I n t e r n a t i o n a l   T e l e c o m m u n i c a t i o n   U n i o n

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

G.989.1
Amendment 1
(08/2015)

SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Digital sections and digital line system – Optical line systems for local and access networks

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40-Gigabit-capable passive optical networks (NG-PON2): General requirements

Amendment 1

Recommendation ITU-T G.989.1 (2013) – Amendment 1

International
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ITU-T G-SERIES RECOMMENDATIONS

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

Recommendation ITU-T G.989.1

40-Gigabit-capable passive optical networks (NG-PON2): General requirements

Amendment 1

Summary

Amendment 1 to Recommendation ITU-T G.989.1 (2013) provides additional information on protection and/or restoration in NG-PON2 networks using flexible wavelength scheduling, which is not covered in clause 9.4, as well as other new requirements of the ITU-T G.989-series systems not captured in ITU-T G.989.1 (2013).

Requirements identified for inclusion in this amendment are:

− Network protection in the case of a multi-wavelength access system. In particular, the possibility of ODN topologies that appear to be type B (shared splitter), but that provide additional capabilities. Also, the potential for 1:n protection in addition to the 1:1 protection previously described.

− Transport of wireless fronthaul links over the access system. Such links have exceptional service requirements and these are evolving as the application develops in the industry.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T G.989.1	2013-03-09	15	11.1002/1000/11810
1.1	ITU-T G.989.1 (2013) Amd. 1	2015-08-13	15	11.1002/1000/12557

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

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.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

Table of Contents

Recommendation ITU-T G.989.1

40-Gigabit-capable passive optical networks (NG-PON2): General requirements

Amendment 1

1) Clause 2, References

Add the following new reference to clause 2:

[ITU-T G.989] Recommendation ITU-T G.989 (2015), *40-Gigabit-capable passive optical network (NG-PON2): Definitions, abbreviations and acronyms*.

2) Clause 3, Definitions

Replace clause 3 with the following text:

See [ITU-T G.989] for the definitions used in this Recommendation.

3) Clause 4, Abbreviations and acronyms

Replace clause 4 with the following text:

See [ITU-T G.989] for the abbreviations and acronyms used in this Recommendation.

4) Clause 7.6, High data rate services

Add new clause 7.6 with the following text:

7.6 High data rate services

To accommodate the prospective increase in customer bandwidth demand, NG-PON2 systems may support an optional extension for services in excess of 10 Gbit/s upstream and/or downstream towards one PON client.

5) Clause 9.4, Resilience and redundancy requirements

Replace clause 9.4 with the following text:

9.4 Resilience and redundancy requirements

PON resilience will become more important in supporting business applications and high value consumer applications, such as IPTV, especially in the node consolidation scenario. Node consolidation/bypass creates a high number of subscriber lines on the highly centralized access node. A redundancy mechanism is required to avoid service disruption to potentially thousands of users in the event of fibre cable or equipment failure. Besides the usual hardware redundancy requirements at the OLT and in the backhaul transmission equipment (towards the metro/core), networks require feeder and/or OTL line redundancy options to avoid large scale customer outages as well as full redundancy for business services requiring end-to-end type C protection. NG-PON2 systems must support the resilience options defined in clause 14 of [ITU-T G.984.1] including duplex and dual parenting duplex system configuration as well as the extensions described in Appendices II and III of [ITU-T G.984.1]. For PON redundancy, use cases and guidelines are defined in [b-ITU-T G-Sup.51].

Figure 9-1 shows an example of fibre path diversity ensuring resilience against cuts in the most vulnerable part of the access network. The redundant feeder fibre could terminate at a diverse CO location, or at the same CO location as the primary OLT.

