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DIGITAL SYSTEMS AND NETWORKS

Access networks – Optical line systems for local and  
access networks

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**Wavelength division multiplexed passive optical  
networks (WDM PON): General requirements**

Recommendation ITU-T G.9802.1

ITU-T



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# Recommendation ITU-T G.9802.1

## Wavelength division multiplexed passive optical networks (WDM PON): General requirements

### Summary

Recommendation ITU-T G.9802.1 describes the general requirements for wavelength routed ODN based WDM PON. The general architecture and system level requirements, such as line rates, capacity in terms of channel count, optical line terminal (OLT) and optical network unit (ONU) modularity, and security are given. The symmetric nominal line rate combinations of 25 Gbit/s and 10 Gbit/s per wavelength channel are supported. The requirements for a range of relevant applications are described in terms of the needed interfaces, physical layer, operation, synchronization, resilience and protection options.

### History

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BiDi, single fibre transmission, WDM access, WDM PON.

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# Recommendation ITU-T G.9802.1

## Wavelength division multiplexed passive optical networks (WDM PON): General requirements

### 1 Scope

This Recommendation, as part of the multi-wavelength passive optical network (MW-PON) [ITU-T G.9802] series Recommendation, describes the general requirements of wavelength division multiplexing (WDM) PON using wavelength routed optical distribution network (WR-ODN), i.e., based on a wavelength multiplexer in the optical distribution network (ODN).

It describes requirements of WR-ODN based WDM PON, including general system architecture, service requirements, physical layer requirements (e.g., reach, channel count options), system level requirements (e.g., line rates, coexistence), and operational requirements (e.g., guidelines for provisioning, monitoring, energy efficiency).

### 2 References

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

- [ITU-T G.652] Recommendation ITU-T G.652 (2016), *Characteristics of a single-mode optical fibre and cable.*
- [ITU-T G.657] Recommendation ITU-T G.657 (2016), *Characteristics of a bending-loss insensitive single-mode optical fibre and cable.*
- [ITU-T G.986] Recommendation ITU-T G.986 (2010), *1 Gbit/s point-to-point Ethernet-based optical access system.*
- [ITU-T G.987] Recommendation ITU-T G.987 (2012), *10-Gigabit-capable passive optical network (XG-PON) systems: Definitions, abbreviations and acronyms.*
- [ITU-T G.988] Recommendation ITU-T G.988 (2017), *ONU management and control interface (OMCI) specification.*
- [ITU-T G.989] Recommendation ITU-T G.989 (2015), *40-Gigabit-capable passive optical networks (NG-PON2): Definitions, abbreviations and acronyms.*
- [ITU-T G.989.1] Recommendation ITU-T G.989.1 (2013), *40-Gigabit-capable passive optical networks (NG-PON2): General requirements.*
- [ITU-T G.989.2] Recommendation ITU-T G.989.2 (2019), *40-Gigabit-capable passive optical networks 2 (NG-PON2): Physical media dependent (PMD) layer specification.*
- [ITU-T G.989.3] Recommendation ITU-T G.989.3 (2021), *40-Gigabit-capable passive optical networks (NG-PON2): Transmission convergence layer specification.*

- [ITU-T G.8261] Recommendation ITU-T G.8261 (2019), *Timing and synchronization aspects in packet networks*.
- [ITU-T G.8262] Recommendation ITU-T G.8262 (2018), *Timing characteristics of a synchronous equipment slave clock*.
- [ITU-T G.9802] Recommendation ITU-T G.9802 (2015), *Multiple-wavelength passive optical networks (MW-PONs)*.
- [ITU-T G.9806] Recommendation ITU-T G.9806 (2020), *Higher speed bidirectional, single fibre, point-to-point optical access system (HS-PtP)*.
- [ITU-T G.9807.1 Amd. 1] Recommendation ITU-T G.9807.1 Amd. 1 (2017), *10-Gigabit-capable symmetric passive optical network (XGS-PON)*.
- [BBF TR-156] Broadband Forum Technical Report BBF TR-156 (2017), *Using GPON Access in the context of TR-101*.
- [IEC 60825-2] International Standard IEC 60825-2 (2004), *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCS)*.
- [IEEE 802.3] IEEE Standards Association IEEE 802.3 (2008), *IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications*.
- [IEEE 1588] IEEE Standards Association IEEE 1588 (2019), *IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems*.
- [IEEE 1588v2] IEEE Standards Association IEEE 1588v2 (2021), *Precision Timing Protocol (PTP)*.

### 3 Definitions

#### 3.1 Terms defined elsewhere

This Recommendation uses the following terms defined in [ITU-T G.987]:

**3.1.1 optical distribution network (ODN):** A point-to-multipoint optical fibre infrastructure. A *simple* ODN is entirely passive and is represented by a single-rooted point-to-multipoint tree of optical fibres with splitters, combiners, filters, and possibly other passive optical components. A *composite* ODN consists of two or more passive *segments* interconnected by active devices, each of the segments being either an optical trunk line segment or an optical distribution segment. A passive optical distribution segment is a simple ODN itself. Two ODNs with distinct roots can share a common subtree.

