200] and [ITU-T L.201] 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 remountable connection.

3.2.3 cable level architecture: Describes the access network topology from cable level, indicating the relation of fibre and cable distribution by illustrating how fibres are distributed across one or multiple cable connection points.

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

3.2.5 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 optical network terminal (ONT) and CPE may be integrated.

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

3.2.7 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 (CO).

3.2.8 feeder area: The area between the optical distribution frame (ODF) and the distribution point.

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

3.2.10 optical fibre level architecture: Architectures indicate the fibre distribution topology from the central office (CO) to every end user or far-end equipment.

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

3.2.12 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 optical network termination (ONT)/ customer premises equipment (CPE).

3.2.13 user area: The area between the access point and optical network unit (ONU)/ optical network termination (ONT) in subscriber premises.

3.2.14 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:

BEP	Building Entry Point
CO	Central Office
CPE	Customer Premises Equipment
C-RAN	Centralized Radio Access Network
CWDM	Coarse Wavelength Division Multiplexing
DWDM	Dense Wavelength Division Multiplexing
FD	Floor Distributor
FDB	Fibre Distribution Box
FTTH	Fibre To The Home
FTTR	Fibre To The Room
FTTx	Fibre To The x, where 'x' stands for the final location on the end-user side
HSP	Higher Speed Passive Optical Networks

IoT	Internet of Things
ISP	Internet Service Provider
LCP	Local Convergence Point
NAP	Network Access Point
NG-PON2	Next Generation Passive Optical Network 2
NID	Network Interface Device
ODF	Optical Distribution Frame
OLT	Optical Line Terminal
ONT	Optical Network Terminal
ONU	Optical Network Unit
OSP	Outside Plant
OSS	Operations Support System
OTO	Optical Telecommunication Outlet
OXC	Optical Cross Connect
PON	Passive Optical Network
TDM	Time Division Multiplexing
WDM	Wavelength Division Multiplexing

5 Conventions

None.

6 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).

6.1 Optical fibre

A suitable choice of optical fibre and splice loss criteria should be made. Single-mode fibre compliant with [ITU-T G.652] is the most appropriate choice for a wide range of telecommunication services in the feeder and local distribution network since this fibre benefits from economy of scale and has long-term potential for future services. [ITU-T G.657] category A fibre is compatible with [ITU-T G.652] fibre and has better macro-bending performance to support small bending radii installation conditions in the drop and home / building network. [ITU-T G.657] category B fibre, with smaller bending radii than category A fibre, is mainly utilized at the end of the access networks particularly inside or near buildings, or in fibre management systems. The user should note that uncertainty regarding the splice values and compatibility issues may be increased when using [ITU-T G.657] category B fibres together with [ITU-T G.652] fibres or [ITU-T G.657] category A fibres.

With current usage of single-mode fibres, it is recommended to utilize fusion splice technology to make splices, and the typical allowed splice loss is less than 0.2 dB (see [ITU-T L.400] for further information).

6.2 Cables, passive components and passive nodes

Cable design should be determined to suit the network architecture adopted. Cables as described in [ITU-T L.100] to [ITU-T L.102] and [ITU-T L.107] to [ITU-T L.111] could be used for outside plant (OSP) cabling in the feeder and distribution network; cables as described in [ITU-T L.105] could be used for drop network; cable as described in [ITU-T L.111] could be used for home/building network; cables as described in [ITU-T L.103] and [ITU-T L.104] could be used as jumpers for short distance connection between passive components.

Optical fibre connectors as described in [ITU-T L.402] and [ITU-T L.404] could be used for termination of user cables in fibre to the x (FTTx) and similar applications. Passive node hardware and housings, with fibre organizers / fibre management systems, are used to protect and manage fibre joints/connections and passive components. Sealed closures for outdoor environments should comply with [ITU-T L.201]; optical distribution frames for CO environments should comply with [ITU-T L.202]; outdoor optical cross-connect cabinets should comply with [ITU-T L.206]; fibre distribution boxes should comply with [ITU-T L.208]; housing to keep both active and passive elements in a single box should comply with [ITU-T L.209]; optical wall outlets and extender boxes used in the users' premise should comply with [ITU-T L.210]. Other passive optical plant hardware and housings should have specific environmental constraints, see [ITU-T L.200]. A line diagram of the optical fibres, cables and passive components along with their relevant ITU-T Recommendations is shown in Figure 1.

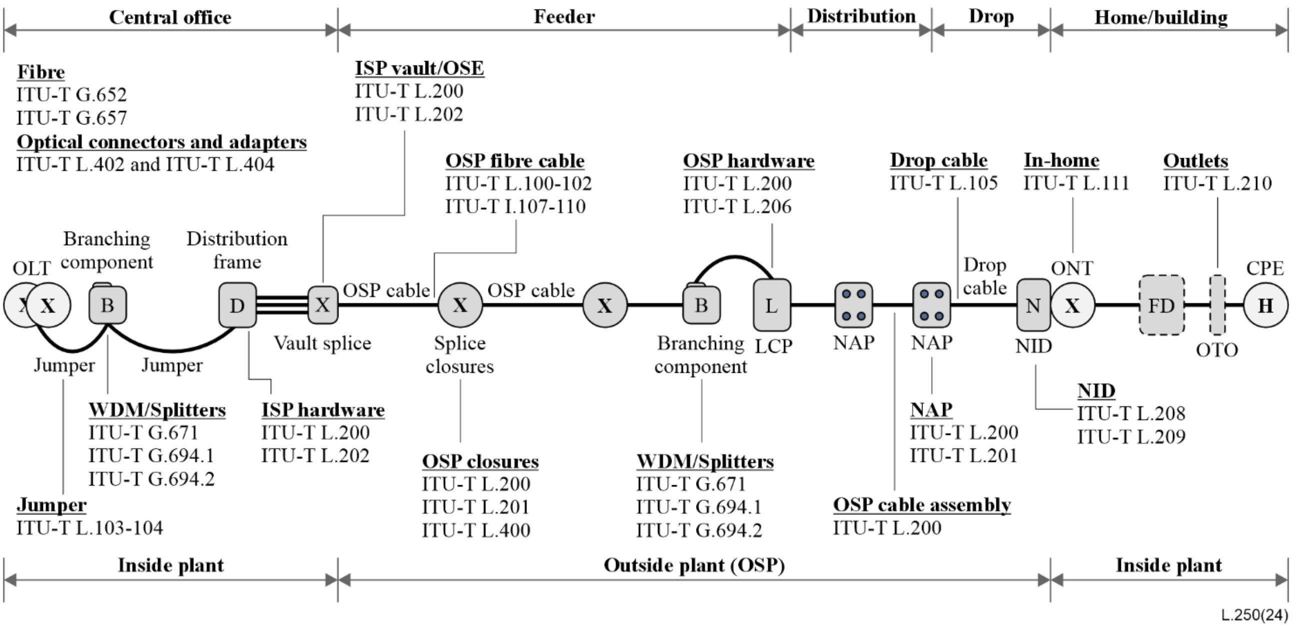


Figure 1 – Optical fibres, cables and passive components and ITU-T Recommendations

