ETSI TR 103 775 V1.1.1 (2021-08)

TECHNICAL REPORT

Access, Terminals, Transmission and Multiplexing (ATTM);
Optical Distribution Network (ODN)
Quick Construction and Digitalization

Reference
DTR/ATTM-0252

Keywords
access, digitalized, pre-connectorized, quick ODN

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Sous-Préfecture de Grasse (06) N° w061004871

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Access, Terminals, Transmission and Multiplexing (ATTM).

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

Fibre to Everywhere is the vision of the Fifth Generation Fixed Network (F5G). Easy deployment of fibre infrastructure, fast and flexible ODN network construction and clear, visible and manageable ODN network are the key to the construction of the new fibre infrastructure. Traditional ODN networking and construction face the following challenges:

- low construction efficiency;
- high costs and disordered resource management.

Especially in the low density access scenarios, the high deployment cost and low efficiency of optical fibres are more obvious. The ODN development in the F5G era should be able to avoid the preceding construction problems and implement flexible networking, fast deployment, visualized and manageable ODN.

1 Scope

The present document describes the ODN quick construction and digital management solutions, which enable the carriers to improve the fibre deployment efficiency, achieve digital resource management, and consequently improve the operation and management efficiency.

The present document describes the system structure of the digitalized quick ODN and the general requirement of pre-connectorized ODN product modules, digital labels, intelligent management terminals and intelligent optical distribution network management systems.

The present document is mainly applicable to the intelligent optical distribution network in access network. It can also be used as a reference for other networks with optical fibre connections.

The present document is mainly based on intelligent optical distribution networks that can collect the ODN information through a smart terminal device (such as a smart phone with the ODN management application) and the digital label in the ODN device. For optical distribution networks that collect electronic label information in other methods, it is possible to refer to the present document similarly.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] IEC 61300 (all parts): "Fibre optic interconnecting devices and passive components - Basic test and measurement procedures".

[i.2] IEC 61753-1: "Fibre optic interconnecting devices and passive components - Performance standard-Part 1: General and guidance".

[i.3] IEC 60068-2-17: "Basic environmental testing procedures - Part 2-17: Tests - Test Q: Sealing".

[i.4] ISO 1998-1:1998: "Petroleum industry-Terminology- Part 1: Raw materials and products".

[i.5] EN 590:2009: "Automotive fuels-Diesel-Requirements and test methods", (produced by CEN).

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

digitalized Optical Distribution Network (ODN): methodology that uses electronic labels to uniquely identify ODN passive elements to enable the implementation of intelligent management functions such as automatic storage of optical fibre information, automatic identification of optical fibre connection, information on calibration of optical fibre resources and visualized onsite operation guide

intelligent management terminals: portable devices that provide management GUIs and visualized onsite operation instructions and provide transmission channels for digitalized ODN facilities to access the digitalized ODN management system

pre-connection optical distribution network: ODN network deployment methodology that uses cables, block terminals and other components that are pre-manufactured in factory with connectors and adapters, enabling that the network connections can be done by plug-and-play operation on site

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

APC	Angled Physical Contact
APP	Application
DQ ODN	Digitalized & Quick Optical Distribution Network
DQ	Digitalized & Quick
EN	European Norm
FAT	Fibre Access Terminal
FDT	Fibre Distribution Terminal
FTTH	Fibre To The Home
FTTX	Fibre To The X
GIS	Geographic Information System
GUI	Graphical User Interface
HC	Home Connection
IL	Insertion Loss
LC	Lucent Connector
O&M	Operations and Maintenance
ODF	Optical Distribution Frame
ODN	Optical Distribution Network
OLT	Optical Line Terminal
OMS	ODN Management System
ONT	Optical Network Terminal
ONU	Optical Network Unit
OPEX	Operating Expenses
OSP	Outside Plant
OSS	Operation Support System
P2P	Point to Point
PON	Passive Optical Network
QR code	Quick Response code
QR	Quick Response
RH	Relative Humidity
RL	Return Loss
RT	Room Temperature

SC	Standard Connector
SN	Serial Number
SSC	Splitting and Splicing Closure
SUS304	Stainless Steel 304
UPC	Ultra Physical Contact
UV	Ultraviolet

4 Overview of Digitalized Quick ODN

FTTH has been recognized by the majority of fixed network operators worldwide as a strategic approach for the deployment of broadband access. Every year tens of millions of fibre access ports are deployed. The most popular technology for FTTH is Passive Optical Network (PON) which is based on a point-to-multi-point Optical Distribution Network (ODN). As the infrastructure of FTTH, ODN consumes the biggest part of investments from operators in constructing its FTTH network; it also takes long time for the construction and significant OPEX costs for operation and maintainance. Hence, a solution to build and operate an ODN quickly and efficiently with low cost is very important for every FTTH operator.

A typical ODN contains fibres, cross-connecting and splitting devices such as Optical Distribution Frame (ODF), Fibre Distribution Terminal (FDT), Splitting and Splicing Closure (SSC) and Fibre Access Terminal (FAT). Its topology and components are illustrated below in Figure 4-1.

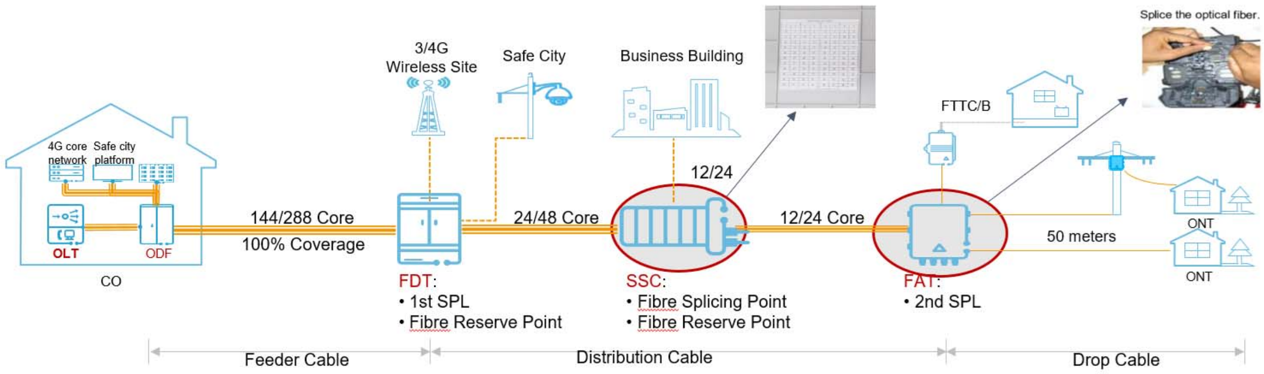

Figure 4-1: ODN Network Structure in FTTx Scenario

The ODN provides a physical optical transmission channel between the Optical Line Terminal (OLT) and the Optical Network Terminals (ONTs). It usually consists of optical fibre cables/optical connectors/optical splitters and box equipments for mounting and connecting these devices. During the construction, it generally can be divided into three parts as shown in Figure 4-1. The first part is the feeder segment, usually from the Optical Distribution Frame (ODF) in the Central Office up to the Fibre Distribution Terminal (FDT), and serves as the trunk optical cable to realize long-distance coverage. The second part is the distribution segment from the FDT to the user access point at the Fibre Access Terminal (FAT) . It allocates optical fibres near the user area along with the feeder optical cable and completes the optical splitting function. The third part is the drop cable segment, from the FAT to the user premise, and connects the end users to the ODN network.

The current network construction process can be classified into high-density scenario and low-density scenarios based on user density scenario.

High-density user scenario: Users live in a densely populated area, where optical splitting is performed at FDTs to form an even-distributed ODN network architecture. The centralized splitting usually includes one-stage splitting or two-stage splitting. For one stage-splitting, there is only a high splitting ratio (such as 1:32 or 1:64) splitter in the whole ODN network. The advantages of one-stage optical splitting are simple network topology, low line attenuation, easy management and maintenance. Therefore it is usually used in the scenarios where the user's density is very high, such as the business and residential campuses.