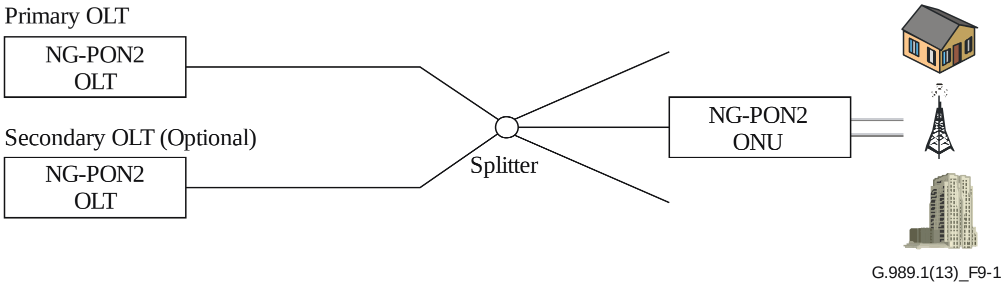

Figure 9-1 – NG-PON2 resilience scenario

Redundant splitters, especially in the highest level of hierarchy, may also be deployed and should be supported. Typically, redundancy requirements become less stringent for the customer premises, unless the end customer is, for example, a large scale enterprise or premium user. In the redundant architecture, rapid restoration may be required. For instance, service interruption time must be less than 50 ms for enterprise or premium users.

The following subclauses show examples of network protection in the case of multi-wavelength access systems.

9.4.1 Type B protection

Transceiver faults occur frequently in some scenarios and feeder fibre faults may occur in other scenarios. In type B protection, OLTs or OLT channel terminations (CTs) and feeder fibres are protected.

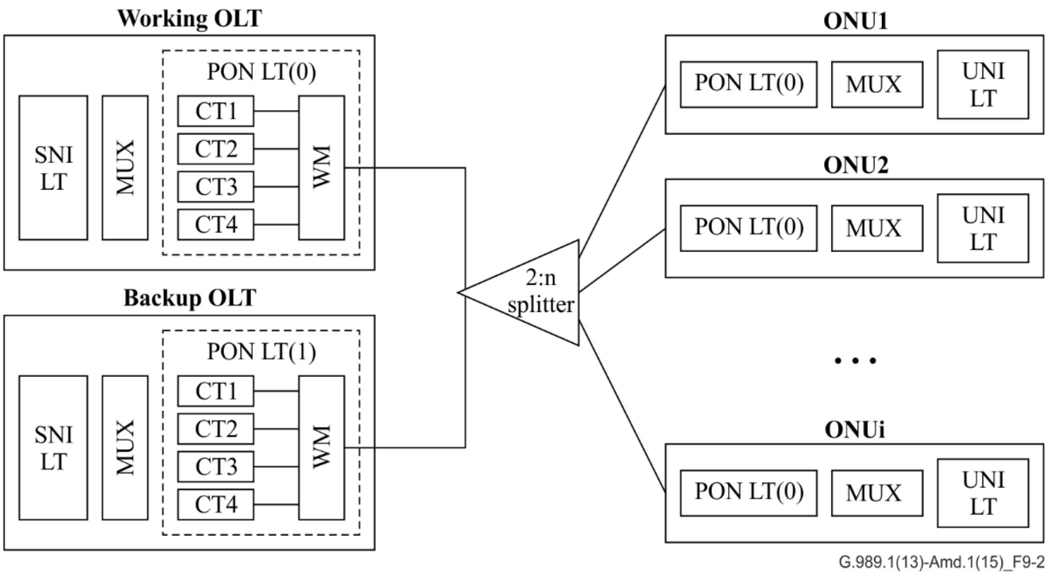

Figure 9-2 – Type B protection – 1:1 model with dual homing

Figure 9-2 shows the 1:1 model of type B protection with dual parenting. The recovery procedure is the same as for type B protection of GPON/XG-PON. The backup OLT is a copy of the working OLT. All backup OLT CTs must be turned off until the protection switchover occurs.