Pre-terminated cable assemblies and plug-and-play passive nodes could be used for quick and efficient installation of the network, by reduction or avoiding of the difficulties posed by field fibre splicing.

6.3 Structural facility

The optical access network architecture originally evolved from copper networks has the form of a star topology radiating from the CO. Optical fibre plant architectures have led to the development of new designs and plant layouts that are far more advanced than those of legacy copper networks. The optical cable plant uses a mixture of aerial, underground, duct and microduct technologies for deployment. For legacy networks, newer microduct applications could be used in the trench, existing ducts, aerial applications and for access to buildings for installation of cables with air-assisted techniques.

7 Access network architectures

7.1 General

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

1) scalability (cable fibre count, spare fibre, split ratio, etc.);
2) survivability (physical redundancy, security, supervisory system, etc.);
3) functionality (bit rate, transmission distance, etc.);
4) cost (construction and maintenance costs);
5) upgrade (increase transmission capacity, increase transmission length, increase number of customers, connected things, etc.).

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. These include:

– Optical fibre level architecture
  • Optical fibre point-to-point
  • Optical fibre point-to-multipoint
  • Ring
– Cable level architecture

7.2 Optical fibre level architecture

7.2.1 Optical fibre point-to-point architecture

The basic configuration for an optical fibre point-to-point architecture is shown in Figure 2. This architecture distributes one or more dedicated fibres from the CO to every potential user or far-end equipment, for example, an optical line terminal (OLT) connects to a subscriber optical network unit (ONU)/optical network terminal (ONT), and forms a dedicated point-to-point channel (1:1). Therefore, many fibres are required because every potential end user/equipment location needs a dedicated fibre back to the signal source. Splitters may be deployed in CO, offering high flexibility and port efficiencies and optical cross-connect cabinets can be used in the outside plant if dedicated pad or pole space accommodations are provided.

This configuration has low optical loss and provides the maximum distance between COs and customers and other end equipment. The insertion loss of the optical line is a sum of fibre, splice and connector losses. This architecture has a high bandwidth capability and provides an easy upgrade path.

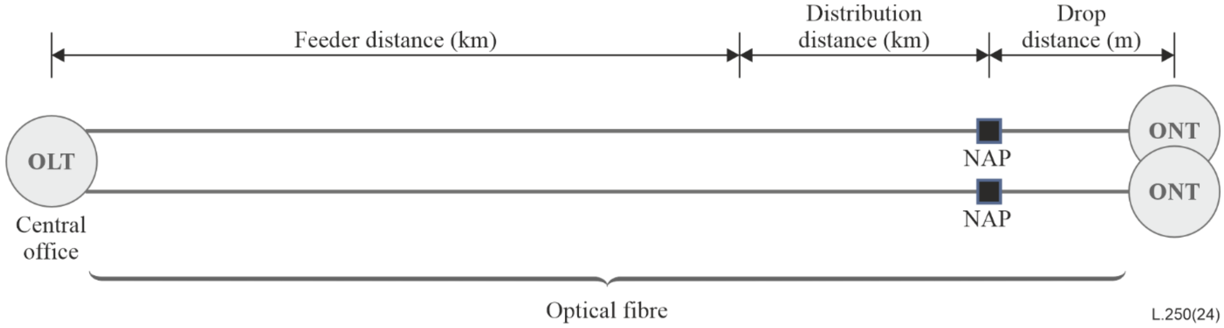


Figure 2 – Optical fibre point-to-point architecture

7.2.2 Optical fibre point-to-multipoint architecture

The basic configuration of an optical fibre point-to-multipoint network is shown in Figures 3, 4 and 5. The feature of the optical fibre point-to-multipoint network is that branching unit(s) are placed in the channel between an OLT and several ONUs/ONTs.

The location of a branching unit is the most important item in terms of network design and construction. Two types of branching units can be used in the network. In one type, the wavelength selective device, has a wavelength multiplexer and de-multiplexer; in the other type is a non-wavelength selective device or splitter. A non-wavelength selective branching unit (splitter) increases the insertion loss and reduces the transmission distance as the number of branches is increased. In contrast, a wavelength selective branching unit is mainly used in wavelength division multiplexing (WDM) systems. The insertion loss does not increase greatly but it can be difficult to control and manage the wavelengths used when the number of branches is increased. The channel between ONU and ONU/ONT is a point-to-multipoint channel with non-wavelength selective branching unit(s), and can use a point-to-point channel with only wavelength selective branching unit(s). Non-wavelength selective and wavelength selective branching unit(s) can also be used in one network.

When a branching unit is installed in a CO, at least one fibre is connected between the CO and an ONU/ONT. Therefore, many fibres are installed and distributed from the CO. Moreover, the environmental conditions for the (fibre optic) branching component have wider tolerance specifications due to the device being installed inside a CO.

A branching unit can be installed in a housing in the outside plant or inside a customer building. The number of fibres between an OLT and a fibre optic branching unit are reduced. However, the environmental conditions for the branching unit may require tighter tolerance specifications because it may be located in the outside plant, on the outside walls of a building, or inside a basement room.