**3.1.2 optical line termination (OLT):** A network element in an ODN-based optical access network that terminates the root of at least one ODN and provides an optical access network (OAN) service node interface (SNI).

**3.1.3 optical network unit (ONU):** A network element in an ODN-based optical access network that terminates a leaf of the ODN and provides an OAN user network interface (UNI).

**3.1.4 passive optical network (PON) system:** A combination of network elements in an ODN-based optical access network that includes an OLT and multiple ONUs and implements a particular coordinated suite of physical medium dependent layer, transmission convergence layer, and management protocols.

## 3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

**3.2.1 OLT CT:** Each of the physical ports in the optical line terminal (OLT) that connects to/from a fibre of the optical distribution network (ODN) is named as channel termination (CT). In the context of wavelength router-based transmission it is interpreted as terminating a channel pair (CP).

**3.2.2 channel pair:** A set of one downstream wavelength channel and one upstream wavelength channel that provides connectivity between an OLT and one ONU.

**3.2.3 channel group:** A set of channel pairs (CPs) carried over a common fibre.

**3.2.4 inter channel termination protocol (ICTP):** A protocol that is executed between the OLT CTs to enable functions such as protection management.

**3.2.5 multiple channel termination module (MCT):** A specific implementation at the OLT network element that terminates multiple WR-ODN based WDM PON system (WRP) channels within a single physical module in a WRP system.

**3.2.6 wavelength routed ODN:** An optical distribution network where the branching node (splitter) is wavelength selective and the port to which an ONU is connected determines the channel pair (CP) to be used for communications.

## 4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AN	Access Node
CBU	Cellular Backhaul Unit type ONU
CG	Channel Group
CP	Channel Pair
CPRI	Common Public Radio Interface
CT	Channel Termination
ICTP	Inter Channel Termination Protocol
MCT	Multi Channel Termination Module
OAM	Operations, Administration and Maintenance
OAN	Optical Access Network
OBSAI	Open Base Station Standard Initiative
OC	Operation Control
ODN	Optical Distribution Network
OLT	Optical Line Terminal
ONU	Optical Network Unit
OPS	Optical (achromatic) Power Splitter
PAYG	Pay As You Grow
PLOAM	Physical Layer Operations, Administration and Maintenance
PON	Passive Optical Network
R/S	Receive/Send Reference point at ONU side

SNI	Service Node Interface
S/R	Send/Receive Reference point at OLT side
UNI	User Network Interface
WDM	Wavelength Division Multiplexing
WR	Wavelength Router
WRP	WR-ODN based WDM PON system
WR-ODN	Wavelength Routed ODN

## 5 Conventions

This Recommendation uses conventions defined in [ITU-T G.9802].

## 6 Architecture of the WR-ODN based WDM PON

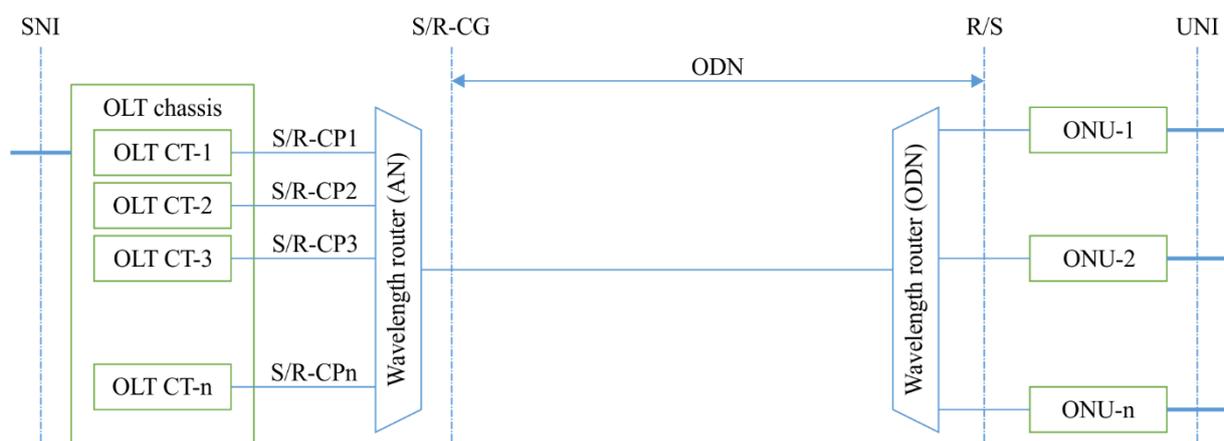
### 6.1 System architecture overview

A WR-ODN based WDM PON system (WRP) consists of the wavelength multiplexing of several channel terminations (CTs), each providing bi-directional connectivity through a pair of wavelengths constituting a channel pair (CP). The system architecture described in this Recommendation is adapted from Figures 6-1 and 6-11 in [ITU-T G.9802].

The passive wavelength router (WR) sits in the ODN routes in each of the CP constitutive of the channel group (CG), towards a different physical drop port. In Figure 6-1, the ODN wavelength routing function is located in a single device, multiple stage structures are also possible but out of the scope of this Recommendation.