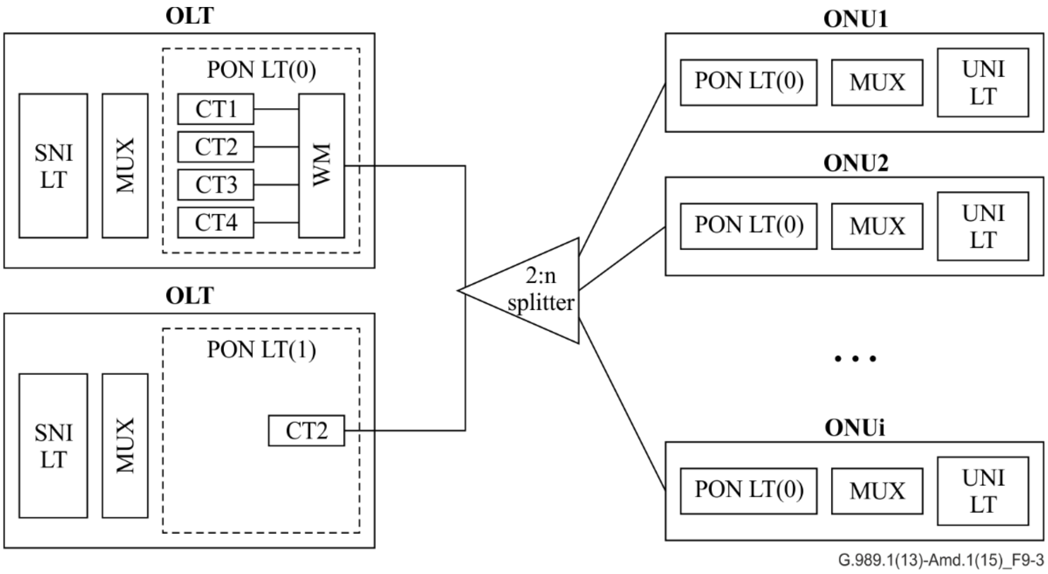

Figure 9-3 – Type B protection – 1:1 model with single backup CT

As shown in Figure 9-3, the backup OLT includes a designated OLT CT to protect the working OLT CTs. When a protection switchover is triggered, the ONUs tune to the wavelength pair supported by the backup OLT CT. The backup OLT CT must be turned off until the protection switchover occurs.

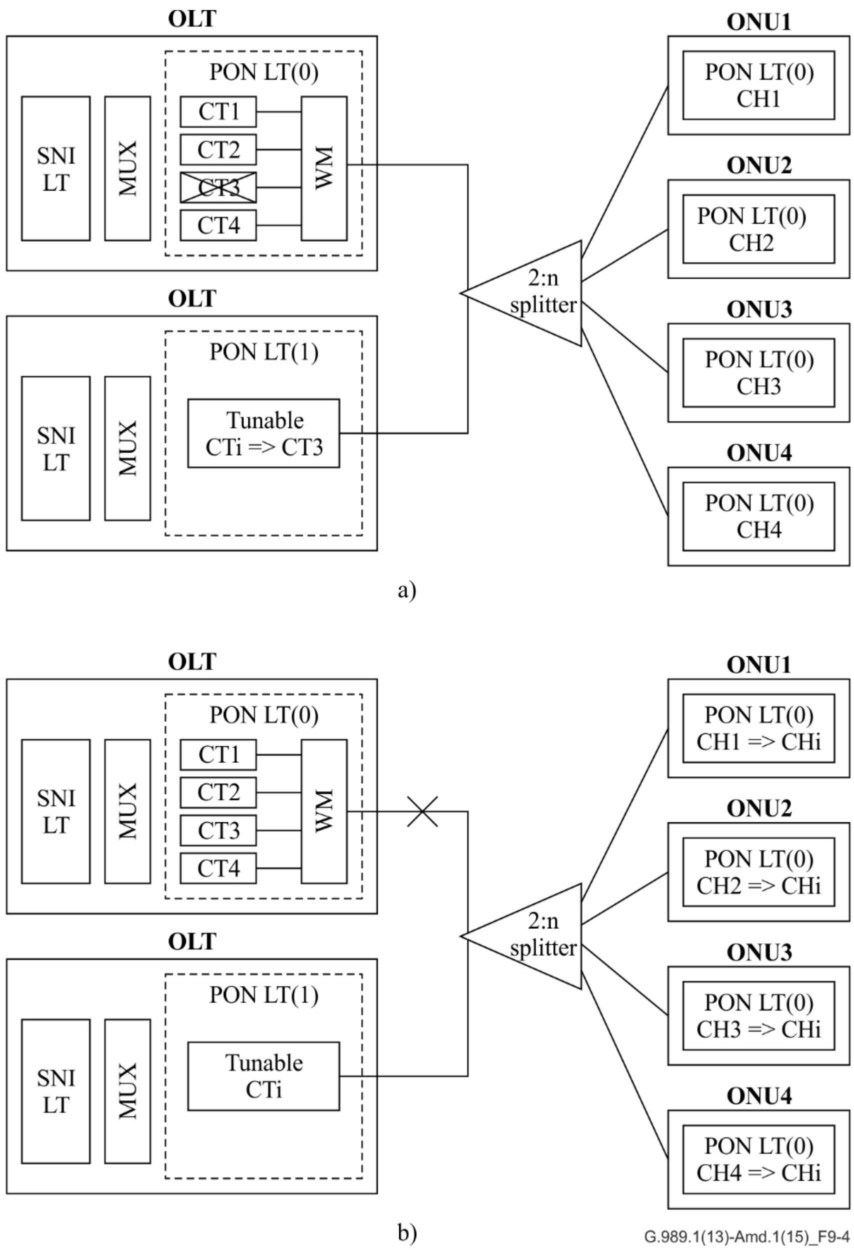

Figure 9-4 – Type B protection – 1:n model (a) CT failure, (b) feeder fibre failure