The advantages of two-stages optical splitting are the flexibility of the networking structure and the saving in distribution cables. Therefore, it is recommended to use two-stages optical splitting for the access of a small group of users. In the two-stage optical splitting scenarios, the first-stage optical splitter is usually deployed in the central office, equipment room or optical cable distribution box, and the second-stage optical splitter is implemented near the users.

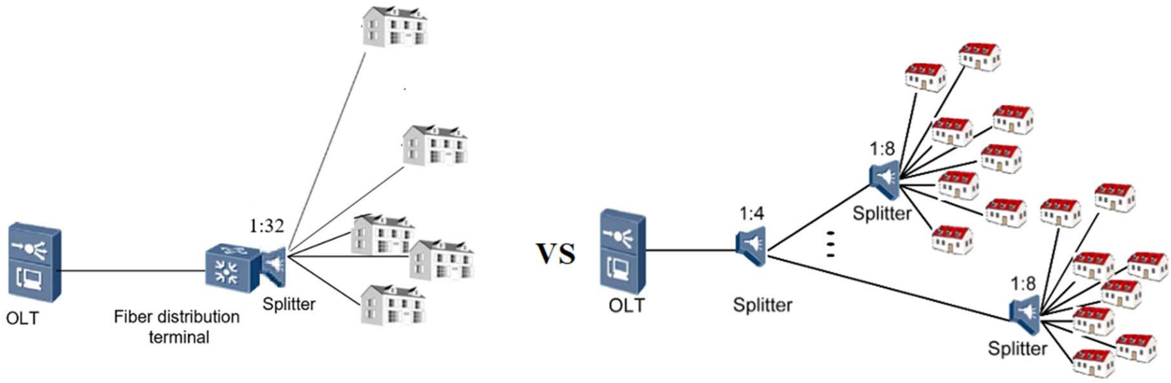

Figure 4-2: Centralized optical splitter ODN construction

Low-density user scenario: For users living in sparsely populated areas, the uneven chain networking solution can be used to deploy the ODN network, to save optical fibre resources. And such solution is also very suitable for the smart city scenarios, where the network is mainly constructed along the road, for example the ONTs are likely installed on the street light poles.

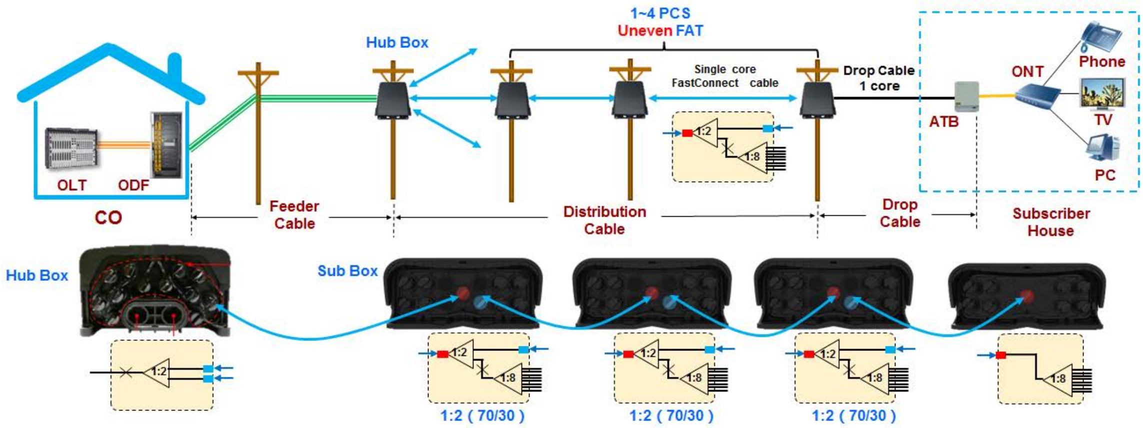

Figure 4-3: Uneven chain networking solution

In low-density scenarios, the uneven ratio chain ODN network scheme can make better use of fibre network resources. In this scheme, compared with the traditional mode that all splitters are equal splitting, uneven splitter is used in the main chain, and different stages splitter are cascaded by the uneven splitters. Generally speaking, the feeder branch can be used to connect next stage splitters, and the drop branch can be used to connect the nearest subscribers. All boxes are connected in series instead of in parallel and this enables the box installation be decoupled from the distribution cable deployment. Comparing to traditional scenario where boxes are connected with 24/36-core optical fibres, in such uneven splitting chain all boxes are connected with a single-core distribution cable, which greatly saves the number of distribution fibres and improve deployment efficiency.

Besides scenario-oriented network deploy mode, network construction efficiency and ODN resource management are also very important to operators. In the traditional ODN network construction, there are a lot of connections points which are mainly realized by fusion or mechanical splicing on site. This procedure is very time consuming and also needs well-trained technicians, which impact the ODN construction efficiency and costs dramatically. On the other hand, ODN is a pure passive network which does not contain any active parts and therefore the connection relationship is normally illustrated by paper or plastic labels. After the connection is made, the relationship will be recorded manually, hence it is prone to mistakes, and label is prone to fall and be damaged as well. Moreover, for ODN troubleshooting, a technician needs to access the database to retrieve the connection data and to look for the corresponding labelled fibre. This makes the management and operation of ODN dependent on non-reliable network data.

Ways to solve the abovementioned issues are:

1) To reduce or avoid onsite splicing by using plug-and-play devices and fibre cable assemblies, which reduces time and needs of trained technician and special equipment.

In this method, all ODN passive elements are pre-connectorized. Distribution cables and drop cables with quick connectors are pre-manufactured in factory and delivered with the system. Outdoor Fibre Access Terminals (FATs) are equipped with quick connectors and support plug-and-play operation. During the on-site construction, the technician can quickly complete the network connection by manually inserting and locking the cables, based on the network plan, which greatly simplifies deployment and improves deployment efficiency.

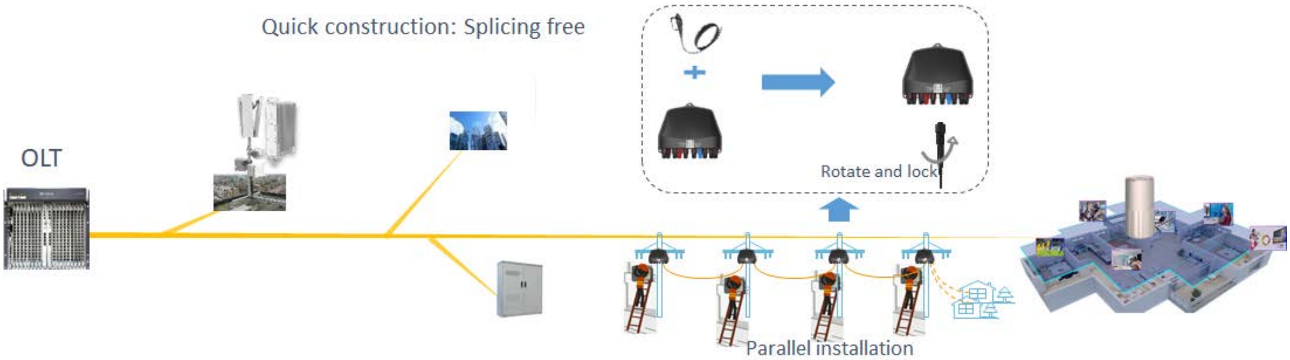

Figure 4-4: Quick ODN construction based on pre-connectorized passive elements

2) Using more robust digital labels which support being recorded/inquired with digital equipment to avoid possible human mistakes, and enable that all the ODN parts and network can be managed by the ODN Management System (OMS).

In this case all ODN passive elements have digital labels for an easy identification, recording and management by the ODN digital management system. The OMS is able to identify and display automatically the distribution topology based on the uploaded position information, and manage the ODN resources, provide needed service accordingly. The labels should be robust and be input/inquired based on digital method.

