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Recommendation

ITU-T G.9802.1 (2021) Amd. 1 (02/2023)

SERIES G: Transmission systems and media, 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
Amendment 1

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Recommendation ITU-T G.9802.1

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

Amendment 1

Summary

Recommendation ITU-T G.9802.1 describes the general requirements for wavelength-routed optical distribution network (ODN) based wavelength division multiplexed passive optical networks or WDM-PONs. The general architecture and system level requirements, such as line rates, capacity in terms of channel count, optical line termination (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.

Amendment 1 adds requirements on failure protection for channel terminations (CTs), ODNs or both in wavelength-routed passive optical networks (PONs).

History *

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Keywords

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

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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Amendment 1

Editorial note: This is a complete-text publication. Modifications introduced by this amendment are shown in revision marks relative to Recommendation ITU-T G.9802.1 (2021).

1 Scope

This Recommendation, as part of the multi-wavelength passive optical network (MW-PON) ITU-T G.9802 series of Recommendations, 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, and energy efficiency).

Amendment 1 to this Recommendation adds requirements on failure protection for channel terminations (CTs), ODNs or both in wavelength-routed passive optical networks (PONs).

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 Issue 4 (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 optical distribution network (ODN) and provides an optical access network user network interface or 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 optical line termination (OLT) and multiple optical network units (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 terms:

3.2.1 channel termination (CT): One OLT CT pertains to one channel pair, including a physical port and a logical function. The physical port in the optical line termination (OLT) connects to/from a fibre of the optical distribution network (ODN). The logical function resides at the OLT network element and terminates a single channel pair in a WRP system, from the management TC layer aspect.~~**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 interpretated 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 optical line termination (OLT) and one optical network unit (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 optical network unit (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
AWG	Arrayed Waveguide Grating
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~~Termination

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

Rx Receiver

SNI Service Node Interface

S/R Send/Receive Reference point at OLT side

Tx Transmitter

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

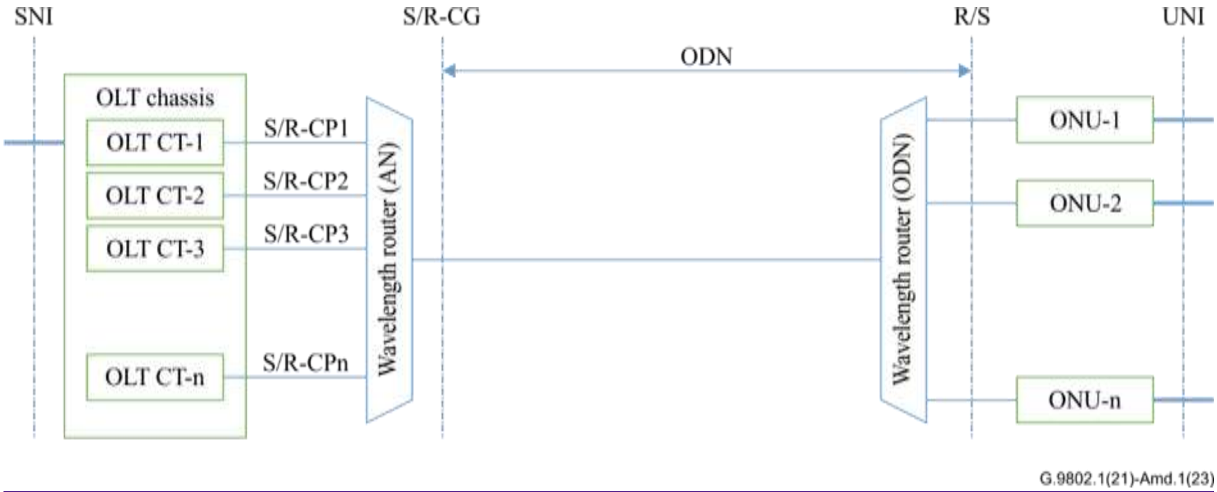
6.1 System architecture overview

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~~ sitting 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 are 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 of 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.



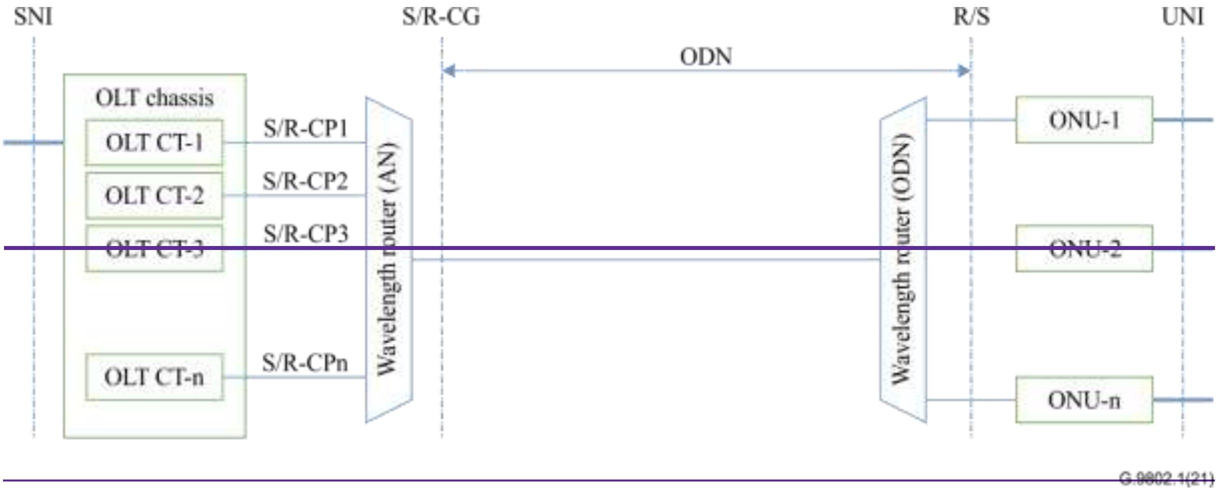


Figure 6-1 – Functional architecture and reference points for WRP

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~~ is 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 so 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

<table>
<tr><th colspan="2">Path layer</th><th></th><th></th></tr>
<tr><td rowspan="3">Transmission media layer – Note</td><td rowspan="2">Transmission convergence (TC) layer</td><td>Adaptation</td><td>Encapsulation</td></tr>
<tr><td>Transmission</td><td>Service transporting
Privacy and security
Synchronization
Management capabilities</td></tr>
<tr><td colspan="2">Physical medium dependent (PMD) layer</td><td>Electrical/optical adaptation
Wavelength division multiplexing (WDM)
Fibre connection</td></tr>
<tr><td colspan="4">NOTE – The transmission medium layer must provide the related operations, administration and maintenance (OAM) functions.</td></tr>
</table>

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 opto-electronic 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.