In Figure 6-1, all CTs are located in the same OLT chassis, and each ONU is associated with a single CP, where the access node (AN) side WR may reside in the OLT chassis. Options in which CPs are originated from different OLT chassis and ONU retrieving several CPs are also possible. Both these options are out of scope of this Recommendation.

NOTE – Since no backward compatibility with legacy ONUs is considered, the term ONU is equivalent to WRP ONU in the present Recommendation.



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**Figure 6-1 – Functional architecture and reference points for WRP**

### 6.2 Common requirements

The WRP systems should support:

- The symmetric nominal line rate combination options per CP:
  - 25 Gbit/s
  - 10 Gbit/s
  - other nominal line rates are FFS
- Simultaneous support of 25 Gbit/s CT and 10 Gbit/s CT on different CPs are required. The nominal line rate per CP can be changed by replacing the CT.
- 12/20/40 wavelength CPs for WR-ODN.
- A WRP ONU shall be wavelength agnostic and usable on any of the ONU side ports of the WR in the ODN.

### 6.3 WR-ODN system reference layering

The layered structure of a WRP is shown in Table 6-1. The protocol reference model is divided into the transmission convergence (TC) and physical medium dependent (PMD) layers, which are the two layers considered in this Recommendation.

The WRP TC layer is divided into PON transmission and adaptation sublayers, which correspond to the transmission convergence sublayer of the tributary units conveying various data types. The PON transmission sublayer terminates the required transmission function on the ODN. The PON-specific functions are terminated by the PON transmission sublayer, and it is not seen from the adaptation sublayer.

**Table 6-1 – Layered structure of WRP**

Path layer			
Transmission media layer – Note	Transmission convergence (TC) layer	Adaptation	Encapsulation
		Transmission	Service transporting Privacy and security Synchronization Management capabilities
	Physical medium dependent (PMD) layer		Electrical/optical adaptation Wavelength division multiplexing (WDM) Fibre connection
NOTE – The transmission medium layer must provide the related operations, administration and maintenance (OAM) functions.			

### 6.4 Compatibility and migration scheme

Two main scenarios for WRP have been identified:

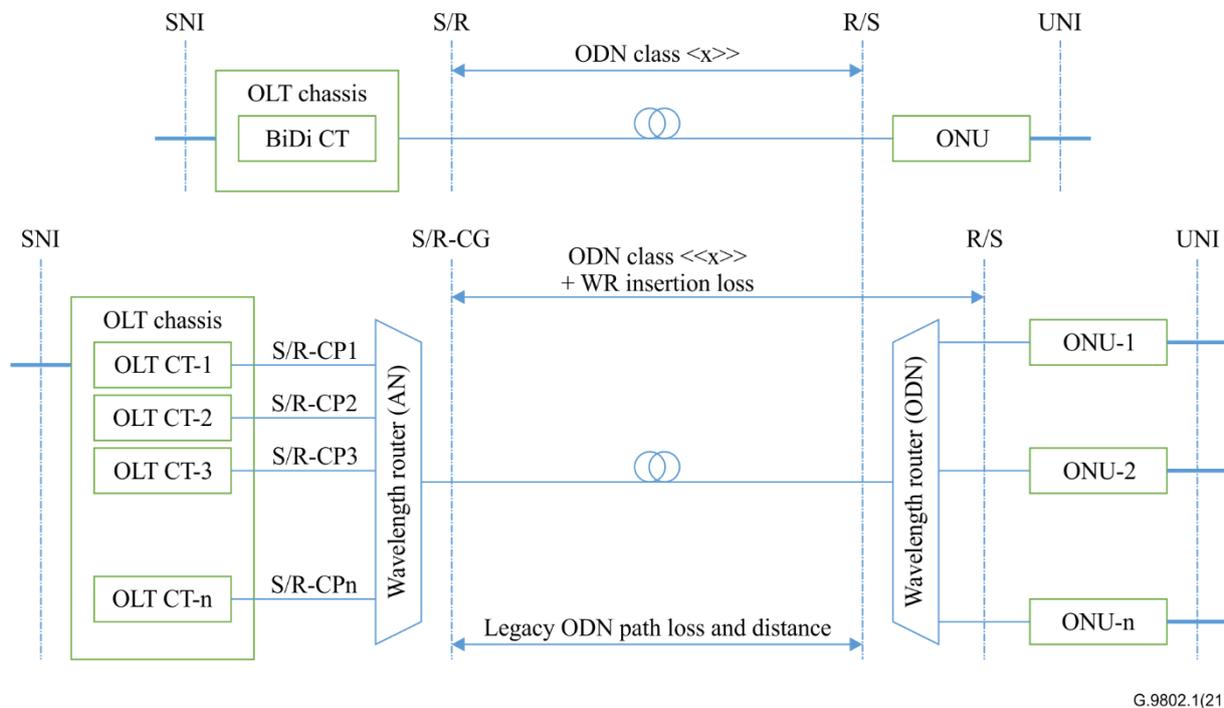
- a) Greenfield in which the ODN will be newly built;
- b) Brownfield in which WRP will be used to upgrade an existing single fibre link, as shown in Figure 6-2.