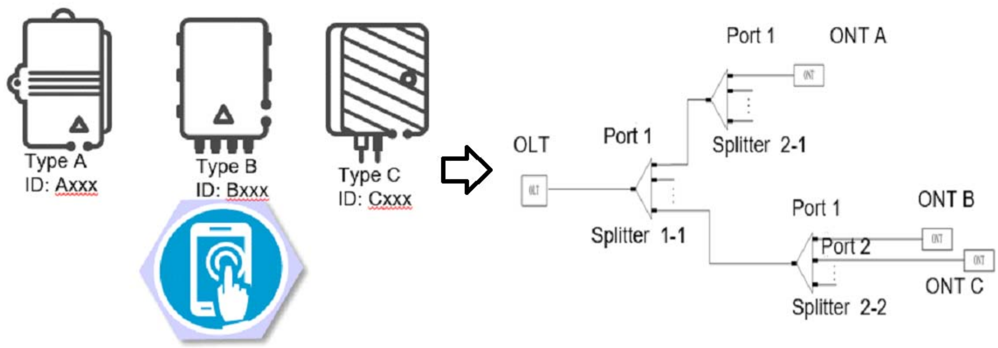

Figure 4-5: Digitalized ODN devices supported digital label and information automatic collection

The OMS uses the ODN passive element information contained in the digital label, and displays the information of connection relationship of each device port and the overall link connection topology, and quickly compares the information with the planning and design solution. In addition, port identification ensures efficient and quick port utilization and solves the problem of low efficiency and error-prone handling caused by paper labels. The details are shown in Figure 4-6.

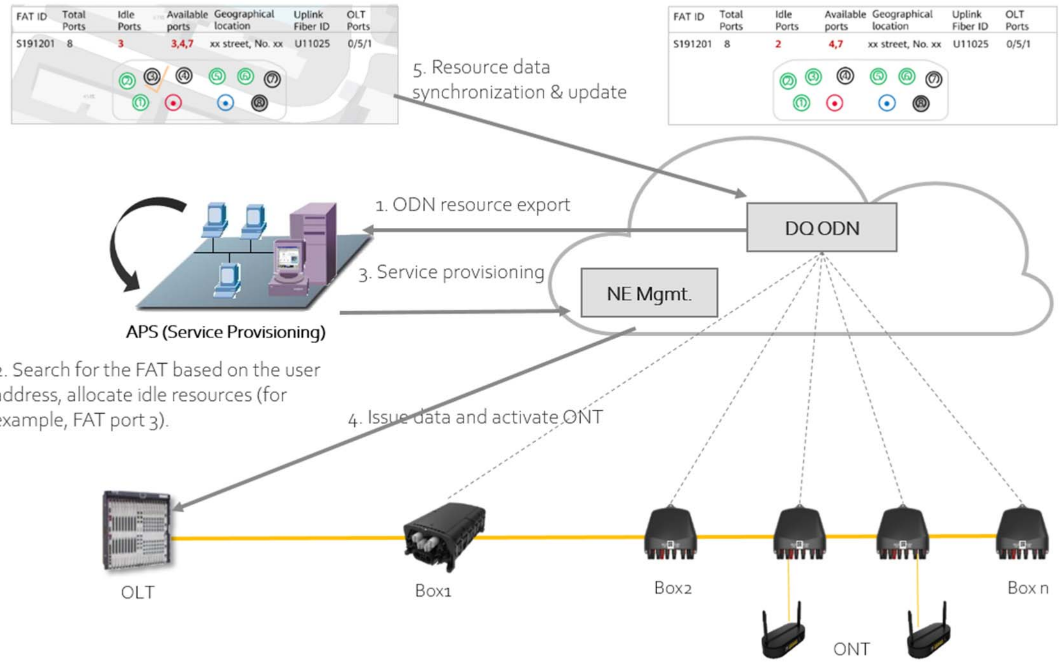

Figure 4-6: Digitalized ODN Management System

In summary, the Digitalized ODN can help to solve the challenges in traditional ODN construction and maintenance. The pre-connection ensures that all nodes are pre-manufactured cable assemblies, connectors and splitters. The pre-connectorized cables are assembled in the factory before delivery and quality control is performed to guarantee the connection quality and prevent uncontrollable quality problems caused by manual splicing on site. It supports plug-and-play and allows in parallel construction, thereby increases the construction speed and supports fast and efficient FTTH deployment. The digital management system implements end-to-end ODN management based on image recognition and ODN digitalization, achieving accurate resource management, quick service provisioning, and improving network O&M efficiency.

5 ODN Quick Construction

5.1 ODN quick construction method overview

Pre-connectorized ODN passive elements are a solution for FTTH infrastructure network architecture that enables a high efficiency network construction, high reliability and low deployment costs. Pre-connection ensures that the network passive elements are pre-manufactured with INGRESS PROTECTION (e.g. IP65, IP68) connectors and adapters. Before shipped from the factory, all network passive elements have been terminated with connectors and adapters, with an assured quality level and suitable for a variety of ODN network environment. Compared to the traditional ODN network, pre-connectorized ODN construction eliminates needs of fibre splicing on site, thus avoids issue of lacking of control and potential inefficiency of fibre fusion splices. At the same time, using this quick installation process and depending on the network structure, the construction mode can be changed from the typical serial construction into a parallel construction mode using several crews, supporting the quick and efficient deployment of ODN.

In simple words, a pre-connectorized based ODN solution is very efficient for ODN construction. Based on the ODN network planning, designing and coverage range, pre-connection can be applied into drop section pre-connection, distribution section pre-connection, and all ODN sections pre-connection. In all these options, the key is to have pre-connectorized passive elements and transfer the manual fibre splicing work onsite to the factory for batch processing and higher reliability.

5.2 Pre-connectorized based ODN Network Construction

5.2.1 Drop section pre-connection

The drop section is the path from the last distributing point, usually the point of stage-2 optical splitting, to the user premises. In this clause, the traditional ODN fibre access terminal splicing operation on the stage-2 optical splitting FAT node is replaced with pre-connectorized cable assemblies, prefabricated in the factory, effectively improving the construction efficiency of the Home Connection section and implementing plug-and-play deployment.

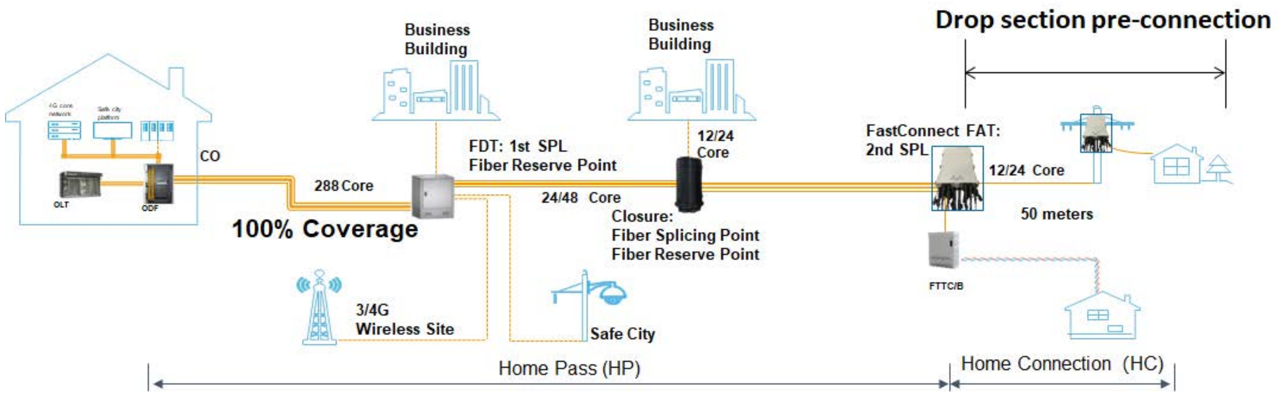

Figure 5-1: Drop section pre-connection network architecture

5.2.2 Distribution section pre-connection

Cascaded unevenly distributed splitters can be used in the distribution section. Small-diameter single-core or dual-core distribution cables are used to implement cascading between Hub boxes and Sub boxes. This solves problems such as large diameters, difficult deployment, high costs, and time-consuming deployment of common 12-core or 24-core distribution cables. The pre-connection architecture that introduces the concept of pre-connection from the distribution section can be summarized as pre-connection of distribution sections.