Figure 9-4 shows the architecture of 1:n type B protection. The backup OLT consists of an OLT CT with a tunable transceiver to protect all working OLT CTs. When a working OLT CT fails, the backup OLT CT tunes its wavelength channels to protect the failed OLT CT, as shown in Figure 9-4(a). The ONUs associated with the failed working OLT CT can remain unchanged. When the feeder fibre from a working OLT CT fails as shown in Figure 9-4(b), all ONUs must tune to the wavelength channels supported by the backup OLT CT.

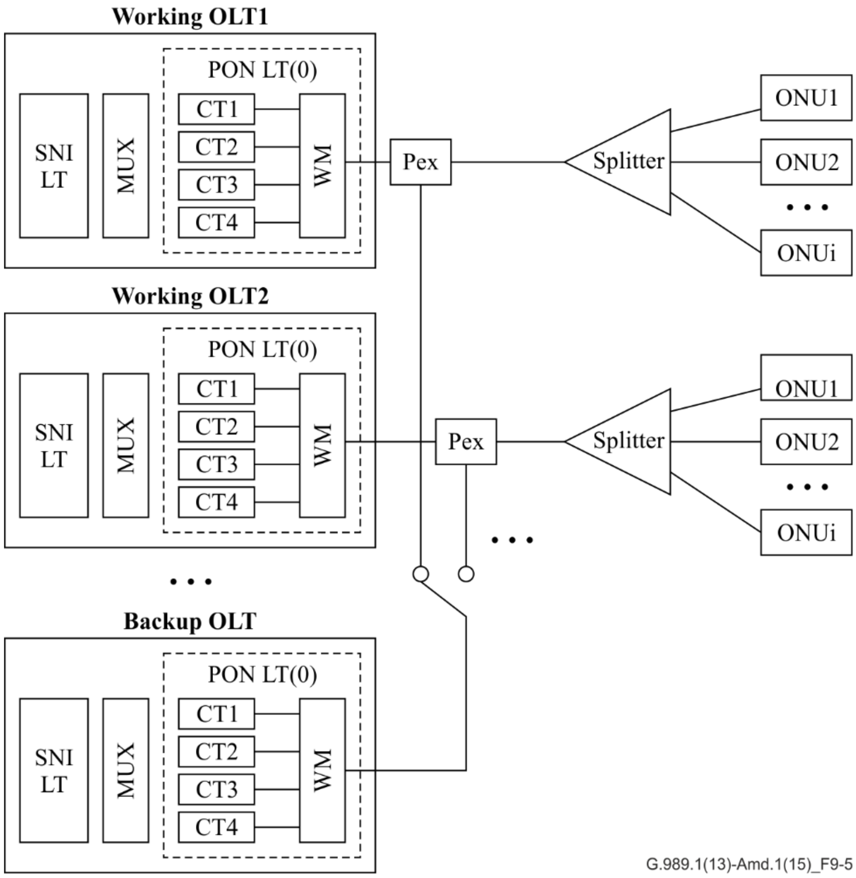

Figure 9-5 – Type B protection – 1:n model with dual parenting

Figure 9-5 shows the 1:n type B protection with dual parenting. The backup OLT supports the same wavelength channels as the working OLTs. When any failure occurs in a working OLT or a feeder fibre, the backup OLT continues the PON operation with the associated ONUs.

9.4.2 Type C protection

For Type C protection, which is a full duplex system (1+1 model), the ONU has two tunable transceivers as shown in Figure 9-6. Accordingly, recovery from failure at any point is possible by switching to the standby facilities. In order to simplify protection management and for fast service configuration, the same wavelength configuration of the working TWDM channel and the backup TWDM channel is recommended. In Figure 9-7, the ONU chooses one tuneable wavelength transceiver plus one fixed wavelength transceiver for backup. In this case, a dedicated wavelength of the tuning range for the backup PON port is allocated to protect the working PON. In addition, if the ONU adopts a two MAC chipsets architecture in type C protection, the ONU can simultaneously activate to both the working OLT PON and the backup OLT PON via two PON MACs and two transceivers. The service recovery time could be less than 50 ms.