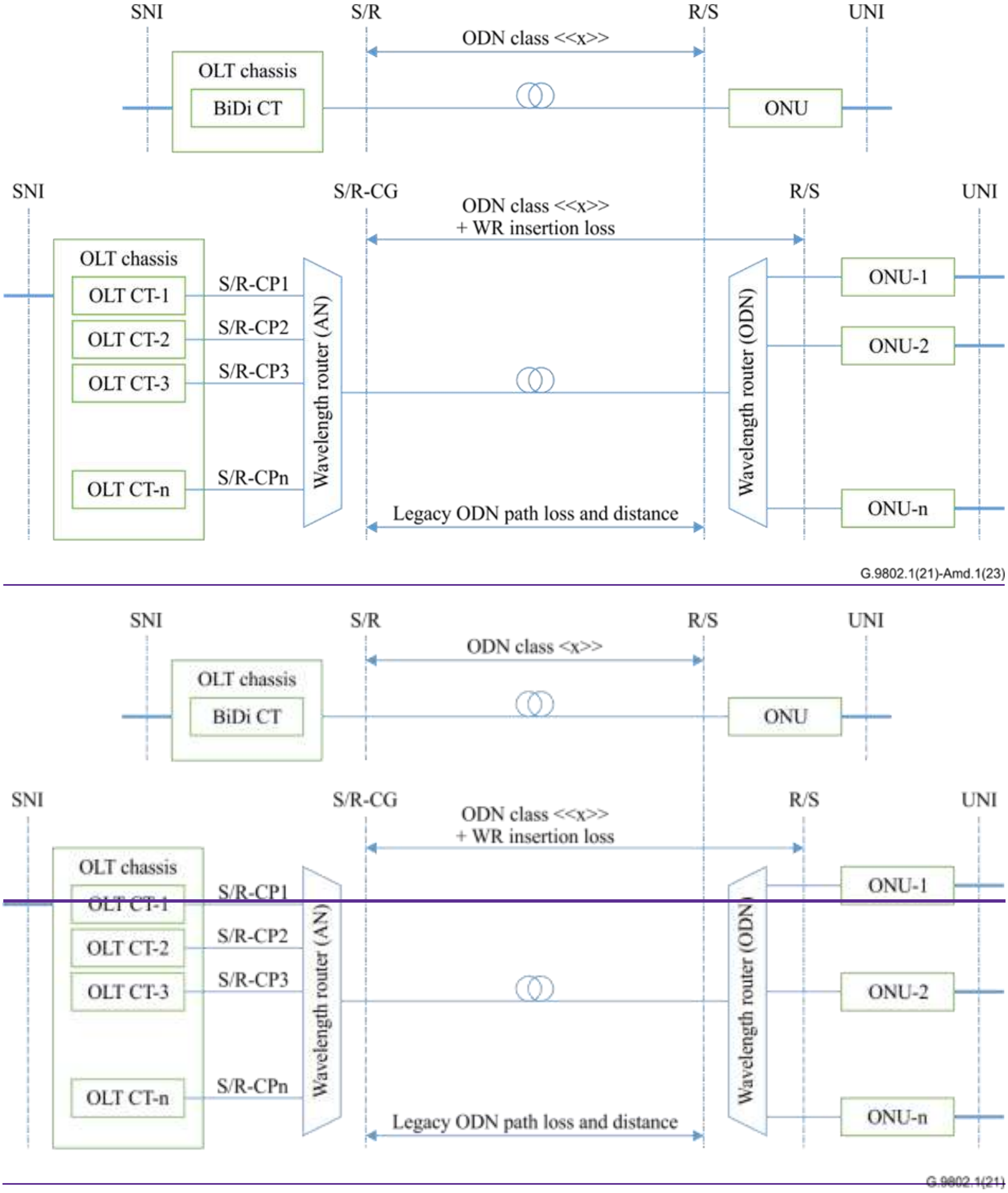


Figure 6-2 – Upgrade example of a legacy link (at the top) to a multi-channel one (bottom)

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~~means to offer transparent forwarding with minimal delay and jitter are required.

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~~ Option 7, Option 8, Option 10	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,~~ Option 7, Option 8, Option 10	
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 utiliz~~s~~ation, reduce power consumption, and 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 a 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~~] (Amendment 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~~ In view of 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~~] (Amendment 1).

Descriptive information for synchronizing requirements of 5G transport services can be found in [b-ITU-T G.Sup.66].

8 Physical layer requirements

8.1 Capacity

Generally, WRP should be capable of offering sufficient capacity to enable the various services required in clause 7. ~~Besides~~In addition, 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~~in excess of the maximum service rate for a single channel.

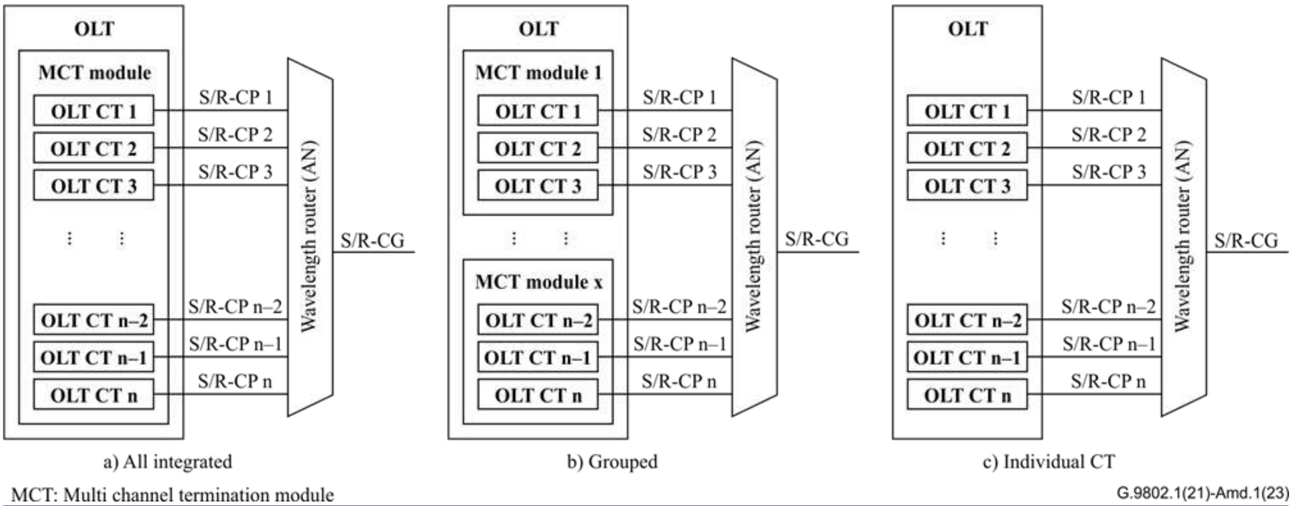
8.2 Support for multiple channel pairs

Given the various deployment scenarios, a WRP OLT shall be able to support multiple CPs, as shown in Figure 8-1.