While in the greenfield scenario, the optical budget is not constrained, convergence with existing well established budget classes is preferable to maximize the benefit from existing modules and avoid an optoelectronic modules market split.

Thus, the optical budget classes of [ITU-T G.989] and [ITU-T G.9806] will be considered for re-use.

When WRP systems are intended for brownfield deployment, the ability to cover the legacy optical budget classes of point-to-point ODNs defined in [ITU-T G.986] and [ITU-T G.9806] is required.

Thus, solutions for legacy optical budget classes with the addition of the WR device's insertion loss are necessary, as represented in Figure 6-2. Class « x » is to be understood as any of the relevant legacy optical budget classes with also due consideration of the legacy link length.



**Figure 6-2 – Upgrade example of a legacy link (at the top) to a multi-channel one (bottom)**

In addition to line rate and distance options, full simultaneous mixing of CT/CPs with different optical budget classes is required.

Pay as you grow (PAYG) provisioning of optical modules is required to allow control of both installation costs and power savings.

Replacement of transceivers on a per CP basis should be made possible to enable future technology migrations, either to higher line rates or towards less power-hungry solutions.

Co-existence with legacy PON is for further study.

## 7 Service requirements

WRP should support mobile fronthaul, midhaul and backhaul services as the first step. Support of high-end residential or business services is not precluded.

Mix-generation antenna sites should be supported. In this context, synchronization enablers including synchronization interfaces are of utmost importance.

### 7.1 Service specific requirements

In order to provide the necessary capacity to convey the targeted wireless flow in its entirety, it requires the offering of transparent forwarding with minimal delay and jitter.

### 7.2 User network interfaces (UNI)

UNI is defined as the interface that includes the following conditions:

- Interconnection between the access network and the customer;

- Described by a well-known standard;
- Includes a physical layer aspect.

Examples of UNIs, physical interfaces, and the services that they provide are shown in Table 7-1.

**Table 7-1 – Examples of UNI and services**

UNI (Note 1)	Physical interface (Note 2)	Service (Note 3)
1 Gbit/s /10 Gbit/s /25 Gbit/s Ethernet [IEEE 802.3] Copper based UNI	1000/10G/25G BASE	Ethernet, or Ethernet based eCPRI (see [b-eCPRI])
1 Gbit/s/10 Gbit/s/25 Gbit/s [IEEE 802.3] Fibre based UNI	1000/10G/25G BASE	Ethernet, or Ethernet based eCPRI (see [b-eCPRI])
Common public radio interface (CPRI) / Open base station standard initiative (OBSAI)	Option2, Option3 Option7, Option8, Option10	Wireless fronthaul
1 PPS	1PPS	Synchronizing interface
NOTE 1 – There are many other services accommodated in WDM PON, but those services do not have specified UNIs. NOTE 2 – Each item in the "Physical interface" column is illustrated by the corresponding entry in the "UNI" column. NOTE 3 – The column labelled "Service" shows which services can be supported by the physical interface.		

### 7.3 Service node interfaces (SNI)

SNI is defined as the interface that includes the following conditions:

- Interconnection between the access network and the service node;
- Described by a well-known standard;
- Includes a physical layer aspect.

Examples of SNIs, physical interfaces and services that they provide are shown in Table 7-2.

**Table 7-2 – Examples of SNI and services**

SNI (Note 1)	Physical interface (Note 2)	Service (Note 3)
1 Gbit/s / 10 Gbit/s / 25 Gbit/s 40 Gbit/s / 50 Gbit/s 100 Gbit/s / 200 Gbit/s / 400 Gbit/s – [IEEE 802.3]	1G/10G/25G/40G/50G/100G/ 200G/400G BASE	Ethernet, or Ethernet-based eCPRI (see [b-eCPRI])
CPRI/OBSAI	Option2, Option3, Option7, Option8	
NOTE 1 – There are many other services accommodated in WDM PON systems, but those services do not have specified SNIs. NOTE 2 – Each item in the "Physical interface" column is illustrated by the corresponding entry in the "SNI" column. NOTE 3 – The column labelled "Service" shows which services can be supported by the physical interface.		

## **7.4 Access node interfaces (ANI)**

Flexible system configurations are required to improve equipment utilisation, reduce power consumption, lower capital expenditure and inventory costs.

To this end, WRP must support flexible and agnostic interfaces to the optical access network (OAN) to enable the OLT network element to accommodate multiple line rate combinations, and modulation formats by the CT replacement. This objective can be achieved by using pluggable access node interfaces.

## **7.5 Synchronization and clock transfer**

WRP OLTs for this application must be able to receive a high-quality timing clock as well as to serve as a master timing source for the ONUs. The ONUs must be able to distribute accurate timing/synchronization to cell sites to meet their frequency/phase/time synchronization requirements.

For this purpose, WRP shall provide a function to transfer the accurate phase/time information between OLT and ONUs while considering the propagation delay and the processing delay between them. Additional inaccuracy incurred in the PON section shall be much less than the reference accuracy to leave margin for other network sections. A summary of the synchronization requirements for different wireless technologies was provided in Table A.II.1 of [ITU-T G.9807.1 Amd. 1].