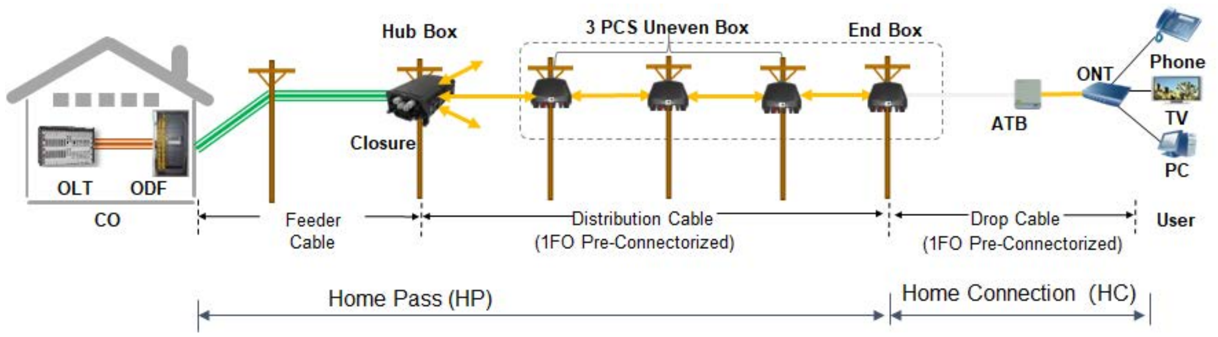

Figure 5-2: Distribution section pre-connection network architecture

5.2.3 All ODN sections pre-connection

The feeder, distribution, and drop cable assemblies from the OLT are prefabricated without need of splicing on field and are plug-and-play on the entire network. This type of architecture that introduces the concept of pre-connection from the feeder section can be summarized as full-process pre-connection.

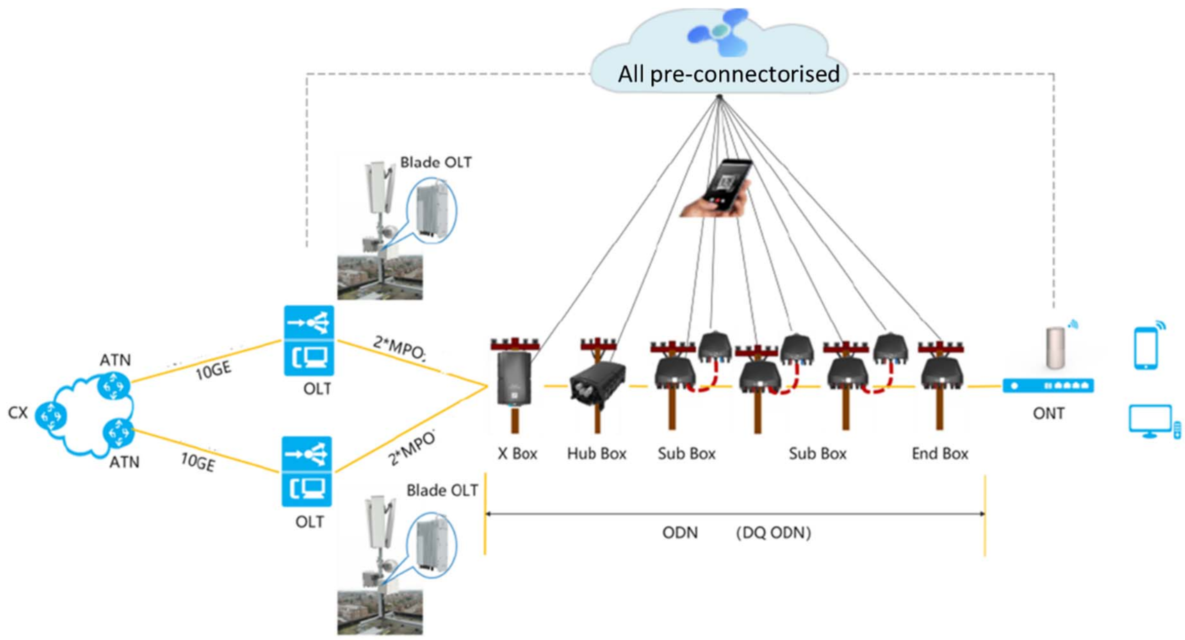

Figure 5-3: All ODN sections pre-connection network architecture

X box: The interface equipment used on the cross-connect point of trunk optical cables and distribution optical cables in the optical transmission network.

Hub box: first stage optical splitting FAT, located at the user access point of FTTH-ODN for connecting the distribution optical cables and drop cables, direct connection, branching and protection of optical fibres.

Sub box: second stage optical splitting FAT, located at the user access point of FTTH-ODN for connecting the distribution optical cables and drop cables, direct connection, branching and protection of optical fibres.

End box: The Sub box in the last stage of optical splitting network.

5.3 Pre-connectorized components and requirements

5.3.1 Components and requirements of drop section pre-connection

The drop cable pre-connection consists of the pre-connected FAT and pre-connectorized drop cable.

General features and requirements of the pre-connected FAT:

1) Applicable to outdoor scenarios, providing environmental protection for optical fibre and optical connectors.

2) Traditional straight-through cable holes and branch cable holes are provided for routing and securing downstream optical cables.

3) Prefabricated drop cable holes: An adapter that supports outdoor application is used and is installed on the FAT panel using nuts or buckles. Each adapter is the entry port for a drop cable. This outdoor adapter needs to be used with a specific pre-connectorized drop cable.

4) Splicing/Fibre spooling unit, which can splice downstream optical cables and optical splitter or pigtails.

5) The optical splitter fixing structure is provided. The output connector of the optical splitter is inserted into the adapter installed on the FAT housing.

6) Digital information labels are printed on the shell surface to allow digital ODN management.

FAT used in pre-connection scenarios are classified into those used in above-ground scenarios and those used in underground scenarios.

Outdoor pre-connectorized FATs for above-ground applications are usually installed on a wall or overhead. Outdoor pre-connectorized FATs used in underground scenarios are usually installed in manholes and hand holes. The operating temperature range is -40 °C to +70 °C. The physical and chemical properties of all components should be stable. The materials should be compatible with each other, and compatible with the optical cable materials that may come in contact with the components and other materials of the OSP. The shell should be made of non-metallic materials that can be used outdoors for a long time, and should be able to resist fungi and UV light. Shell exterior metal components and fasteners should be corrosion resistant materials such as SUS304 stainless steel.

For illustration purposes, Figure 5-4 shows an example of a ground pre-connected FAT:

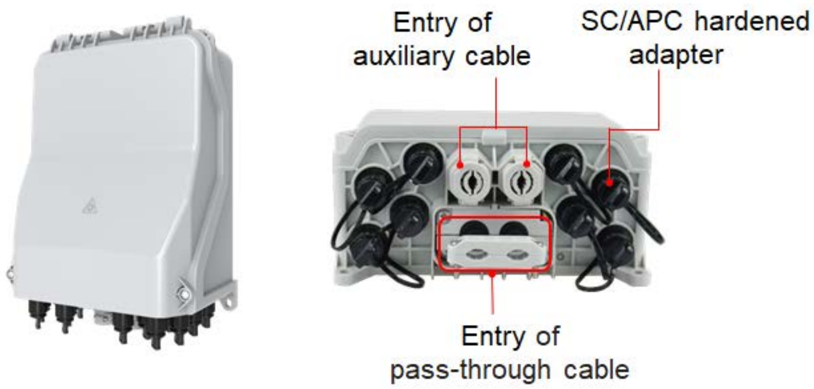

Figure 5-4: Example of ground pre-connected FATGeneral

Requirements for pre-connectorized drop cable:

1) The cable is connected to the Sub box and ONU in outdoor scenarios.