– All integrated, which means all CPs are supported by a complete and integrated array of CTs within a~~n~~ multiple channel termination (MCT) module;

– Grouped, which means CPs are distributed in several MCT modules, and each MCT module comprises of several CTs;

– Individual CT, which means each CP is supported by an independent CT.



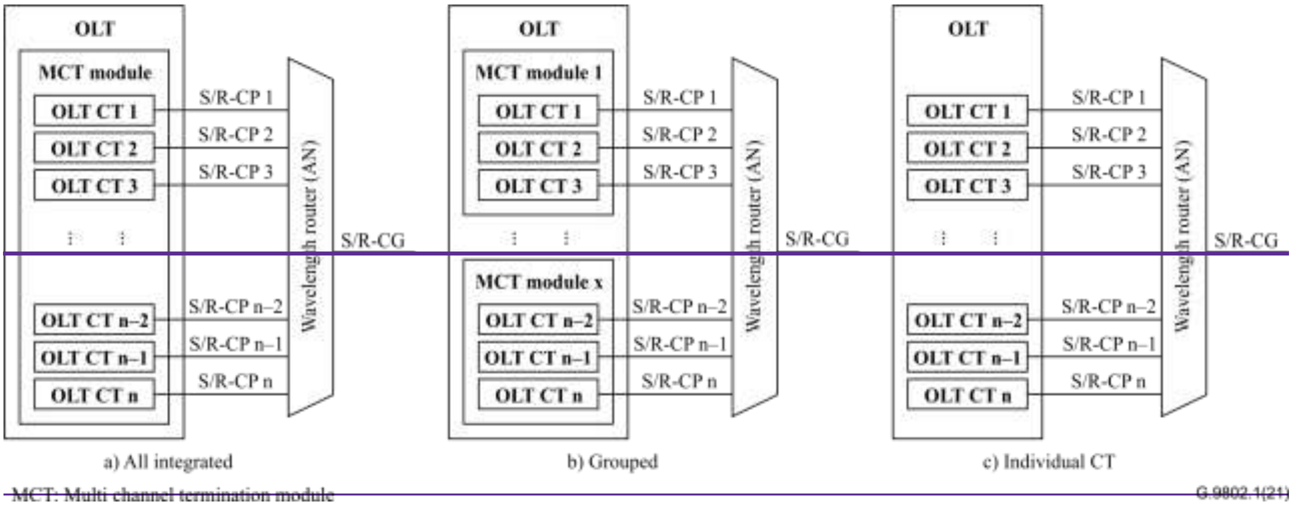


Figure 8-1 – CP integration options

8.3 Wavelength router capability

The WR in the ODN includes wavelength filters (e.g., arrayed waveguide gratings (AWGs)). At the WR, the ODN branches out to drop fibres, one or several for each ONU. Thus, the ONU's wavelengths will be determined by its physical connectivity to the WR in the ODN, e.g., by one port or multi-port on a WR.

8.4 Fibre type and fibre reach

The system must support using fibre types described in [ITU-T G.652] and [ITU-T G.657].

The system must support the maximum fibre distance classes of:

– 0 to 10 km for wireless applications that are latency sensitive;

– 0 to 20 km for a more general purpose and to match the legacy PON ODN minimal reach.

9 System level requirements

9.1 Pay as you grow expectations

The WRP enables ~~the ~~addition of ONUs and OLT CT that are not service affecting to traffic flows that are already up and running.

The replacement of one CT by another combination on the given point-to-point wavelength channel must be individual by conception.

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~~ above 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, and hence 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 operate~~s~~ 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~~ management of 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~~ has not 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~~ in field operations in the 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~~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 compatible 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 in WDM PON local framing is optional and no bandwidth map is provided, and still 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~~ indicating 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~~ Consequently 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 a splitter function is embedded. In this scenario, OLT CTs are protected. The protection OLT CTs are a copy of the working OLT CTs. The physical connection to realize ICTP can be directly connected by OLT equipment, or through the upper layer network.~~an OPS function is embedded~~.