The basic configuration for an optical fibre point-to-multipoint architecture network with 1-level branching is shown in Figure 3. In this architecture a dedicated fibre connects each end user/equipment to a local convergence cabinet which contains a branching component (example splitter or WDM). This architecture is commonly deployed where a large central office serves concentrated pockets of end user / equipment locations. This configuration deploys feeder cables that run from the CO to an OSP cabinet with a branching unit, then distribution cables serve downstream network access points (NAPs) which then connect to end users/equipment on a (1:1) ratio. The insertion loss of the optical line is the sum of fibre, splice, branching unit and connector losses. This architecture can easily change split ratios or WDM channels and transport technologies, and the centralized branching location optimizes optical line terminal efficiencies.

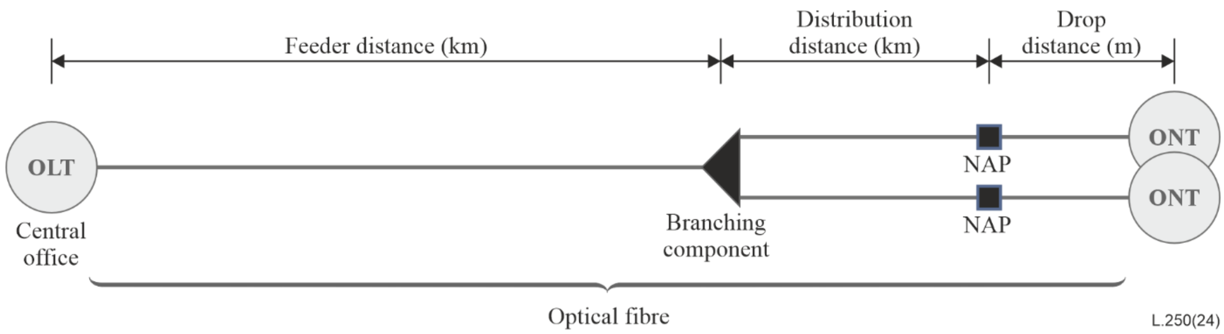


Figure 3 – Optical fibre point-to-multipoint network (in the case of 1-level branching)

The basic configuration for an optical fibre point-to-multipoint architecture (with 2-level branching) is shown in Figure 4. In this architecture a dedicated fibre drop cable connects each end user/equipment to the closest downstream terminal access point. This configuration deploys a relatively lean fibre architecture with fewer fibre-count feeder and distribution cables. The lower fibre-count distribution cables serve downstream end users/equipment on a (1:1) ratio. The insertion loss of the optical line is the sum of fibre, splice, branching unit and connector losses. This architecture has flexible split ratio combinations of 1×2, 1×4, and 1×8 splitters and can reduce splitter access point size due to the distributed split locations.

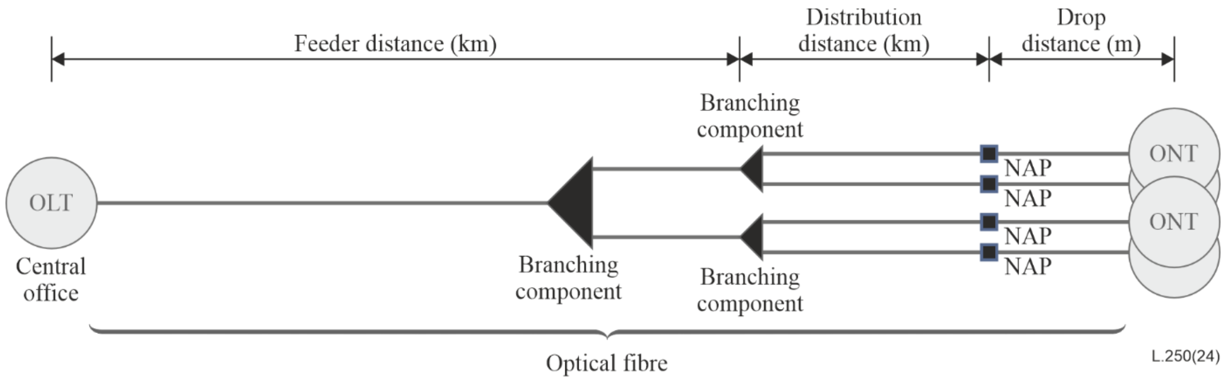


Figure 4 – Optical fibre point-to-multipoint network (in the case of 2-level branching)

By deploying branching units with asymmetrical branching ratios (non-wavelength selective or wavelength selective), the branches would have a main branch carrying a large part of the optical power or wavelengths and several branches that share the rest; the optical fibre point-to-multipoint network could be a distributed tap architecture. The basic configuration for a distributed tap architecture is shown in Figure 5. This architecture is suitable for sparsely populated areas or fringe/land locked areas where future growth is unlikely. This architecture deploys dedicated fibre connecting each subscriber to the splitter terminal. Asymmetric tap branching terminals are concatenated in series leveraging a single OLT for signal. This configuration deploys extremely low-fibre-count cables as distribution cables. The lower fibre-count distribution cables serve downstream end user/equipment on a (1:1) ratio. The insertion loss of the optical line is the sum of fibre, splice, branching unit and connector losses. This architecture has flexible split ratio combinations of 1×2, 1×4, and 1×8 splitters and can reduce splitter access point size due to the distributed split locations.

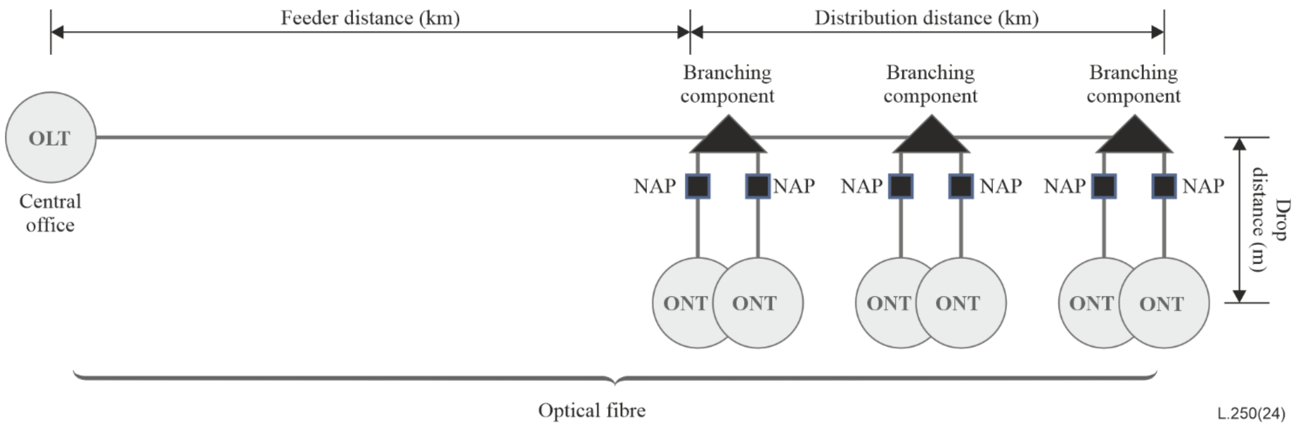


Figure 5 –Optical fibre point-to-multipoint network (in the case of 3-level distributed tap architecture)