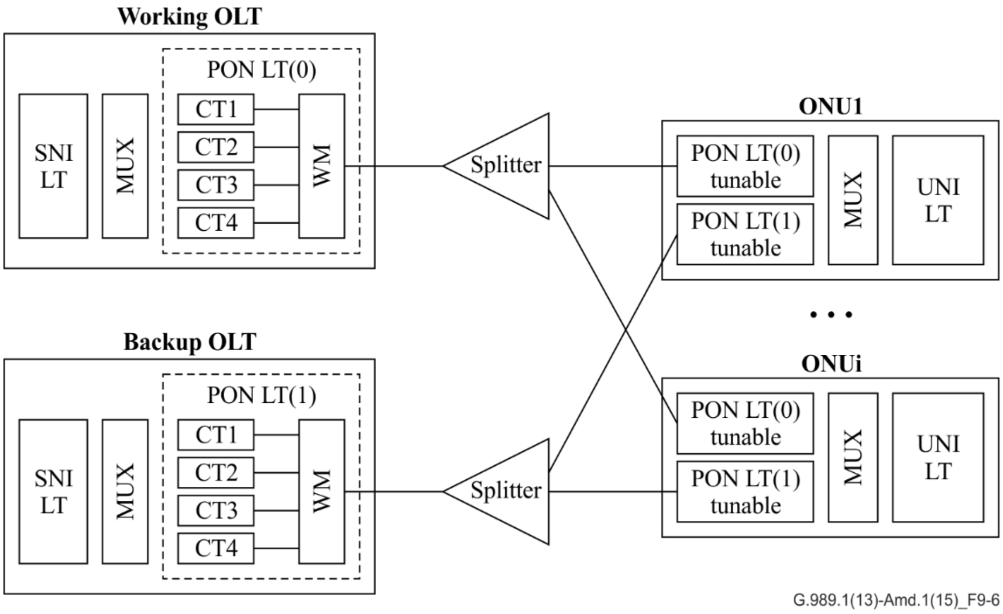

Figure 9-6 – Type C protection – 1+1 model with two tunable transceivers in ONUs

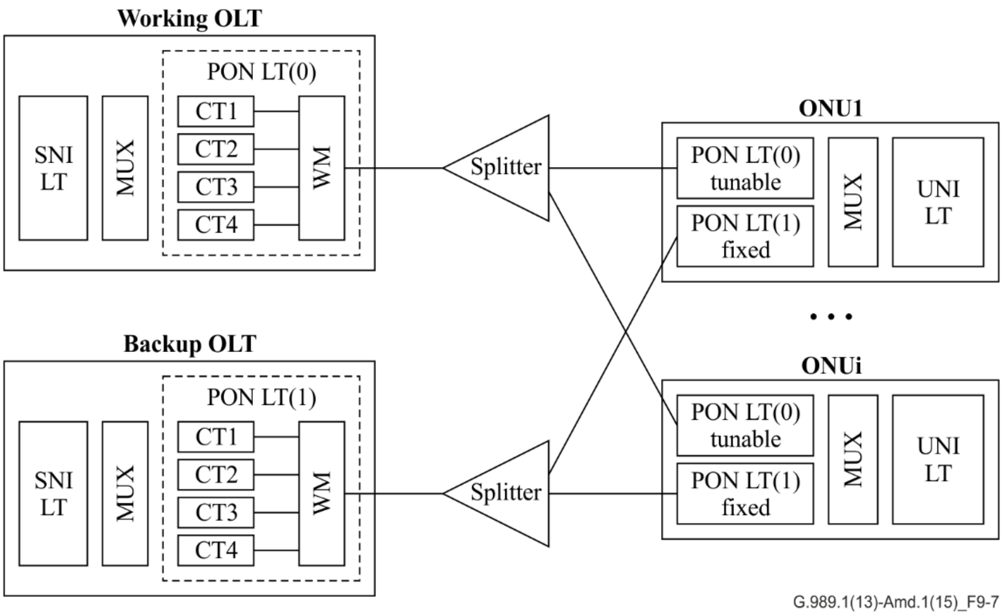

Figure 9-7 – Type C protection – 1+1 model with one tunable transceiver and one fixed transceiver in ONUs

9.4.3 Type W protection

In type W protection, which is the newly defined category in this Recommendation, only the OLT (or OLT CT) is protected. In some cases, type W protection is achieved by using wavelength tuning in ONUs.