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

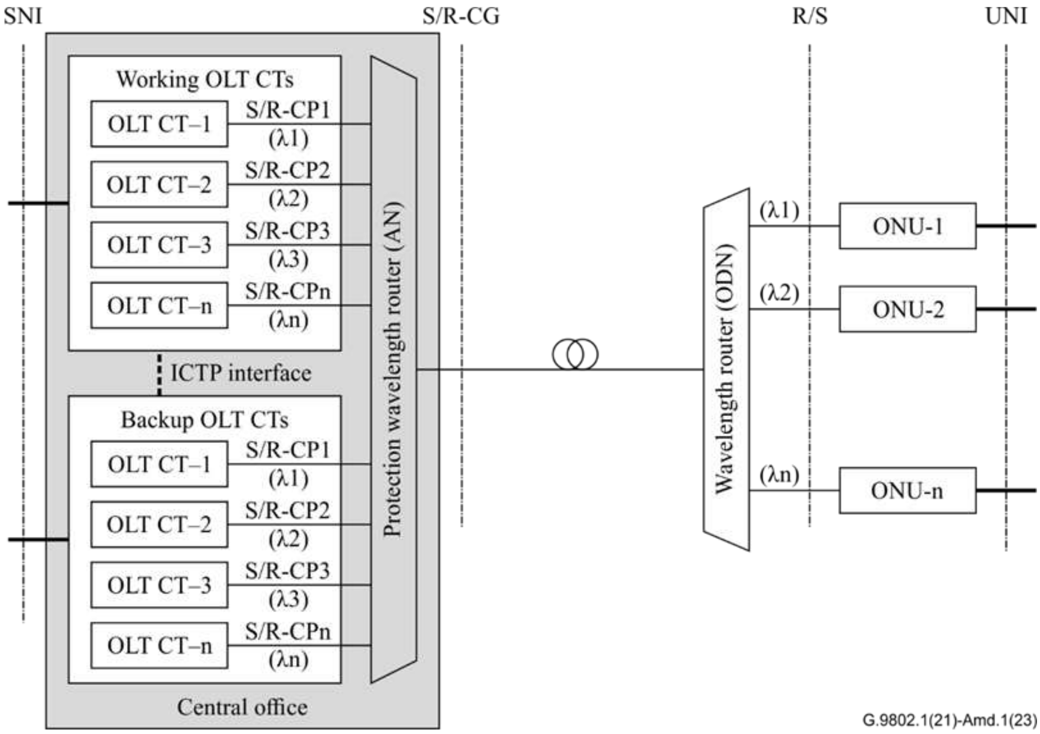


Figure 11–1 – Example of full CT protection scenario

Reference architecture options of protection wavelength router (AN) in a full CT protection scenario is shown in Figure 11-2. In case of reference architecture option a) (with splitter), all backup OLT CTs must be turned off until the protection switchover occurs. For reference architecture option b) (with optical switch), all backup OLT CTs can be turned on during regular working phase, and take over operation when the protection switchover occurs by setting optical switch to corresponding wavelength router (AN).

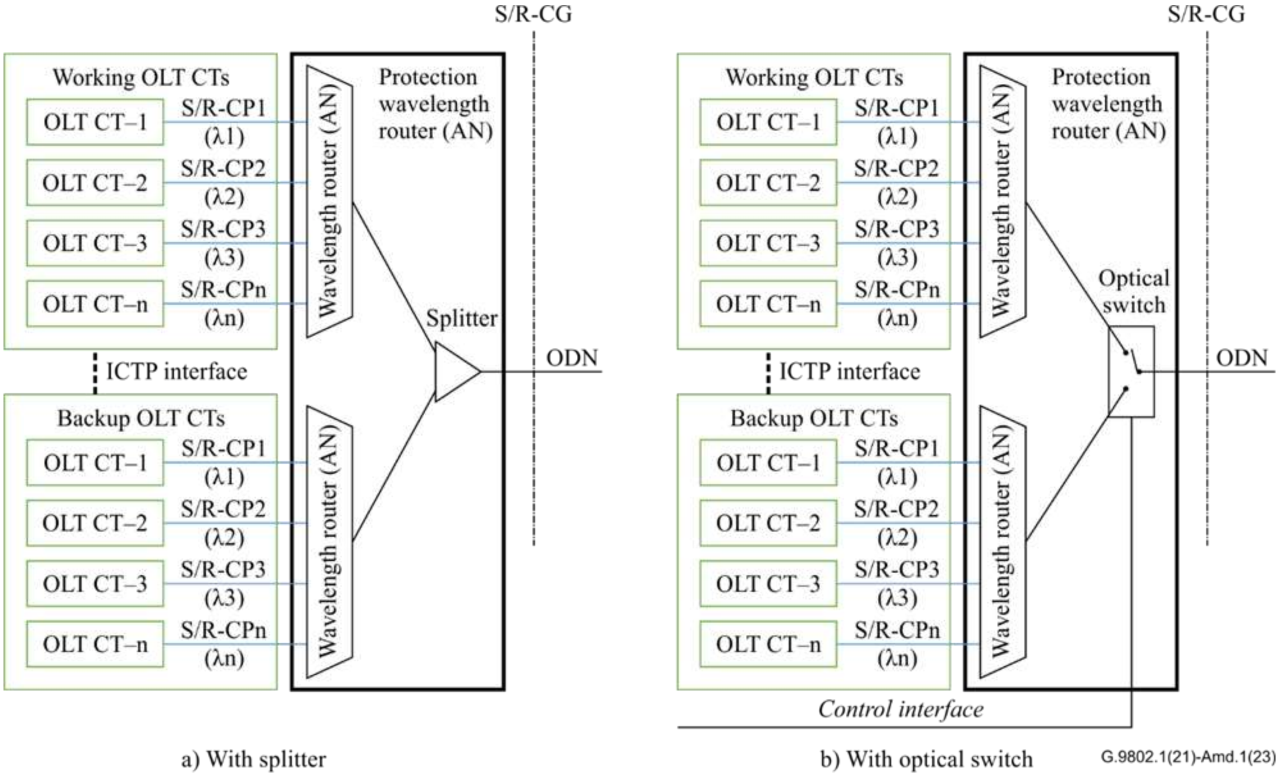


Figure 11–2 – Reference architectures of protection wavelength router (AN) in full CT protection scenario

Similarly, usage of a tunable single protection CT will require ~~an~~ introduction of ~~an OPS~~a splitter, as shown in Figure 11-3~~2~~.