7.2.3 Optical fibre ring architecture

The basic configuration of an optical fibre ring network is shown in Figures 6a and 6b. This starts and ends at the same OLT in a CO and uses two or more fibres to connect to ONUs/ONTs. For optical fibre point-to-point ring networks as shown in Figure 6a, a very large number of fibres are installed and distributed from CO to customers, connected things or mobile communication base stations. By contrast, the multiple-type ring networks as shown in Figure 6b, can reduce the number of distributed fibres compared to point-to-point ring networks. The advantages of ring networks are high reliability with redundancy and ease of maintenance for alternative routing.

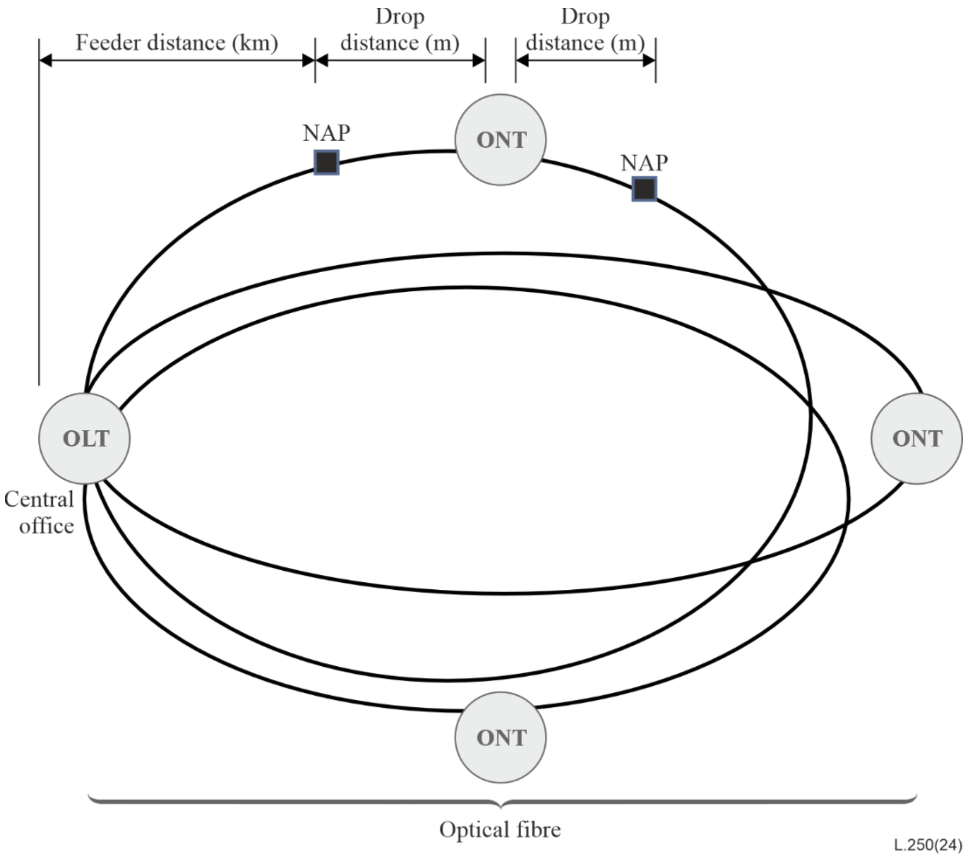


Figure 6a – Ring network (Optical fibre point-to-point type)

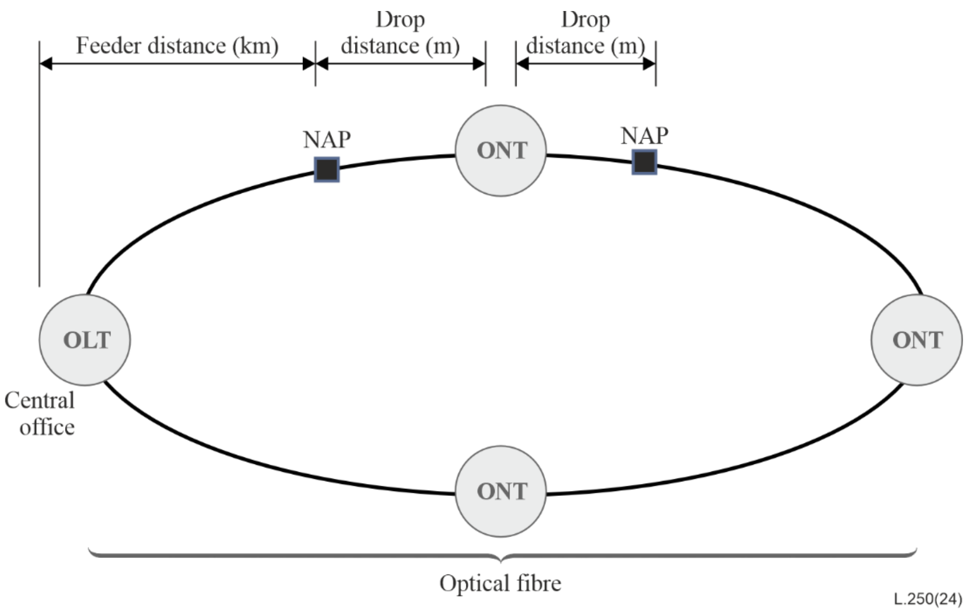


Figure 6b – Ring network (Multiple type)

7.3 Cable level architecture

Cable level architecture is one of the key considerations in access network design because it is strongly related to construction cost and the performance of the access network. The cable level architecture is the physical cabling of a logical topology across all the cable connection points in an area, and the cable topology at each point forms the basic unit of the cable network. Generally, a cable level architecture is realized by combing multi types of the basic topology units, and the whole access network is realized by combing multi types of cable level architectures.