2) The cable connectors on the Sub box side are pre-fabricated before delivery and are plug-and-play. Fibre splicing or mechanical splicing on the user side (ONU) is based on customer requirements.

3) Supports the DQ ODN management function and has a digital information label on the end of the connector.

4) The coupling force between the drop cable connector and optical cable should be greater than 300 N.

5) Pre-connectorized drop cables are used in both above ground scenarios and underground scenarios.

Pre-connectorized cables are usually used aerially in the above ground scenario. Pre-connectorized cables in underground scenarios are usually installed inside ducts. The operating temperature range is -40 °C to +70 °C. The physical and chemical properties of the materials used by all parts should be stable and the materials should be compatible. The connector should be made of high-strength materials that can be used outdoors for a long time. The materials should be resistant to fungi and UV. The materials of underground optical cables should meet the requirements of resistance to chemical reagent boxes and kerosene. Optical cables are made of highly reliable materials. The main types of cables on the ground are 5 mm outer diameter round cables and 2 × 5,3 mm flat drop cables. The main type of underground optical cables is 5 mm outer diameter round cables.

For illustration purposes, Figure 5-5 shows some examples of pre-connectorized drop cables.

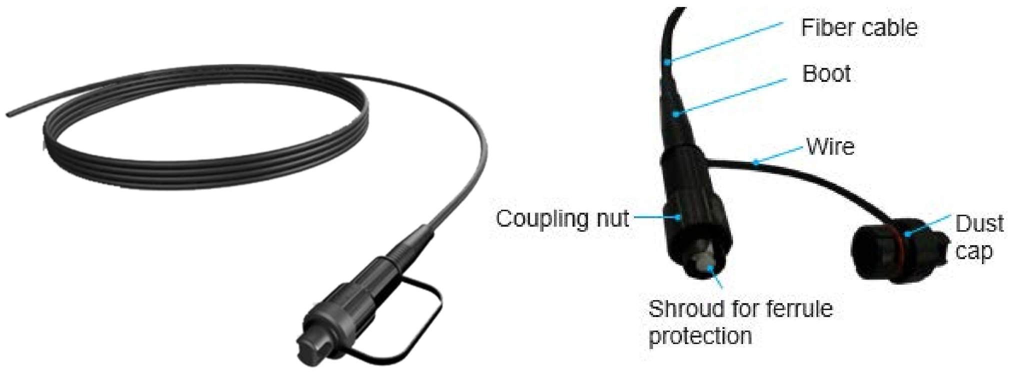

Figure 5-5: Examples of pre-connectorized drop cable

5.3.2 Components and requirements for pre-connection of distribution sections

The pre-connection of the distribution section is usually composed of the pre-connectorized Hub box, pre-connectorized Sub box, pre-connectorized end box, pre-connectorized single-core/dual-core distribution cable, and pre-connectorized drop cable.

The pre-connectorized Hub box has the following features:

1) Applicable to outdoor scenarios, providing environmental protection for optical fibre and optical connectors.
2) Traditional straight-through optical cable holes are provided for routing and securing downstream optical cables.
3) Prefabricated drop cable holes: an adapter that supports outdoor scenarios is used. The adapter lock nut or latch is installed on the FAT panel. Each adapter is the entry port for a drop cable. This outdoor adapter needs to be used with a specific pre-connectorized drop cable.
4) Splicing/Fibre spooling unit, which can splice downstream optical cables and optical splitter or pigtails.
5) The Hub box is used as the first-stage optical splitting point. Multiple 1:2 optical splitters are required. The output connector of the optical splitter is inserted into the adapter installed on the case shell. The input end of the optical splitter is spliced with the downstream optical cable.
6) Support of the DQ ODN management function, there is a digital information label on the shell surface, which works with the DQ ODN management system to support digitized management.

The Sub box of the termination terminal has the following features:

1) Applicable to outdoor scenarios, providing protection for optical Fibre and Fibre connectors.
2) Full pre-connection mode. That is, input and output optical cables are pre-connectorized and have traditional straight-through optical cable holes for routing and securing downstream optical cables.
3) Prefabricated drop cable holes: An adapter that supports outdoor application is used and is installed on the FAT panel using nuts or buckles. Each adapter is the entry port for a drop cable. This outdoor adapter needs to be used with a specific pre-connectorized drop cable.
4) Splicing/Fibre spooling unit, which can splice downstream optical cables and optical splitter or pigtails.
5) Provides a fixed optical splitter unit. Generally, the Sub box is used as the stage-2 optical splitting point and one built-in 1:n optical splitter. The input and output connectors of the optical splitter are inserted into the pre-connection adapter, and the optical splitter input is spliced with the downstream optical cable.
6) For network elements that support the DQ ODN management functions, there is a digital information label on the shell surface, which works with the DQ ODN management system to support digital management.

For illustration purposes, Figure 5-6 shows an example of pre-connectorized Sub box used in distribution section.

Figure 5-6: Example of pre-connectorized Sub box used in distribution section

The Pre-connectorized cable at the distribution end has the following features:

1) The Pre-connectorized cable is connected to the Hub box and Sub box in outdoor scenarios.

2) Connectors on the Hub box and Sub box sides are prefabricated before delivery and are plug-and-play (splicing-free).

3) Supports the DQ ODN management function and has a digital information label on the end of the connector.

4) The coupling force between the connector and optical cable should be greater than 800 N.

5) The distribution terminal is pre-connectorized with single-core SC and a few dual-core LC connectors. The performance requirements of the dual-core pre-connectorized cable are the same as those of the single-core pre-connectorized cable.

For illustration purposes Figure 5-7 shows examples of pre-connectorized distribution cables.

Figure 5-7: Examples of pre-connectorized distribution cable examples

The functions of the pre-connectorized drop cable are the same as those in clause 5.3.1.

5.3.3 Components and requirements of All ODN sections pre-connection

The all ODN sections pre-connection consists of the X Box, Hub Box, Sub Box, multi-core feeder, single-core or dual-core distribution cable, and drop cable.

The Pre-connectorized X Box is a fast connect closure that is sealed mechanically. It is used for connecting blade OLT and Hub Box. It is a device with all inlet and outlet cables pre-connectorized, eliminating the need of closure opening and fibre splicing.

Aggregates PON and P2P services and divides the services into multiple office directions to the Hub box.

The X Box supports onsite unpacking and maintenance, but all ports are configured before delivery and do not support onsite scheduling.

The X Box has a QR code. The port layout supports image recognition, and OMS supports digital management.

The functions of the Hub Box and Sub Box are the same as those in clause 5.3.2.

The multi-core feeder pre-connectorized cable has the following features:

1) The multi-core connector is used to meet the requirements of outdoor scenarios. The connection between the OLT and the Hub box is established.

2) Connectors on the OLT side and Hub box side are prefabricated before delivery and are plug-and-play (without splicing).

3) Supports the DQ ODN management function and has a digital information label on the end of the connector.

4) The coupling force between the connector and optical cable should be greater than 800 N.

For illustration purposes Figure 5-8 shows examples of multi-core feeder pre-connectorized cable.

Figure 5-8: Examples of multi-core feeder pre-connectorized cable

The functions of the pre-connection distribution cable and pre-connection drop cable are the same as those in clauses 5.3.1 and 5.3.2.

5.3.4 Basic Performance Requirements for Pre-connectorized passive elements

All passive elements, including FAT, closure, optical splitter, and connectors should comply with the IEC 61753-1 [i.2] standard based on their application environment. Table 5-1 lists the basical performance requirements of pre-connectorized cables based on IEC standards.