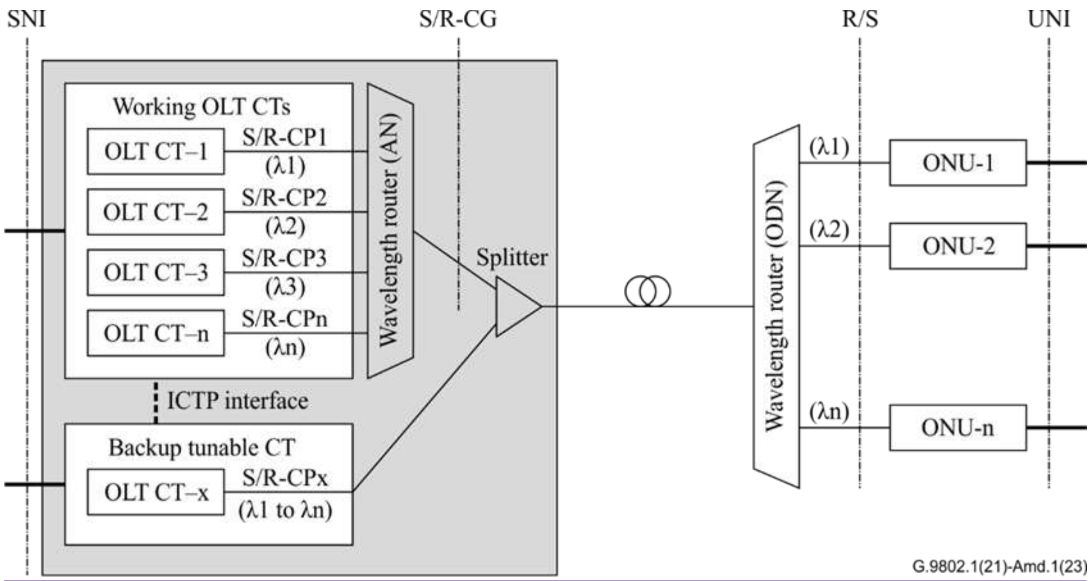
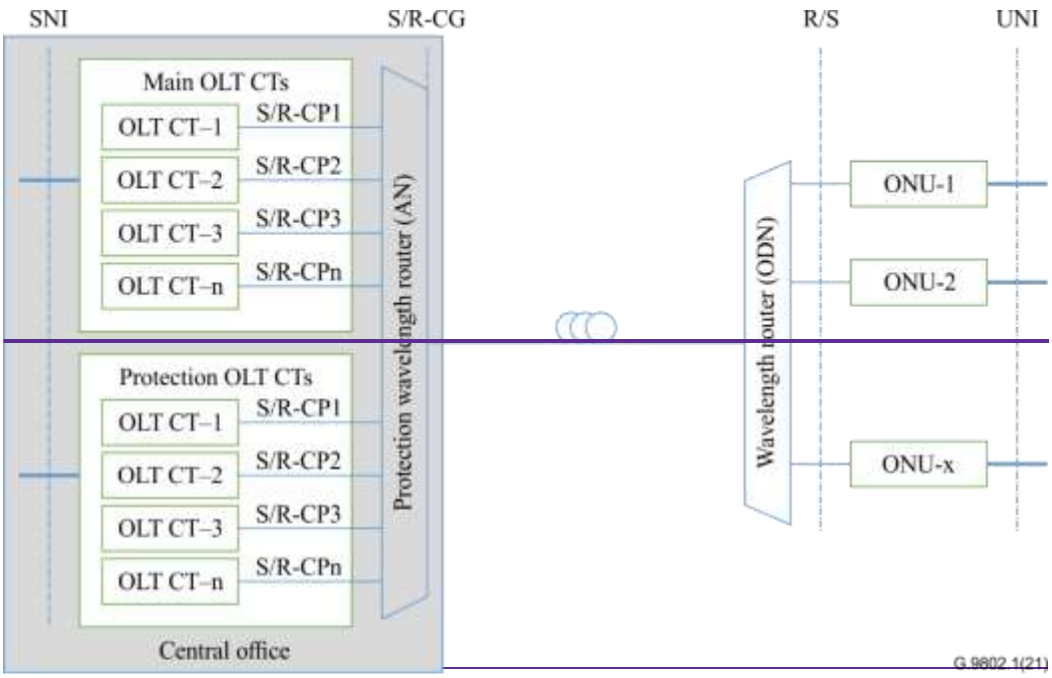
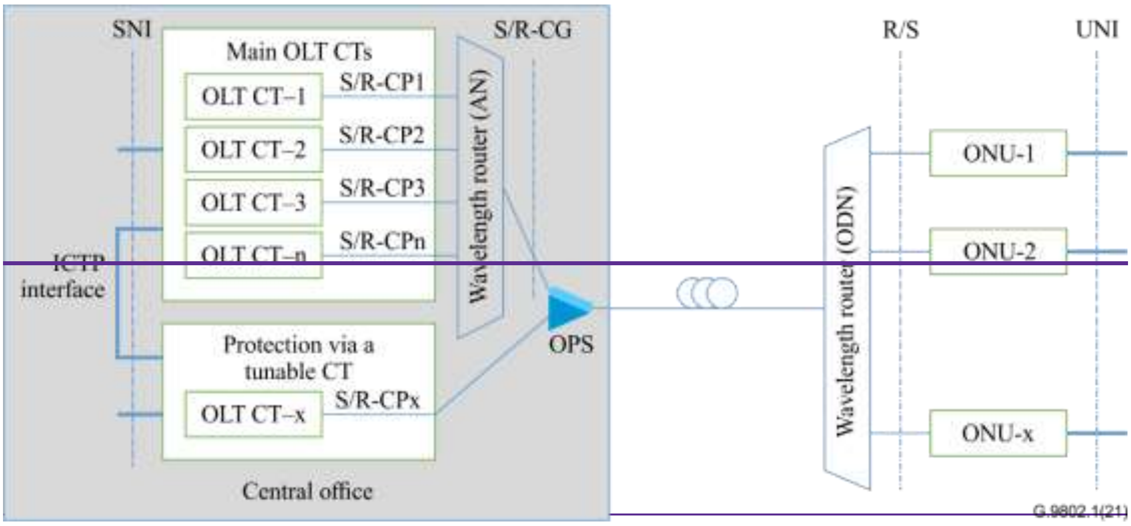


Figure 11–3 – Example of individual CT protection through a splitter and a tunable CT



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



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

In the case of concurrent OLT CT operation on a given CP, special care must be taken to coordinate the OLT CTs. The backup tunable CT can be turned on and set to the corresponding channel pair when the protection switchover occurs, to take over operation for one of the working 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.

In Figure 11-4, a scheme similar to that in Figure 11-3 is shown that protects against a single CT failure. This employs a tuneable CT that provides protection over any one of the other CTs. The ONUs must have the ability to tune over two adjacent wavelengths. Unlike Figure 11-3, two feeder paths are provided to the remote 2:n WR. Reference information for 2:n WR can be found in [b-Dragone] [b-Agrawal]. Note that the backup CT tunes over a shifted wavelength range (channels 2 through n+1) compared to the working OLT (channels 1 through n). This is to account for the two different common ports being used. ONU tuning is required.