The basic topology units fall into four types: direct-connection unit, mid-span unit, branching unit, and ring unit. For direct-connection unit, the fibres are connected directly at cable joint by splices or jumpers on a (1:1) ratio to extend the length of cable line or allocate the fibres to demand locations without introducing too much insertion loss. For mid-span units, the optical fibres are accessed from the mid-span of the cable at demand location. This unit is suitable for areas where the demand is unexpected or the demand scale is small. For branching units, a branching component (e.g. 1×2, 1×4, 1×8) is utilized to distribute the fibres from one cable to multi-cables, increasing the number of fibres and expanding the capacity of the network. For ring units, the fibres are accessed from the mid-span of the cable or from the splice/ jumper enclosure and form a closed loop line. These units are generally used to form a cable ring architecture to attain high reliability. General schematics of the basic topology units are summarized in Figure 7.

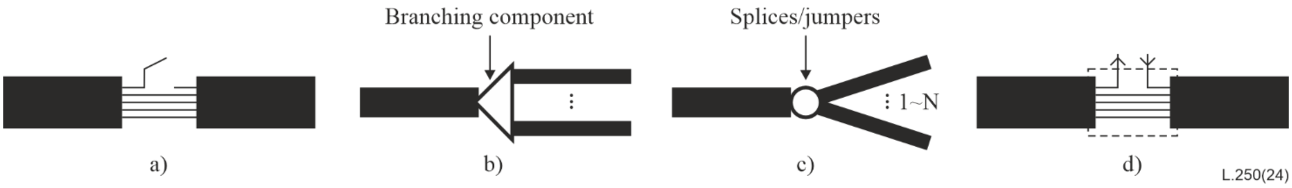
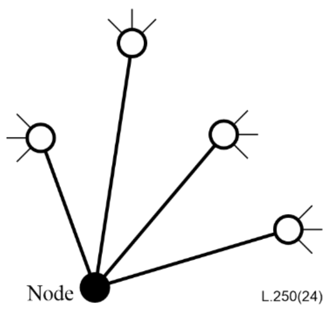
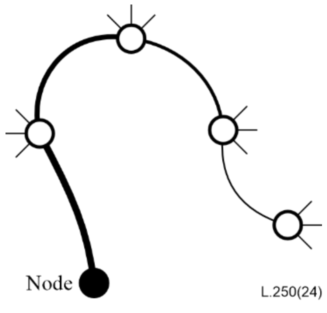
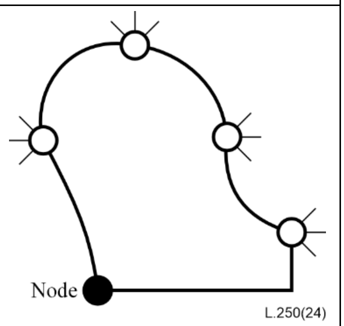
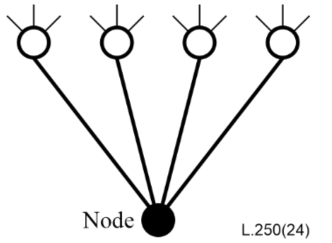
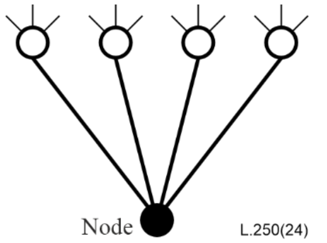
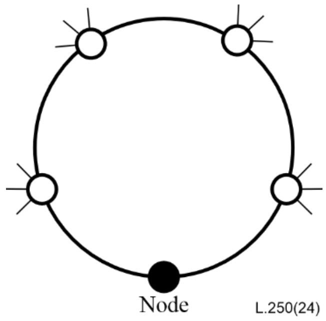


Figure 7 – Schematics of basic cable topology units: a) Mid-span unit; b) Branching unit; c) Direct-connection unit; d) Ring unit.

The cable level architectures fall into two types: star and ring topologies. A logical star topology can be deployed as a point-to-point cabling or as a gradual decrease cabling physical architecture. Both of these architectures have trade-offs with regard to construction cost, flexibility and reliability. When high reliability in the network is required, the ring architecture is used for its ease of establishing redundant cable routes between distribution areas. The ring topology increases the reliability of the access network and the architecture can be adopted as a topology that accommodates various services with different reliability requirements.

General features of cable level architectures and the basic topology units each architecture may include are summarized in Table 1.

Table 1 – General features of cable level architectures

	Star	Star (gradual decrease)	Ring
Physical cabling			
Logical (Data flow)			
Basic topology units may include	Direct-connection unit, Mid-span unit, Branching unit	Direct-connection unit, Mid-span unit, Branching unit	Direct-connection unit, Mid-span unit, Branching unit, Ring unit
Initial construction cost	Moderate	Low	High
Repetitive construction cost	Moderate	High	Low
Reliability	Moderate	Low	High

7.4 Convergence architecture

The previous optical fibre level and cable level architectures in clauses 7.1, 7.2 and 7.3 can be converged in order to meet the various requirements of accommodating broadband services. The convergence architecture is an extended network architecture using active/passive node (w/ or w/o splitters) and another or the same architecture. Examples of converged architecture based on point-to-point ring architecture and ring architecture are illustrated in Figures 8a and 8b, respectively. Figure 8a is an example of an upgrade network combining ring and point-to-multipoint architectures to efficiently accommodate increased demand in a service area. The 1st level of branching component is connected with a ring network from CO and it can be connected to either the 2nd level of the branching component or directly to ONUs/ONTs. 1st and 2nd level branching components have flexible split ratio combinations typically 2×N and 1×N (where N = 2, 4, 8, 16). Figure 8b shows concatenated ring architecture which can provide a highly reliable redundant fibre on a different route anywhere in the service area. It is recommended to not have many converged levels in the architecture since this can raise channel loss and network complexity.

In some applications, the ONTs can also be an active device that could also work as the OLT of a local area optical access sub-network. For example, fibre to the room (FTTR) in living units or offices, and optical local networks in factories or industrial premises. In these cases, the access network is extended by the sub-networks. The sub-networks could have their own topologies, making the overall network a multi-level convergence architecture.