The mechanisms, for instance, as specified in [ITU-T G.8261] and [ITU-T G.8262], for distributing accurate timing to the 3G/4G/5G cell sites are for further study depending on the performance and economics. Given the extra complexity in delivering timing to applications such as mobile backhaul, the additional functionality might be limited to specific "cellular backhaul unit type (CBU)" ONUs.

Aspects of clock propagation, frequency and time of day synchronization scenarios, and Ethernet synchronization messaging channel (ESMC) messages transport over PON with precision timing protocol [IEEE 1588v2], can be respectively referred to in Appendices A.IV, A.V and A.VI of [ITU-T G.9807.1 Amd. 1].

Descriptive information for synchronizing requirements of 5G transport services can be found in [b-ITU-T G.Sup66].

# **8 Physical layer requirements**

## **8.1 Capacity**

Generally, WRP should be capable of offering sufficient capacity to enable various services required in clause 7. Besides, the WRP should offer an upgrade to greater line rates without foreseeable technology roadblocks or bottlenecks.

### **8.1.1 Aggregate capacity at OLT S/R-CG**

A WRP, which operates over multiple wavelength channels, shall be able to support a nominal line rate per wavelength channel of approximately symmetrical 10 Gbit/s or 25 Gbit/s. Within each wavelength channel, the WRP shall support the same requirements with respect to service rate diversity, a full 10 GigE interface, and a full 25 GigE interface.

### **8.1.2 Capacity at ONU**

A WRP ONU shall be able to support the maximum service rate of approximately 10 Gbit/s or 25 Gbit/s. Note that depending on the target application (e.g., mobile backhaul, mobile fronthaul, etc.) and specific deployment requirements, an ONU may support a lower service rate such as 1 Gbit/s Ethernet, common public radio interface (CPRI) option 3, etc. A WRP ONU is required to offer a 10 Gbit/s or 25 Gbit/s physical interface to the customer. An advanced WRP ONU supporting multiple CPs shall be able to support service rates above/over the maximum service rate for a single channel.



## 9.2 OLT side modularity

OLT CTs, unless intended for protection, should be independent from one another, in line rates and modulation format. On a given CP the replacement of one CT by another combination (e.g., line rate) on the CP must be possible individually.

Given the focus on mobile fronthaul, the OLT design should facilitate multiplexing connectivity (i.e., sum of SNI capacity = sum of ANI capacity).

Ideally the OLT will be able to individually populate the WRP with OLT CT up to its maximal channel capacity. Hot plug-and-play behaviour is expected.

However, since implementations of MCT OLT CT can prove more efficient, a granularity of four and upper is envisioned.

Still in case of such MCT modules, ability to activate them individually and proportionality of power consumption to activated CPs is requested.

## 9.3 ONU side modularity

Given the focus on mobile fronthaul, generally there are two ONU design options according to ONU form factor and RU connection mode that needs to be addressed:

- 1) **Module option:** The ONU is implemented as a pluggable stick supporting only one CP, which is convenient for deployment by plugging it into RU, saving space and minimizing the power supply requirement. In this option, optical penalty and limitation on management channel should be considered. Hot plug-and-play behaviour and dying gasp feature is expected.
- 2) **Device option:** The ONU is a standalone device with one or more CPs, which can serve single or multiple RUs in a site. In case of serving multiple RUs, ability to activate each CP individually is requested.

## 9.4 Interoperability

The optical access equipment implemented under the WRP suite of ITU-T Recommendations is expected to be fully interoperable as far as OLT and ONU are concerned, and support open, standards-based interfaces for any external functions.

## 9.5 Security

High levels of security are required from WRP especially as they are meant to provide high end users and high-end application traffic. Despite the inherent isolation provided by the WR, physical layer security, secure authentication and an optional encryption method should also be provided.

# 10 Operational requirements

## 10.1 Provisioning method

The provisioning methods for WRP systems will reflect the versatility required by the variety of services to be conveyed. This will specifically have to address the diverse requirements of synchronizing schemes and the necessity to estimate the transmission delay between OLT CT and ONU for any CP.

Individual provisioning of OLT CT is required to provide a full PAYG capability even in case of OLT CTs implemented in modules containing multiple CTs (aka MCT).

In order to enable a sanity check of the OLT CT together with the ODN prior to ONU connection, the means to check adequate transmit power and establish an optical path loss measurement must be

provided. An operation control (OC) message derived from the one described in clause 8.3 of [ITU-T G.9806] is required.

Since only colourless ONUs will be used over a WR-ODN, automated discovery by both ends under OLT CT initializing is required.

Authentication methods will be replicated from [BBF TR-156].

Management of CGs ending at a same remote site will be provided enabling correlated monitoring and troubleshooting experience.

## **10.2 Test and diagnostics function**

The goal of WDM PON supervision is to reduce the operational expenditure of the PON systems, without significantly increasing the capital expenditure by including all necessary test and diagnostic capability in full compatibility with the required bandwidth and time transfer performances required by the targeted services.

A test and diagnostics function are mandatory to support, and it shall be non-service affecting. Current ITU-T legacy PON's capabilities of basic testing and diagnostics, which operates at the PON and data layers, with reporting back of alarms and events, shall be taken as a basis for WRP.