Table 5-1: Performance test requirements for pre-connectorized cables

Item	Method	Criteria	Standard
Insertion Loss	—	Single-core cable :IL ≤ 0,3 dB, IL(Avg) ≤ 0,1 dB multi-core feeder cable: IL ≤ 0,35 dB	IEC 61300-3-4 [i.1] Method B
Attenuation of random mated connectors	—	Single-core cable : ≤ 0,12 dB mean ≤ 0,25 dB max. for ≥ 97 % of the connections multi-core feeder cable: ≤ 0,5 dB max. for ≥ 97 % of the connections	IEC 61300-3-34 [i.1]
Return Loss	—	RL ≥ 60 dB (APC RL ≥ 50 dB (UPC)	IEC 61300-3-6 [i.1]
cable retention(for Single-core cable)	Load: 300 N, 2 minutes duration per cable per test temperature Sealing test conducted at test temperatures -15°C and +45 °C Optical test conducted at +23 °C ± 3 °C	1. No damage that will affect the device function 2. δIL ≤ 0,2 dB	IEC 61300-2-4 [i.1]
cable retention(for multi-core feeder cable)	Load: 800 N 2 minutes duration per cable per test temperature Optical test conducted at +23 °C ± 3 °C	1. No damage that will affect the device function 2. ΔIL ≤ 0,5 dB, RL ≥ 60 dB	IEC 61300-2-4 [i.1]

Item	Method	Criteria	Standard
Torsion	Cycle with torque angle: +90° and -90° Point of application: 400 mm from end of sealer 5 cycles per cable per test temperature 5 minutes in each extreme position Sealing test conducted at test temperatures -15°C ± 2 °C and +45 °C ± 2 °C Optical test conducted at +23 °C ± 3 °C	1. No damage that will affect the device function 2. δIL ≤ 0,2 dB	IEC 61300-2-5 [i.1]
Impact (method A)	5 drops per test sample 1,5 m drop height per test temperature Sealing test conducted at test temperatures -15 °C ± 2 °C and +45 °C ± 2 °C Optical test conducted at +23 °C ± 3 °C	1. No damage that will affect the device function 2. δIL ≤ 0,2 dB	IEC 61300-2-12 [i.1]
Fibre optic connector proof test with static load	Load: 50 N (side pull 90°) Duration: 5 seconds Test conducted at +23 °C ± 3 °C	1. No damage that will affect the device function 2. δIL ≤ 0,2 dB	IEC 61300-2-50 [i.1]
tightness	Pressure: (40 ± 2) kPa; Temperature: (23 ± 3)° C; Duration:15 minutes; Depth: Just below water surface	No bubbles indicating a leakage should be observed during the test	IEC 61300-2-38 [i.1] Method A; IEC 60068-2-17 [i.3] Test Qc
Tightness under load	Load: 11,3 N (side pull 90°) Pressure in the sample: 40 kPa Duration: 1 minute	No bubbles indicating a leakage should be observed during the test	IEC 61300-2-38 [i.1] Method A IEC 61300-2-50 [i.1]
Change of temperature	Temperature range: -40 °C to +65 °C Duration at extreme temperatures: 4 hours duration Temperature change rate: 1 °C/minute ,12 cycles	1. No damage that will affect the device function 2. δIL ≤ 0,2 dB	IEC 61300-2-22 [i.1], IEC 61753-1 [i.2]
Long-term reliability	Temperature: +75 °C Humidity: 95 % RH Duration: 1 000 hours	1. No damage that will affect the device function 2. δIL ≤ 0,2 dB	IEC 61300-2-19 [i.1], IEC 61753-1 [i.2]
Resistance to solvents and contaminating fluids(only for underground)	HCl at pH 2 - NaOH at pH 12 - Cable compound (petroleum jelly), ISO 1998-1 (1.60.132) [i.4] - Automotive diesel oil ISO 1998-1 [i.4] (1.20.131) and EN 590 [i.5] - 10 % nonylphenol ethoxylate solution (Igepal) - (at +50 °C ± 2 °C) Duration: Automotive diesel - 1 hour immersion, 24 hour drying at RT Others: 5 days, no drying	No damage that will affect the device function The tightness performance is ok	IEC 61300-2-34 [i.1]

5.4 Pre-connectorized ODN installation procedure and requirement

The pre-connection construction sequence is as follows:

1) Length selection of pre-connectorized optical cables: calculate the total length (from box to box) based on the design drawing and route re-test. Select pre-connectorized optical cables of proper length.

2) Check the pre-connectorized optical cable: check the appearance of optical cables and optical Fibre features.

3) Installation of pre-connectorized distribution cables: hang up each segment of pre-connectorized optical cable tray onto the pole and secure it.

4) Coil pre-connectorized distribution cables: install the cable spool and coil the long part of each pre-connectorized optical cable.

5) Installation of pre-connectorized closures: install the Hub box and Sub box according to the pre-connectorized uneven optical splitting solution.

6) Pre-connectorized drop cable construction: construction process of pre-connectorized drop cables (HC).

7) Post-installation check: check the installation quality.

8) Acceptance test: measure and accept the optical cable deployment according to the acceptance criteria.

6 Digitalized ODN System

6.1 Digitalized ODN Reference Model

Digitalized ODN consists of Digitalized ODN facilities, intelligent ODN management system, and intelligent management terminals. They can interconnect with a third-party Operations Support System (OSS). Figure 6-1 shows the reference model of the OSS.

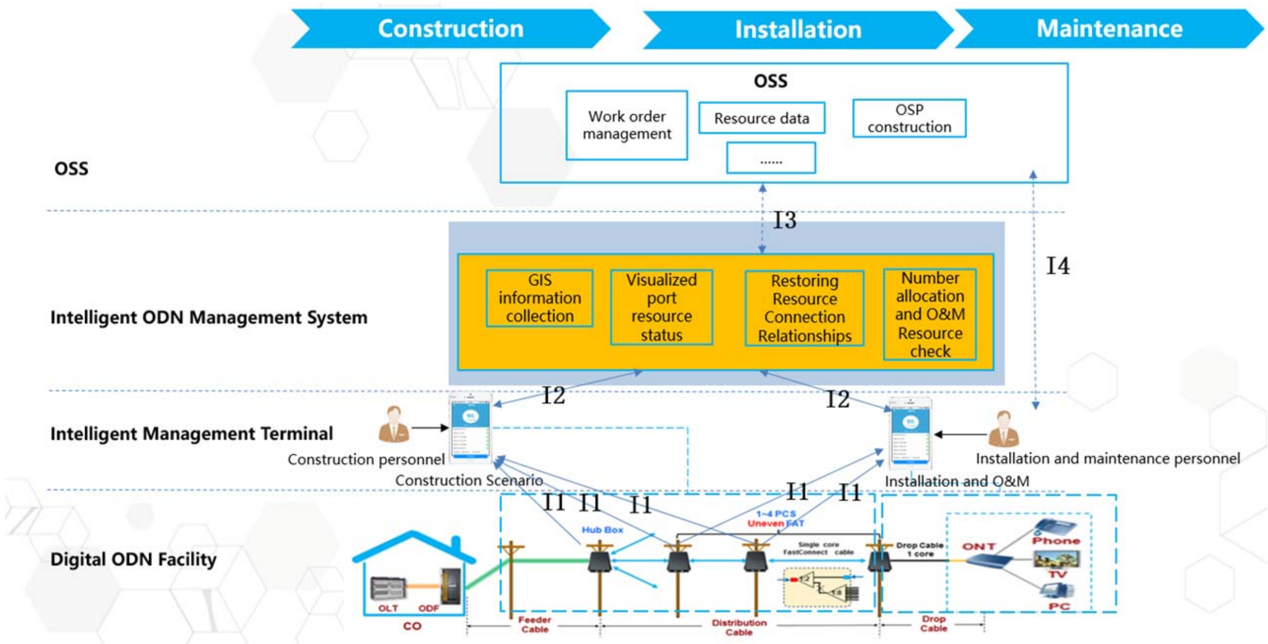

Figure 6-1: Digitalized ODN reference model

Digitalized ODN devices are ODN passive elements with digital features added. The intelligent management terminal is a tool for Digitalized ODN, both for the inventory of ODN during network construction as well as for O&M management. The intelligent ODN management system is a platform with several functionalities for an efficient digitalized ODN data management. For details, see clause 6.3.