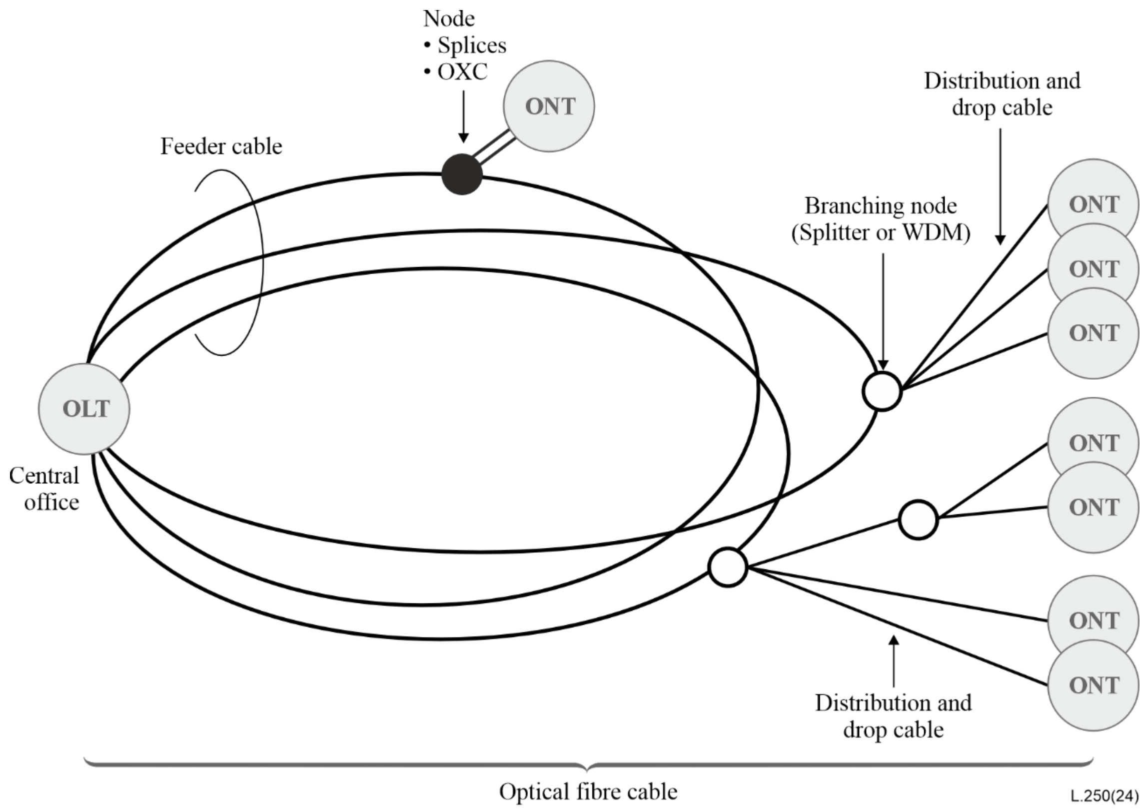


Figure 8a – Converged network (Point-to-multipoint)

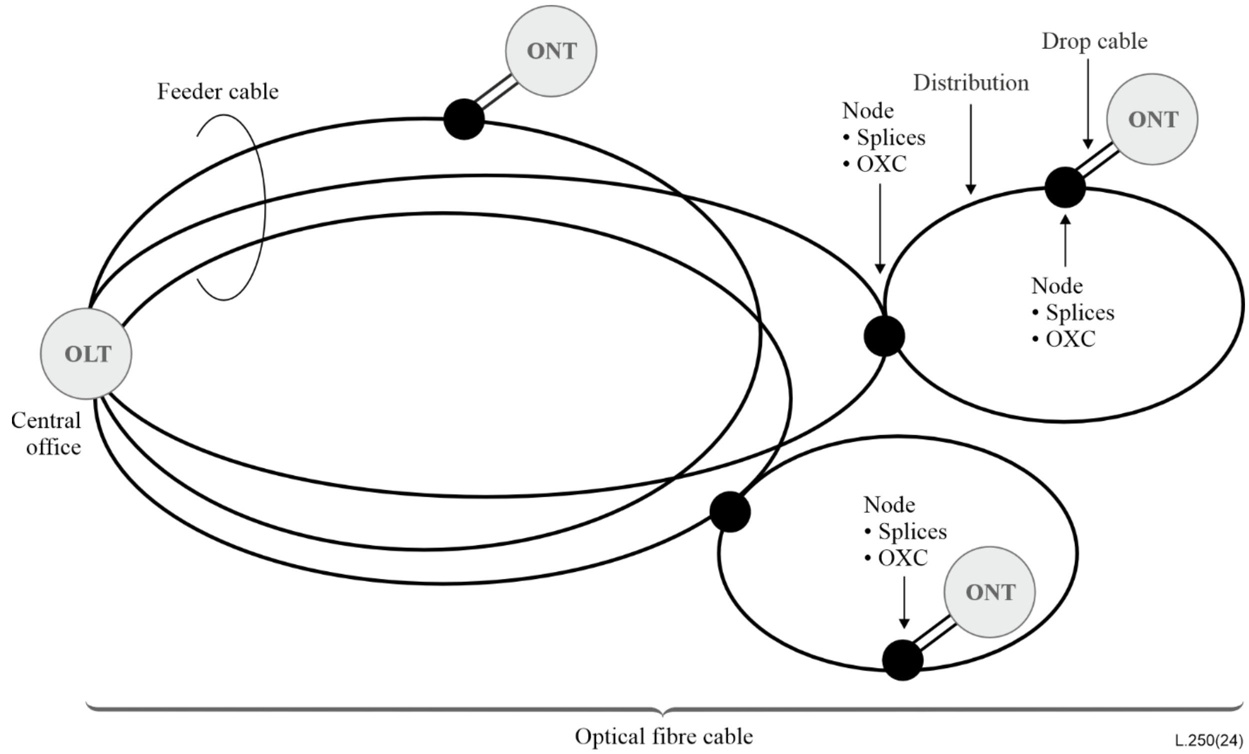


Figure 8b – Converged network (Concatenated ring)

8 Cabling characteristics

The cabling characteristics for an overall end-to-end network from the CO to user's home could be defined in the following main parts:

– Optical distribution frame (ODF) in CO;

– Feeder cabling between the ODF and the local convergence point (LCP, or service area interface, SAI);
– LCP (e.g., a cabinet);
– Distribution cabling between the LCP and a drop point (DP) or a network interface device (NID) at building entrance point (BEP);
– DP (e.g., a fibre distribution box (FDB)) or NID (e.g., an ODF at building telecommunication room);
– Drop cabling from a DP to an optical telecommunication outlet (OTO), possibly including floor distributor (FD);
– OTO;
– Equipment cord between an OTO and ONT / ONU. Specific in-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 NID to the OTO. Typically, one to four fibres are either collected in one indoor cable or they can also be taken from multiple fibre cables.