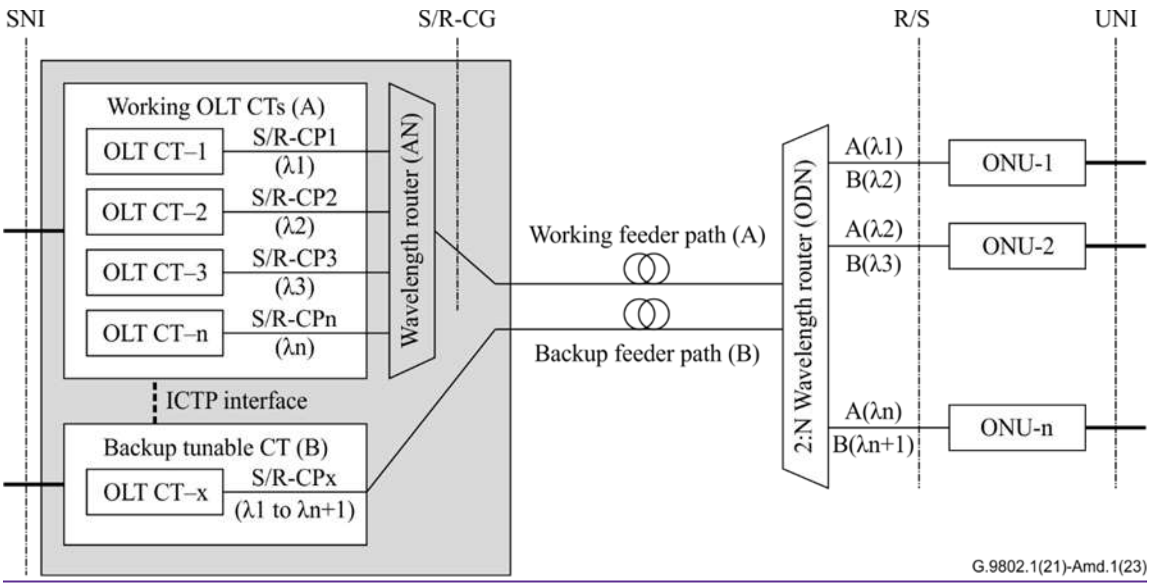
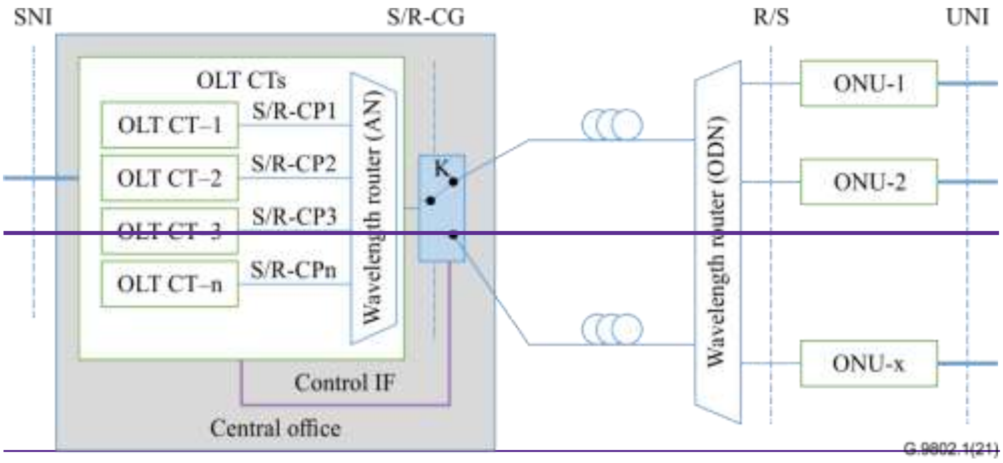


Figure 11-4 – Example of individual CT and ODN protection using a 2:n wavelength router and a tuneable CT

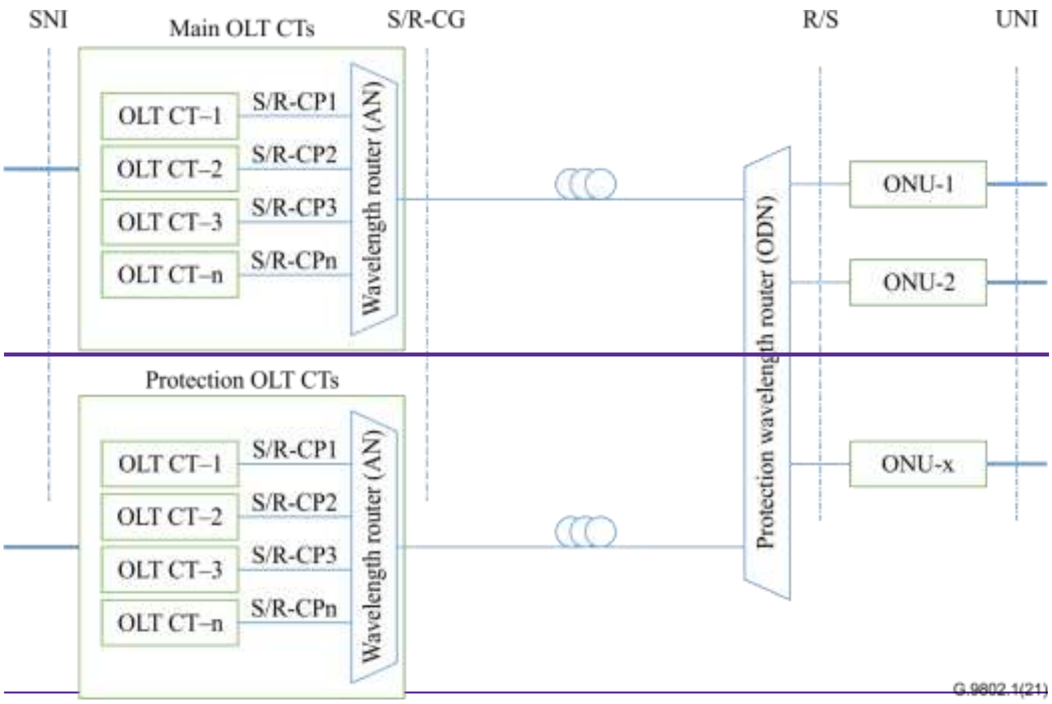
11.3 ODN failure protection

An example of feeder protection through a single OLT with an external splitter is shown in Figure 11-5. The protection switchover occurs by setting optical switch to corresponding feeder path.~~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~~