## **10.3 System management and monitoring**

Network operation simplification requires managing the WRP system (i.e., the sum of all CTs together with their respective ONUs), as a single entity, with ONUs being managed via OLTs, wherever possible. Therefore, WRP shall support full PON real-time management through ONU management and control functions. Concepts and approaches implemented for legacy PON (e.g., OMCI) should be reused as much as possible.

Given the significant effort already expended in defining a converged management framework across optical access systems, ONU management in WRP systems must be based on OMCI ([ITU-T G.988]) suitably augmented with WRP specific MEs.

The method of conveying physical layer operations, administration and maintenance (PLOAM) and OMCI messaging described in [ITU-T G.9806] will be re-used for Ethernet based transmission.

For some applications like mobile fronthaul, operations, administration and maintenance (OAM) requirements may focus on optical layer control and supervision, with the dying gasp function for the possible outage event in the emergency case.

End-to-end performance monitoring enables operators to diagnose and register where customer traffic may have been dropped or throttled. Higher layer tools, such as Ethernet performance monitoring, need to support the capability of monitoring and the verification of ingress and egress traffic flows in PON network elements.

For services requiring transparent transmission, keeping bitstream integrity, a method to add necessary management information transparently within the tolerance of the service to be conveyed must be supported.

For the above requirements, a minimum number of OAM signal transmission methods should be defined to avoid the market split. For example, methods to carry the OAM signals can be similar to (1) Transparent AMCC specified in [ITU-T G.989.2], (2) Transcoding AMCC specified in [ITU-T G.989.3], (3) Overcoding AMCC which is to externally apply one of the xByB coding defined in Transcoding AMCC to the binary client signal, and (4) OAM Ethernet frames specified in [ITU-T G.986] and [ITU-T G.9806].

Note that the management channel capacity should enable software download without service interruption.

For dual managed ONUs, the WRP system shall optionally support collaborative ONU management partition between WRP OMCI and remote configuration mechanisms for all types of ONU accommodated.

#### **10.4 System troubleshooting**

The notion of common management of events across CP gathered in logical groups is expected to help per remote site troubleshooting.

PON systems with their monitoring and control systems will allow operators to decide on the utilization of proactive or reactive fault repairs in most fault cases. It is of course up to the operators to decide how to use PON status reports.

#### **10.5 Environmental and physical requirements**

Outdoor operation may be needed in many of the envisaged applications for WRP systems; thus, ONUs shall operate over outdoor temperature ranges. The following are informative examples of environmental requirements:

- ATIS-0600010.01.2008: (Class 4 unprotected environment)  
*–40°C to either +46°C ambient plus solar loading, or +70°C ambient*
- Telcordia GR-487  
*–40°C to either +46°C ambient plus solar loading, or +70°C ambient*
- ETSI ETS 300 019-1-4: (Class 4.1E: Non-weather protected locations – extended)  
*–45°C to +45°C ambient plus solar loading*

Optionally, the OLT should also be able to operate over the extended outside temperature range.

#### **10.6 Energy saving objectives**

The ultimate target of energy efficiency should be that zero payload is to be conveyed equals zero power consumed and that power consumption per channel is proportional to the payload to be conveyed.

Following the PAYG principle, an OLT CT that hasn't been logically provisioned should induce no power consumption. As long as no ONU is responding on the CT's CP, the power consumption of the OLT CT should remain negligible.

Even in the case of OLT CTMCT, the individual power up/down function of the OLT CT is required.

WRP systems will provide the best user and network energy efficiency experience combining sleep periods behaviours when the link is idle.

Power saving mechanisms are required and mechanisms including ITU-T PON sleep modes and line rate switching during low duty periods will be considered. Necessary adjustments can be tailored to the actual payload to be conveyed.

#### **10.7 Eye safety**

All necessary mechanisms must be provided to ensure that no eye damage can be caused to field operations in case of crews unaware of the risks associated with access to fibre, including labelling and safety locking mechanisms if necessary. The system must meet all applicable requirements for the classification, service group designation, and accessibility to ensure the safe operation and servicing of the optical fibre communication system at each node. Since the WRP features a multiplicity of CPs in the feeder section, the total optical power resulting from one CT at send/receive reference point at OLT side (S/R)-CP and the sum of all the wavelengths at S/R-CG on the fibre must be within the safe operation range.

The WRP network elements need to conform to the following specific classes defined in [IEC 60825-2], respectively:

- Class 1M for OLT,
- Class 1 for ONU,
- Class 1M for RE.

## **11 Resilience and protection on ODN**

Mechanisms required for operation over a WR-ODN should be made compatible as much as possible with operation over optical (achromatic) power splitter (OPS) (e.g., as per ITU-T G.989.1 principles). This will enable network elements to be made compatible at logical level for chipsets.