A more detailed reference model for cabling of this network is shown in Figure 9:

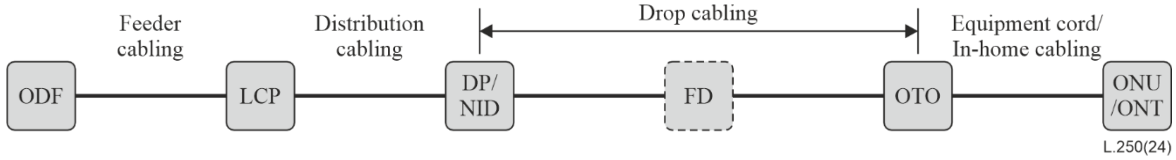


Figure 9 – Detailed reference end-to-end network from the central office to user's home

In other applications, OLTs/ONUs replace certain points of LCP, DP/NID, FD or OTO shown in Figure 8 and terminate the optical access networks. They may be located in equipment boxes, on poles, on towers or in telecommunication rooms of buildings. The networks accordingly consist of part of the cabling system in Figure 9.

9 Deployment method for high reliability

Access networks that can accommodate business communication service and/or C-RAN for mobile communication should offer high reliability specified in a service level agreement. A highly reliable access network can be realized by the use of redundant fibre deployment. The reliability of the cable network is determined by what kind of accidental risk event is possible and then mitigation is to be assured by the deployment of a redundant fibre/cable architecture. Five recommendations are possible as redundant fibre/cable deployment methods:

1) fibres in one cable element (fibre bundle, fibre ribbon, buffer tube, etc.);
2) different cable elements of one cable;
3) different cables on the same route;
4) different cables on the different routes from one CO;
5) different cables on the different routes from different COs.

The reliability of each redundant recommendation is summarized in Table 2. It is recommended to select a redundancy policy based on the risk.

Table 2 – Redundant recommendation versus service interruption

Accidental risk event	1)	2)	3)	4)	5)
OLT or ONT / ONU failure	o	o	o	o	o
Obstacle relocation work	x	o	o	o	o
Accidental harm	x	x	o	o	o
Route breakage by natural disaster	x	x	x	o	o
Power outage at CO	x	x	x	x	o
NOTE – o and x mean supported and not supported, respectively.					

When an unexpected event happens, possible protection / restoration methods include:

1) Optical connectors allow craft to cross-connect around failures (obviously slow);
2) Optical switches are used to reroute signals over the diverse paths (reasonably fast);
3) Active equipment switching, such as type B protection in time division multiplexing passive optical networks (TDM-PONs), or wavelength protection in WDM-PONs;
4) Full duplex protection, where there are two redundant fibre links, and the active equipment uses the best one.

10 Upgrading the optical network

When the transmission capacity, transmission length and/or number of customers, connected things increases, it will become necessary to upgrade the optical network. At such a time, telecommunication companies should consider the contents of Table 3 and select the appropriate method to upgrade the optical network.

Table 3 – Network upgrade methods

<table>
<tr><th></th><th>Optical fibre point-to-point architecture</th><th>Optical fibre ring architecture</th><th>Optical fibre point-to-multipoint architecture</th></tr>
<tr><td>Increase transmission capacity</td><td colspan="2">• Use higher rate line systems</td><td>• Use higher bit rate systems (e.g., NG-PON2 or HSP systems)
• Coexistence of multiple system on access network (see [ITU-T G.9805])
• Reduce the split ratio (example from 1×32 to 1×16)
• Use WDM system (CWDM, DWDM)</td></tr>
<tr><td>Increase transmission length</td><td colspan="2">• Reduce number of optical fibre / cable links by using, for example, blown fibre / cable techniques
• Use optical fibre amplifier</td><td>• Reduce number of optical fibre links by using, for example blown fibre / cable techniques
• Use WDM system (use (fibre-optic) branching component with wavelength multiplexer and de-multiplexer)
• Reduce number of branches (split ratio) or change to point-to-point network</td></tr>
</table>

Table 3 – Network upgrade methods

	Optical fibre point-to-point architecture	Optical fibre ring architecture	Optical fibre point-to-multipoint architecture
			• Use optical fibre amplifier
Increase number of customers	• Change to optical fibre point-to-multipoint architecture and increase number of branches • Install new cable	• Install new cable • Change to convergence architecture	• Increase number of branches (split ratio) • Install new cable
Increase reliability	• Provide redundant fibre (Note)	• Change to convergence architecture (concatenated ring architecture) • Provide redundant fibre (Note)	• Change to ring architecture • Provide redundant fibre (NOTE)
NOTE – See clause 9.			

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

11 Optical transmission performance for optical access networks

Optical access networks should be designed to meet the performance requirements (attenuation range, return loss, chromatic dispersion, etc.) as described in [ITU-T G.982], [ITU-T G.984.1] to [ITU-T G.984.7], [ITU-T G.986], [ITU-T G.987], [ITU-T G.987.1] to [ITU-T G.987.4], [ITU-T G.989], [ITU-T G.989.1] to [ITU-T G.989.3], [ITU-T G.9802.1], [ITU-T G.9806], [ITU-T G.9807.1], [ITU-T G.9807.2], [ITU-T G.9804.1] to [ITU-T G.9804.3], [ITU-T G.698.4], [ITU-T G.698.5] and [ITU-T G.698.6].

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

12 Optical safety

Optical safety should consider [ITU-T G.664].