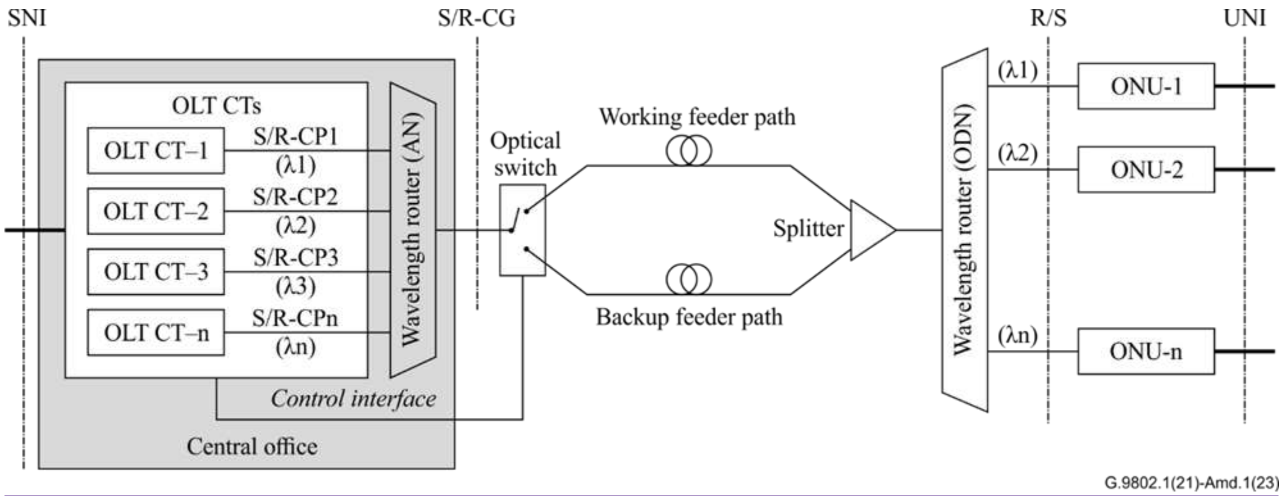


Figure 11–5 – Example of feeder protection through single OLT with an external optical switch

An alternative scheme of ODN protection utilizing 2:n wavelength routers is shown in Figure 11-6. In this case, the OLT CT's and the ONUs must have the ability to tune over two adjacent wavelengths. For example, CT-1 can transmit at λ1 and λ2. The choice of wavelength then determines which feeder path would be used. As the dual input WRs are a matched pair, those two wavelengths would appear at the port for ONU-1, completing the connection. This scheme avoids the use of an optical switch and the splitter. It also has the feature that both feeder paths can be used simultaneously for different channels, thereby providing assurance that the backup path is viable.

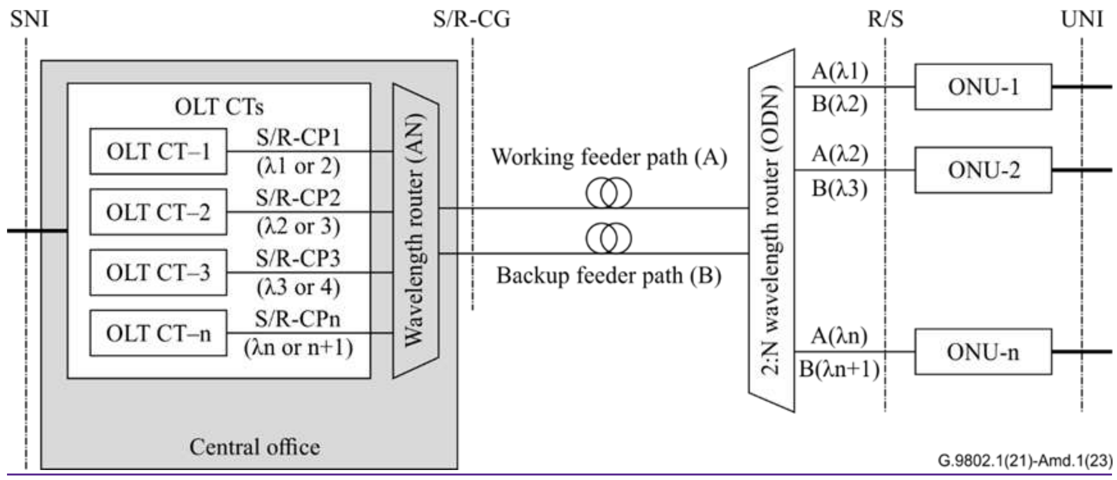


Figure 11-6 – Example of feeder protection using a single OLT with adjacent channel tuneable CTs, 2:n wavelength routers, and tuneable ONUs

11.4 CT and ODN failure protection

An example of feeder protection through dual OLTs is shown in Figure 11-7. In this case, OLT CTs and feeder path are both protected. The protection OLT CTs is a copy of the working OLT CTs, and must be turned off until the protection switchover occurs. This should be taken care of by implementation of the silent start behaviour at the OLT CT side, when detecting upstream data on the given channel pair termination.

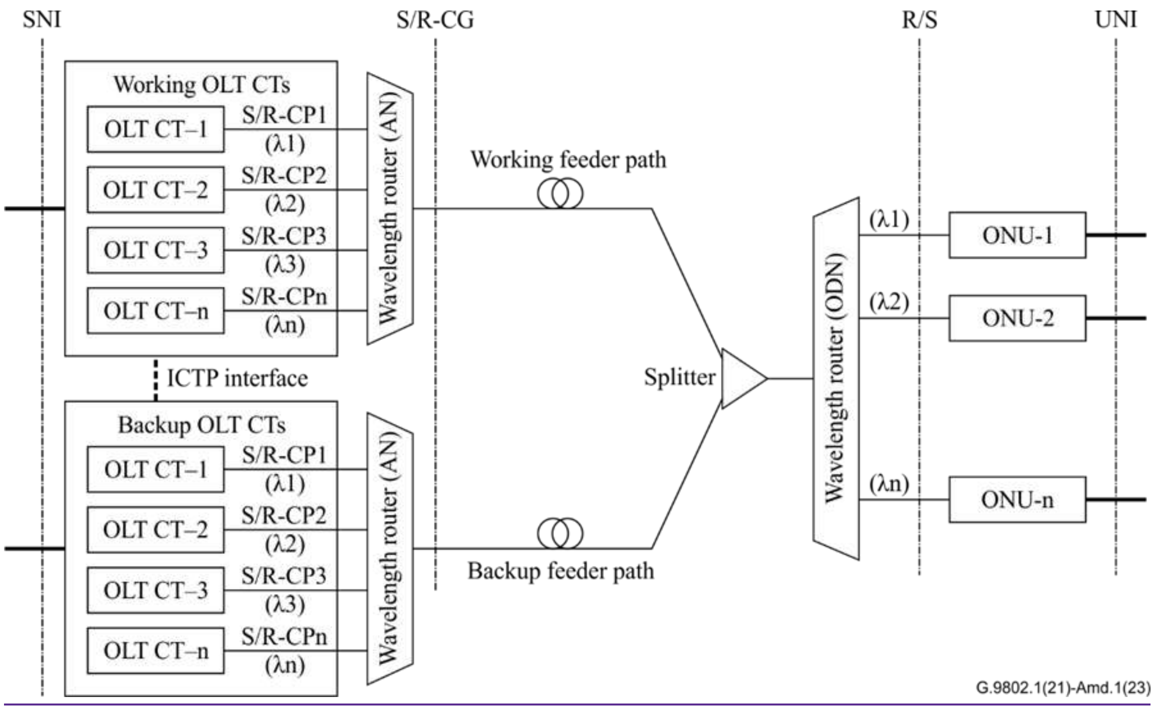


Figure 11–7 – Example of feeder protection through dual OLT

Figure 11-8 shows an alternative method to protect both the CT and feeder path using dual OLTs. A single 2:n WR at the remote node, and tuneable ONUs. Note that the two OLTs wavelength sets are offset by one channel. The working OLT "A" has CT wavelengths 1 through n. The backup OLT "B" has CT wavelengths 2 through n+1. This shift in wavelength is needed so that the 2:n WR delivers a pair of wavelengths to each ONU port. This scheme avoids the use of the splitter and thereby its loss as well.