### **11.1 Rogue behaviour prevention, detection and mitigation**

Given the optical access legacy of ONUs designed for PON or point to point BiDi transmission implementing silent start behaviour, reciprocal non harming behaviour is required:

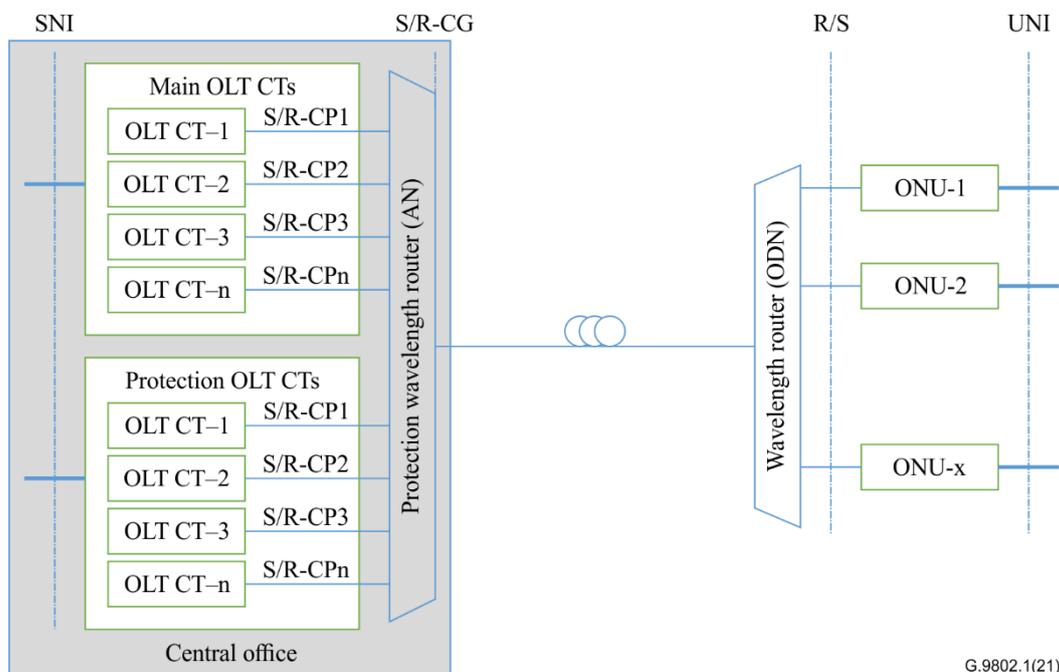
- ONU transmission can only start after recognition of an explicit request to transmit received from an OLT CT;
- As WDM PON local framing is optional and no bandwidth map is provided, ONU identification is still useful for management, indicating that the channel is idle and must be secured:
  - On the ONU side, recognition of an explicit message indicates that the associated upstream wavelength associated to the downstream wavelength to constitute a CP must be provided by the OLT;
  - From the upstream direction signal, the OLT CT must secure that if transmitting, it does not collide with an already transmitting parallel OLT CT operating on the same wavelength. Such situations that could occur in certain protection schemes have to be prevented.
- Means to prevent misinterpretation between sleeping periods and idle status must be provided. So silent start timers must exceed the maximal sleep period to cover at least one wake-up sequence.

### **11.2 CT failure protection**

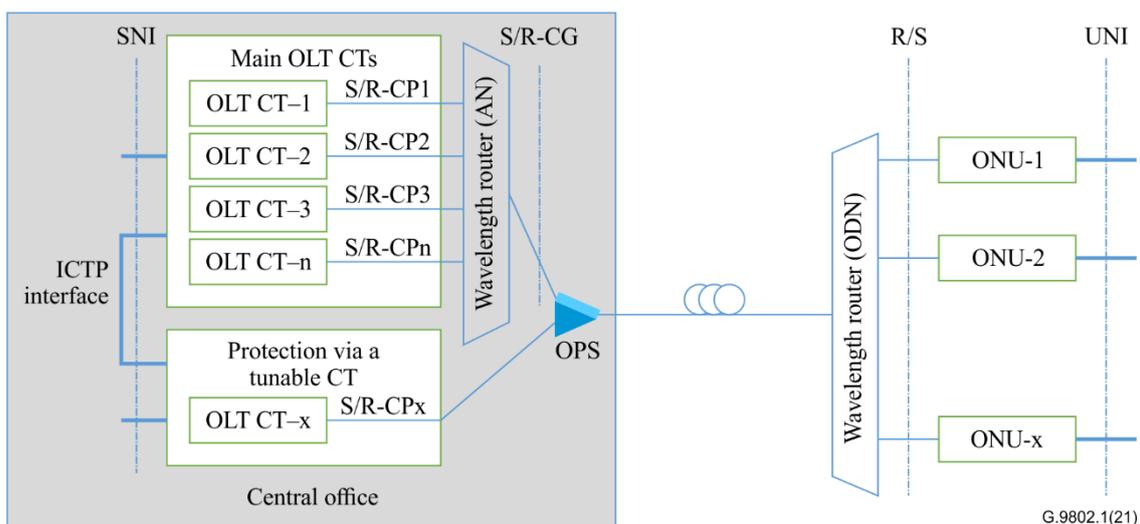
Given the nature of the WR-ODN WDM PON architecture, since using the same CP, CT protection is equivalent to the corresponding ONU protection as shown in Figure 11-1 with a specific WR structure in which an OPS function is embedded.

Design options of the WR boxes in the following figures are for further study.