Digital features can be used throughout the ODN network construction, installation, and O&M phases to implement visible and manageable resources, accurately manage ODN port resource data, and effectively reduce O&M costs.

The digitalized ODN interfaces are described as the following:

- I1 interface: It is an interface used for intelligent management terminals to obtain digitalized ODN settings.
- I2 interface: It is an interface between the intelligent ODN management system and the intelligent management terminal. The intelligent management terminal can upload the collected device information to the intelligent ODN management system, and the intelligent management terminal can obtain device data and work orders from the intelligent ODN management system.
- I3 interface: It is an interface between the intelligent ODN management system and the OSS. It is used to synchronize ODN resource data and send work orders.

- I4 interface: It is an interface between the intelligent management terminal and the OSS. The OSS can directly obtain device data from the intelligent management terminal or deliver data to the intelligent terminal from the OSS. This is an optional interface and the function can be added based on OSS requirements.

6.2 Digitalized ODN Functional Entity

6.2.1 Digital label

A digital label records digital code information based on chips or QR codes to identify passive elements and related connections. The main requirements of the digital label are as follows:

1) The combination of "Manufacturer ID", "Production Type", "Production date" and "Serial Number" carried in the digital label constitute a unique Identifier (ID) of an ODN device, and it should be unique globally. Optional information items can be contained in the digital label printed on the device, and can also be obtained from the management system data base through its ID .It is recommended to include the items shown in Table 6-1, where general information items should be mandatory, and the remaining items can be optional.

Table 6-1: Digital Labels items

No.	Items	Values	Note
1	Manufacturer ID		General Information
2	Production Type		General Information
3	Production date		General Information
4	Serial Number		General Information
5	Ports Quantity		Optional
6	Port Function		Optional
7	Operating temperature		Optional
8	Length		Optional
9	……..		Optional

2) The digital label should be firmly attached to the passive element.

3) Shape and size of a digital label should not affect the maintenance of the label itself and its associated facilities.

4) The environment requirements of digital labels should be consistent with the optical fibre connectors or boxes where the labels are attached.

5) The mechanical characteristics of the digital label carrier (including the digital label) should meet the mechanical performance requirements of the attached optical fibre connector and the container.

For illustration purposes Figure 6-2 shows two examples of the digital label on digitalized ODN products:

Figure 6-2: Digital label examples on digitalized ODN passive elements

6.2.2 Intelligent management terminal

As a portable device with an ODN management software application, like a smart phone, tablet computer, it provides a management operation interface to identify intelligent ODN devices and manage onsite operations. It communicates with the intelligent ODN management system through the I2 interface and communicates with the OSS through the I4 interface.

The intelligent management terminal performs the following functions:

1) Automatic identification and recording of intelligent ODN facility information and port information by scanning digital labels.

2) Download, import, export, query, delete, and feedback work order processing results.

3) Provision of visualized onsite operation guide services through the management interface.

4) Communication with the intelligent ODN management system.

5) Communication with the OSS (Optional).

6.3 Intelligent ODN management system

The intelligent ODN management system manages intelligent ODN facilities through the intelligent management terminal. It communicates with the intelligent management terminal through the I2 interface and communicates with the OSS through the northbound interface I3.

The intelligent ODN management system provides the following functions:

1) Provides a visualized ODN network topology based on port information. Figure 6-3 shows an example.

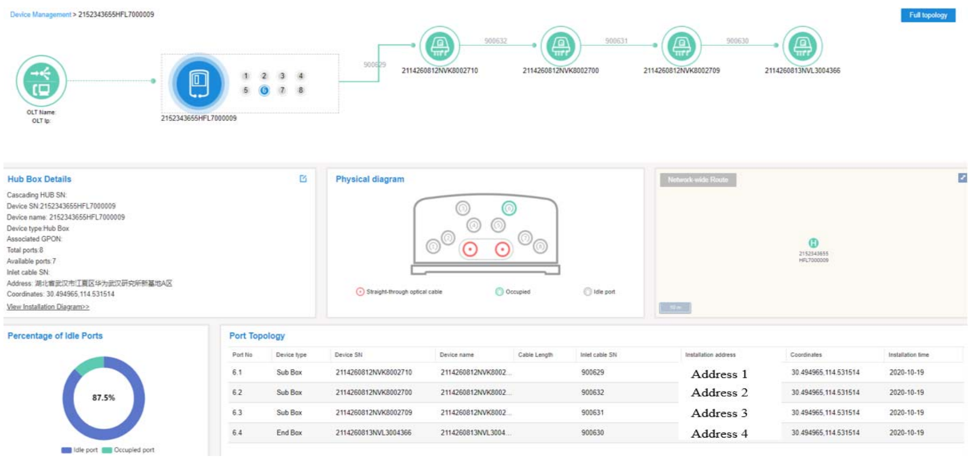

Figure 6-3: Example of ODN network topology display (for illustration purposes only)

2) Manages intelligent ODN facilities, stores, imports, and exports intelligent ODN facility information, queries the longitude and latitude coordinates of each node device in the management system, and compares the longitudinal and lateral coordinates of the onsite node device with those recorded in the system. Figure 6-4 shows an example of ODN network facility location information management and coordination. Through the ODN management system, the O&M personnel can query the number of ODN ports in each region and the geographical location of each ODN port, and compare the query results with the actual situation.

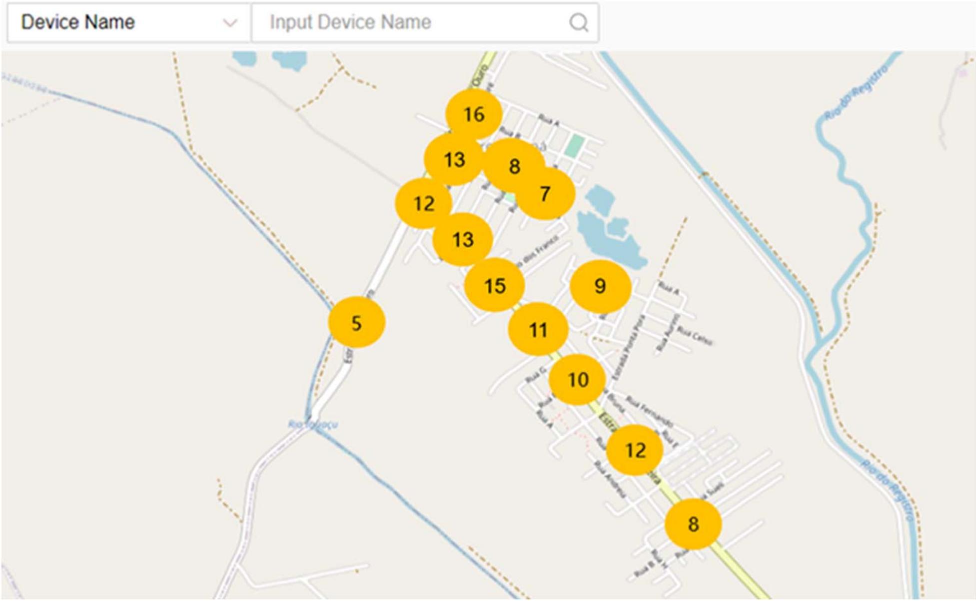

Figure 6-4: Example of ODN network facility location information (for illustration purposes only)

3) Receives, processes, and forwards service orders, manages alarms, and reports the alarms to the OSS. Communicates with the intelligent management terminal and communicates with the OSS through the common communication interface.

6.4 Digital System Management and O&M

6.4.1 Digitalized ODN management overview

The Digitalized ODN system can be applied to ODN device construction, service installation, and O&M phases to implement fast and accurate resource entry, port-level precise number allocation, and link topology restoration.