13 Installation of optical access network

Generally, there are four stages in the installation of an optical access network for an area or a country, namely initial stage, growth stage, mature stage and final stage as illustrated in Figure 10. The topologies for each stage as well as the deployment of optical fibres cables and passive components should be carefully considered to suit each stage since they are strongly related to the cost, upgrade and performance of the access network.

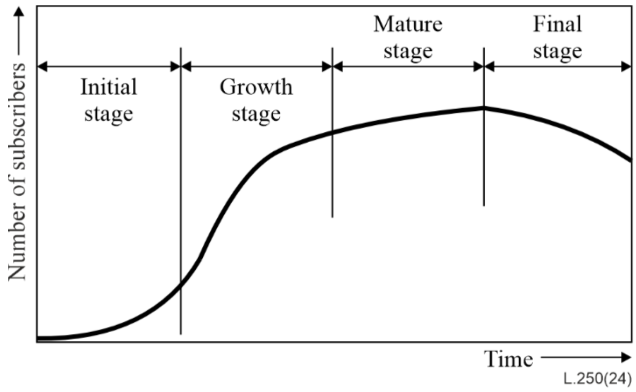


Figure 10 – Progressive increase in number of FTTx subscribers

13.1 Initial stage

In the initial stage, the demand for optical fibre will be dispersed over a wide area and the number of subscribers may be small. Therefore, effective and economical approaches need to be considered for optical fibre distribution. For example, the point-to-point topology can be introduced to meet demands from the few subscribers while the 1-level point-to-multipoint topology supports relatively concentrated subscribers. Access points need to be carefully allocated to achieve low construction cost and workability. Furthermore, it is important to take demand growth into account during network design and construction. Measures like spare fibres or additional branching points can be introduced to handle future demands. Technologies that support the deferment of costs for subsequent up-scaling of fibre capacity could be considered.

13.2 Growth stage

In the growth stage, the demand will occur randomly and frequently over a wide area, and the response to the demands should be quick and efficient. In particular, in the area between the last access point and individual home, apartment, business building, etc., which is the so called "the last mile of network", it is very important to design the network architecture to achieve easy optical fibre distribution because this part of the access network occupies the largest scale of optical fibres. Furthermore, effective and economical optical fibre distribution scheme for rural areas is needed since most demand in the growth stage will be widely dispersed in rural areas.

Additionally, as the access network will experience rapid network infrastructure expansion including optical fibres, cables and passive elements in the growth stage, the ability to manage and maintain the infrastructures effectively is critical. For example, there will be a need to use the optical fibre network maintenance support, monitoring and testing system described in [ITU-T L.302] and [ITU-T L.310].

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

13.3 Mature stage

In the mature stage, the emerging demand for new optical fibres will be small and a huge amount of network infrastructures will already be in place. Therefore, effective management and maintenance of network infrastructures becomes the most important issue. Building a network infrastructure database is a widely used method to manage the infrastructure and maintenance concerns, which are described in [b-ITU-T L.360].

In addition, subscribers who require very high reliability should be provided with two or more fibres using a ring network. Telecommunication companies should take account of the above factors in each stage when selecting the appropriate architecture and network infrastructures to construct access networks.

13.4 Final stage

In the final stage, demographic considerations may suppress demand for optical fibre and the plant and land could 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

Installation and maintenance issues

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

I.1 Optical network maintenance support, monitoring and testing system

Optical network maintenance support, monitoring and testing is described in [ITU-T L.302]. The maintenance wavelength shall be selected in accordance with [ITU-T L.301].

When using an optical fibre ring network or an optical fibre point-to-multipoint network using a (fibre optic) branching components, 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 described in [ITU-T L.310]. The maintenance wavelength shall be selected in accordance with [ITU-T L.301].

I.2 Digitized management of physical infrastructures in optical access network

Passive components and facilities make up the main part of the optical access network. Digitizing the passive physical infrastructures by creating uniform data structures for the passive components and facilities, together with their spatial and connection relationships, would bring greater convenience for network planning, management, and maintenance. By digitization, the optical access network could be mapped to, and visualized in an operations support system (OSS) as described in [b-ITU-T L.360]. ID tags (e.g., QR code, RFID) mounted on or embedded in the network elements would make the digitization quick and error-free, see [b-ITU-T L.361]. Passive node elements with automated tag detection in optical access networks are described in [b-ITU-T L.207]. By scanning ID tags, information saved in the tags or in the OSSs could be read by the personal terminals of field engineers. When the elements are installed, the positioning information of personal terminals could also be used to initialize location data of the network elements in the OSSs.

I.3 Electrical power supply

The electrical power supply and battery backup to an ONU or an active node should be selected by considering the outage rate of commercial power suppliers, the cost when using commercial power suppliers, the time to repair a power source failure, and the reliability requirements of the services being provided, as described in [b-ITU-T L.203]. Where it is not easy to get power from a nearby source, optical/metallic hybrid cables as described in [b-ITU-T L.109.1] could be used for remote power supply. A combined housing as described in [ITU-T L.209] to keep both active elements such as ONT, battery and its charge controller (power supply) as well as passive elements such as fibre patch panel, connectors, splitters and fibre splice trays, instead of having multiple separate boxes for active and passive elements could be used. This combined housing is especially helpful to service providers for FTTx applications in areas where ownership, space, safe custody and availability of power supply source are hurdles to deployment.

I.4 Electrical safety

Electrical safety should consider [b-ITU-T K.51].

Bibliography

[b-ITU-T K.51] Recommendation ITU-T K.51 (2016), *Safety criteria for telecommunication equipment*.

[b-ITU-T L.109.1] Recommendation ITU-T L.109.1 (2022), *Type-II optical/electrical hybrid cables for access points and other terminal equipment.*

[b-ITU-T L.203] Recommendation ITU-T L.203/L.44 (2000), *Electric power supply for equipment installed as outside plant*.

[b-ITU-T L.207] Recommendation ITU-T L.207 (2018), *Passive node elements with automated ID tag detection.*

[b-ITU-T L.301] Recommendation ITU-T L.301 (2000), *Maintenance wavelength on fibres carrying signals*.

[b-ITU-T L.360] Recommendation ITU-T L.360/L.80 (2008), *Operations support system requirements for infrastructure and network elements management using ID technology*.

[b-ITU-T L.361] Recommendation ITU-T L.361/L.64 (2012), *ID tag requirements for infrastructure and network elements management*.

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