Similarly, usage of a tunable single protection CT will require an introduction of an OPS in Figure 11-2.



**Figure 11-1 – Example of full CT protection**



**Figure 11-2 – Example of individual CT protection through an OPS and a tunable CT**

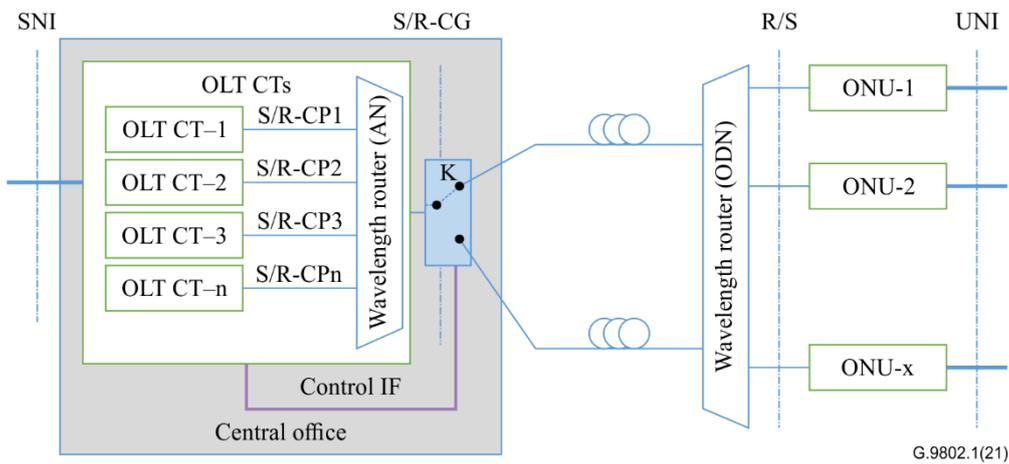
In case of concurrent OLT CT operation on a given CP, special care must be taken to coordinate the OLT CTs.

Even if inter channel termination protocol (ICTP) (See [b-BBF TR-352]) is used, each OLT CT must implement a silent start behaviour to prevent any collision.

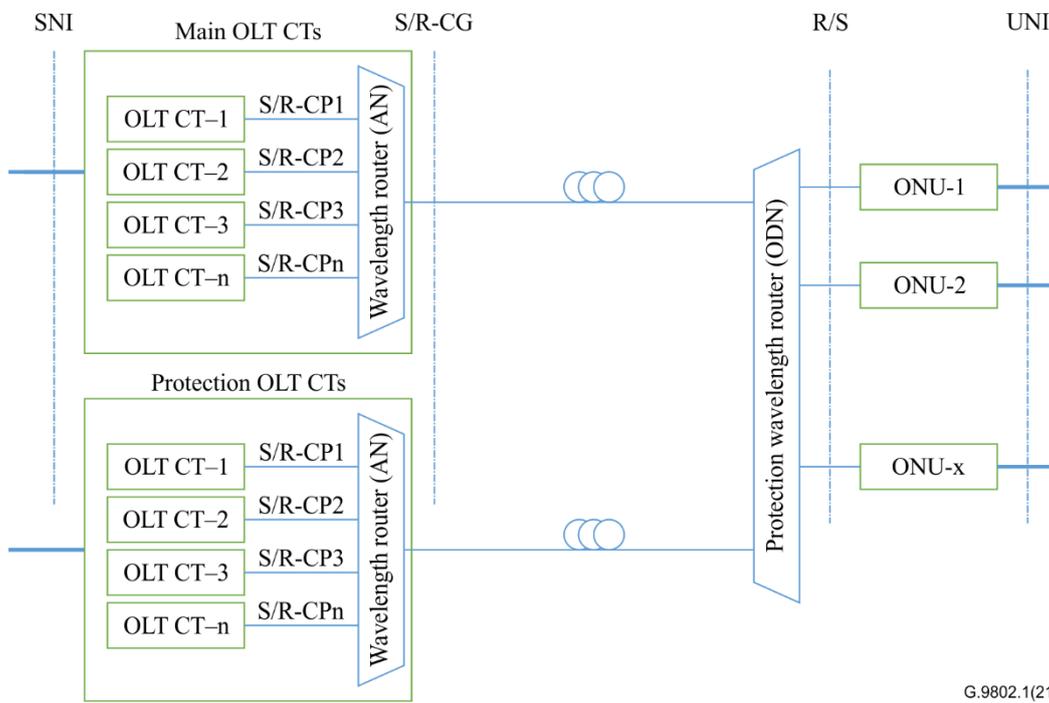
### 11.3 ODN failure protection

Protection of the feeder section with single attachment in Figure 11-3 or through a redundant OLT located in the same CO or through dual attachment in Figure 11-4.

Details of the necessary structure of local and remote feeder protection enabling WRs or additional devices are for further study and impact on an optical budget should be kept minimal.



**Figure 11-3 – Example of feeder protection through single OLT through an external optical switch**



**Figure 11-4 – Example of feeder protection through dual OLT**

## Bibliography

- [b-ITU-T G.Sup66] ITU-T G Sup. 66 (2020), *5G wireless fronthaul requirements in a passive optical network context*.
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