6.4.2 New Device construction

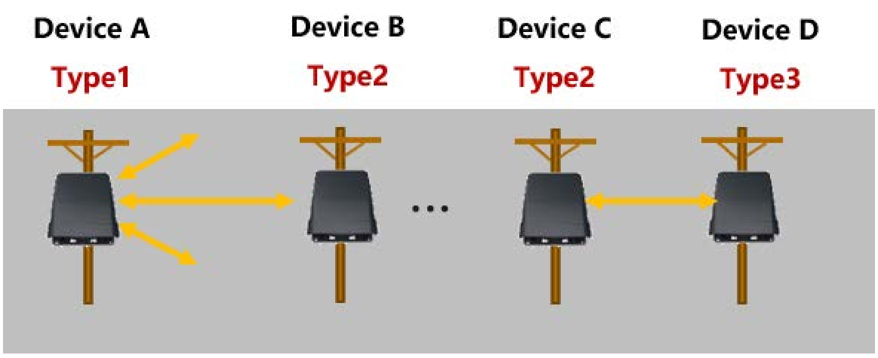

Figure 6-5: New digitalized ODN devices creation

As shown in Figure 6-5, an optical link A->B->C->D is created on the ODN.

In traditional ODN equipment solutions, frequently the information on the exact installation location of the devices and the accurate connections between the devices is not available. In digitalized ODN, such problems can be solved.

Digitalized ODN device creation process:

1) After devices are installed, the intelligent management terminal is used to collect information about a single Digitalized ODN facility, including the device type, device ID, number of ports, optical cable ID of the input port, optical cable ID of the output port. The geographic information is automatically set by the intelligent management terminal.

2) The intelligent management terminal sends information back to the intelligent ODN management system. After the management system aggregates all device information, the following functions can be implemented:

   a) The number of devices that were created for each type of devices.

   b) The Geographic Information System (GIS) information of devices can be restored, and the device installation position can be directly displayed on the map.

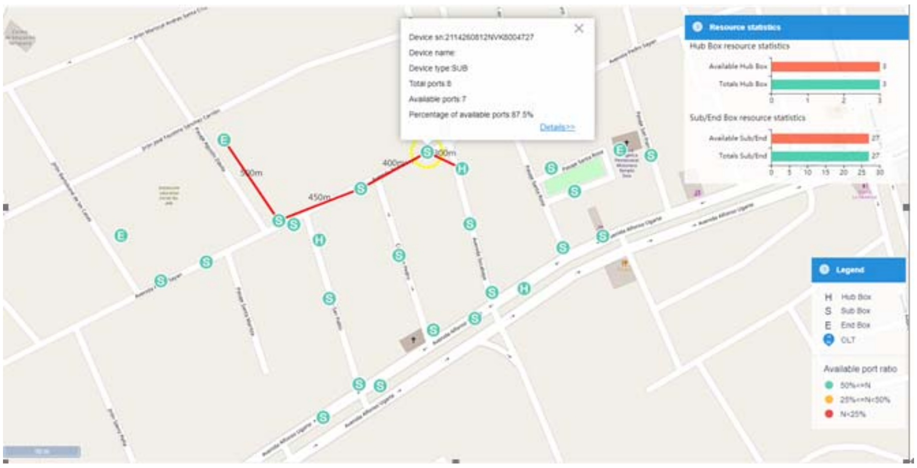

Figure 6-6: Example of GIS information collection and storage (for illustration purposes only)

   c) The topology connection relationship can be restored based on the collected information. The connection relationship between A->B->C->D can be restored.

Figure 6-7: Example of a Digitalized ODN connection relationship display (for illustration purposes only)

   d) After a device is created, all ports on the device are unoccupied and the availability is 100 % at the beginning.

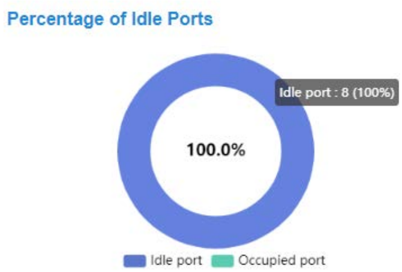

Figure 6-8: Example of Digitalized ODN ports usage status

6.4.3 Service provision

Digitalized ODN device service provision process. For example, the operator needs to provide broadband service for Eric's home, while the location of devices (FATs) A, B, C, D, and Eric's home are shown on the map in Figure 6-9.

Figure 6-9: Example of Digitalized ODN service provision

1) The OSS can synchronize the GIS information and port status information of storage devices in the intelligent ODN management system through the I3 interface. Based on the user service provisioning requirements and GIS information, the OSS obtains the nearest available device (in the example, this is device D). Obtain the port status of device D from the intelligent ODN management system. Select an unoccupied port as the port to be provisioned and generate a corresponding work order. For example, provide the service for Eric's Home on port 1 of device D, and send the work order information to the intelligent ODN management system through the I3 interface.

2) The intelligent management terminal obtains work order information through the I2 interface. The O&M personnel arrive at device D, insert the pre-connection cable to port 1, and use the intelligent management terminal to collect information about device D. In addition, the O&M personnel can verify that port 1 is not used. The intelligent management terminal obtains the latest port usage status and barcode information of the device.

3) The O&M personnel scan the ONU SN information on the intelligent management terminal and establish the connection between port 1 of device D and the ONU.

Figure 6-10: Example on establishing ports connection relationship in Digitalized ODN

4) After the construction and service provisioning is completed, the intelligent management terminal sends the device data and the according ONU information to the intelligent ODN management system through the I2 interface.

Through the digitalized ODN installation process, the device resource status can be accurately obtained to implement precise service provisioning. After the implementation, the device resource information is updated to the intelligent ODN management system in a timely manner. In this way, the resource data on the live network can be updated in real time and accurately. User services are precisely bound to specific ports to implement fibre core-level link visualization. Accurate resource data ensures reliable information for subsequent service provisioning and O&M. The OSS can synchronize data from the intelligent ODN management system to implement accurate data management. In the case no OSS is available, the intelligent ODN management system can also accurately manage the resource information of Digitalized ODN devices.

6.4.4 O&M

During new deployment and service installation, the Digitalized ODN system provides accurate device connection data, port usage data, and user optical link data in the intelligent ODN management system or OSS (if the OSS synchronizes data from the intelligent ODN management system), providing data support for the O&M process and simplifying the O&M process.

The following describes the O&M process when Eric wants to unsubscribe the service:

1) After receiving Eric requests to unsubscribe the network service, the OSS queries the ONU information and queries the port 1 on device D based on the data created during service provision, and deletes the service provision.

2) Two methods can be used for processing the unsubscribe application in ODN management system:

    a) On the OSS, set port 1 of device D to unsubscribed, mark port 1 as available status and the patch cable in port 1 can be removable in the intelligent ODN management system. In this case, there is no need to remove optical cables at once. When new services are provisioned, port 1 of device D can be reused for service provisioning for new users.

    b) Issue a maintenance order on the OSS to remove the optical cable from port 1 of device D. The OSS issues the maintenance order to the intelligent ODN management system. The O&M technician downloads work orders from the intelligent management terminal, remove the optical cable from port 1 of device D, and use the intelligent management terminal to collect information about device D and send the latest device status to the intelligent ODN management system.

In this process, Digitalized ODN O&M can accurately manage device resources and prevent fibre resource waste caused by inaccurate resource information.

7 Summary and Recommendation

The present document describes an approach for quick ODN construction with several options to be flexible and adaptive to different deployment scenarios. The approach is based on pre-connection technologies, digital labelling and the digitalized ODN management systems to improve ODN deployment and management efficiency. Based on high quality and high reliability connectors and assemblies manufactured in the factory, pre-connection-based ODN construction can avoid onsite fibre splicing and enable plug-and-play features during onsite construction, which improves the ODN construction efficiency and connection reliability. The digital ODN management system implements end-to-end digital management of ODNs, which helps improving ODN network construction and maintenance efficiency and resource accuracy. The quick digitized ODN construction uses modern mobile and cloud-based application to increase the quality and reliability.

It is recommended that technical standards will be defined for the components required for quick network construction, digitalized labels for ODN components, and the interfaces of the digital ODN management system and deployment applications. The standards will enable interoperable quick digitized ODN construction technologies enabling faster, reliable and efficient ODN construction and maintenance.

History

Document history		
V1.1.1	August 2021	Publication