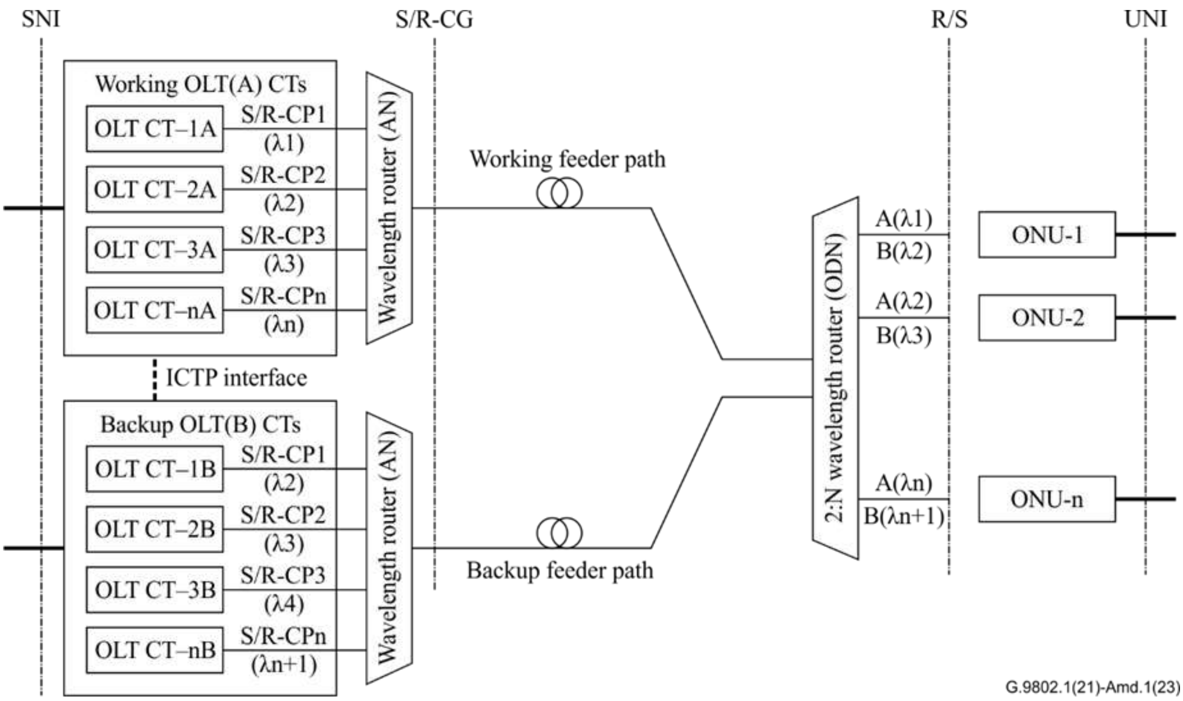


Figure 11-8 – Example of CT and feeder protection using dual OLTs, 2:n wavelength router, and tuneable ONUs.

Figure 11-9 shows a scheme that provides individual CT and ODN protection through the use of adjacent channel tuneable CTs, dual 2:n wavelength routers, and adjacent channel tuneable ONUs. The most important aspect here is that the WR common ports are cross connected. In this way, each ONU port has a wavelength path to two different CT ports, as denoted in the figure. For example, ONU-1 can be connected to CT-2 using channel 2 over the working fibre, or connected to CT-0 using channel 1 over the backup fibre. By correctly tuning the OLT CTs and ONUs, both feeder failure and all single CT failures can be overcome. In fact, about half of the double CT failure cases can be recovered as well. The OLT must have n+2 CTs to serve n ONUs.

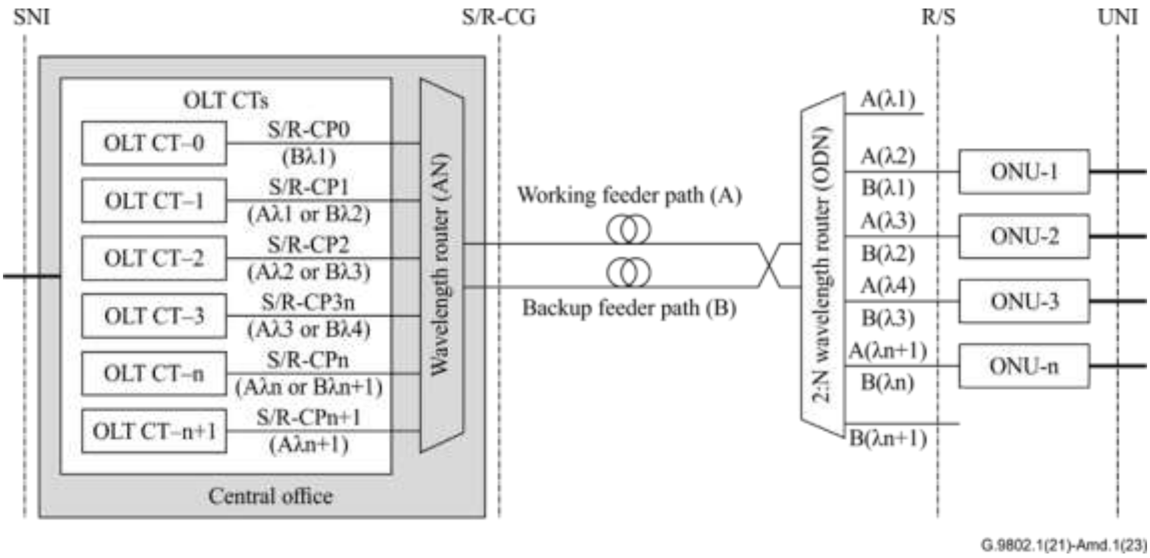


Figure 11-9 – Example of individual CT and feeder protection using tuneable CTs, dual 2:n WRs, and tuneable ONUs

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

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