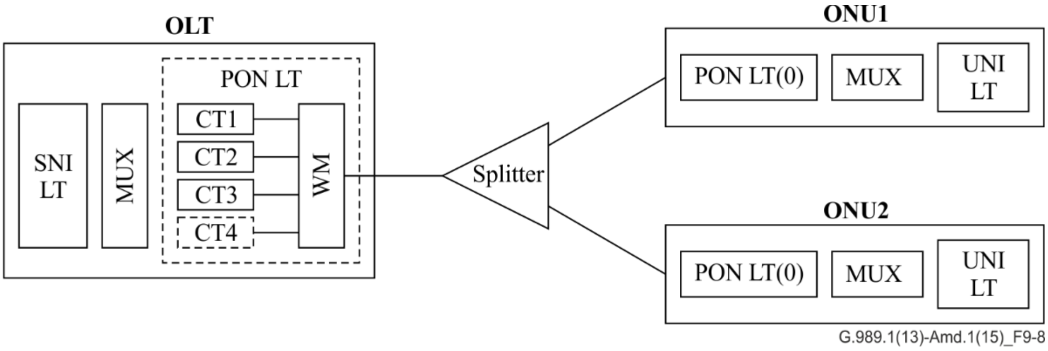

Figure 9-8 – Type W protection - 1:n model with backup OLT CT

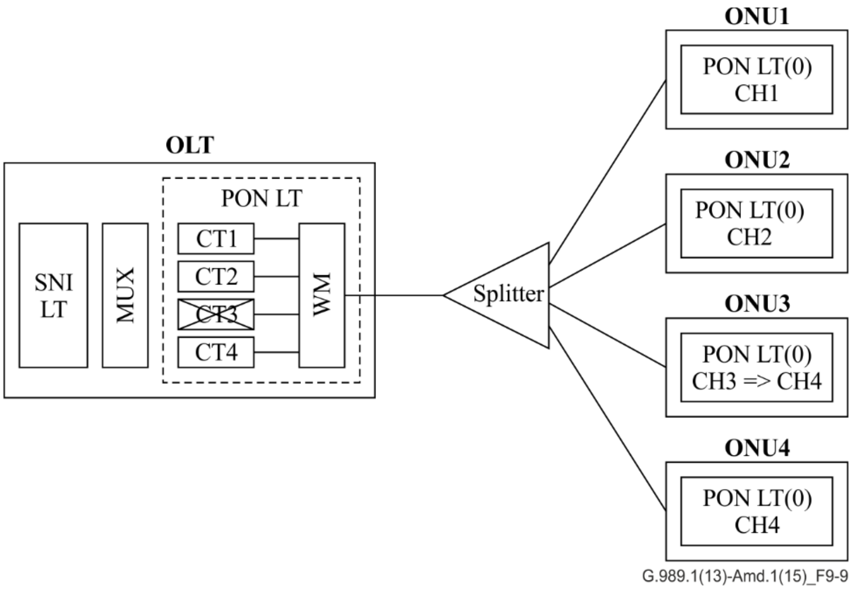

Figure 9-9 – Type W protection – 1:n model with all active OLT CTs

The 1:n model of type W protection is shown in Figure 9-8. In the TWDM system, one of the OLT CTs is configured to be the backup OLT CT for other working OLT CTs. CT4 in Figure 9-8 is set to be the backup OLT CT. When any failure occurs in a working OLT CT, the affected ONU tunes to the associated backup TWDM channel based on the pre-configuration information stored in the ONU.

Figure 9-9 shows another 1:n model of type W protection. This protection feature is inherent in the nature of NG-PON2 ONU wavelength tunability. All OLT CTs are active during operation. Each OLT CT can protect the other OLT CTs. If an OLT CT fails, its ONUs tune to wavelengths associated with other OLT CTs. In Figure 9-9, OLT CT3 fails and it is protected by OLT CT4. In another approach with a shorter protection time, the backup channels can be pre-configured in the ONUs. When a failure occurs, the affected ONUs can tune to the backup channels without waiting for the OLT instructions.

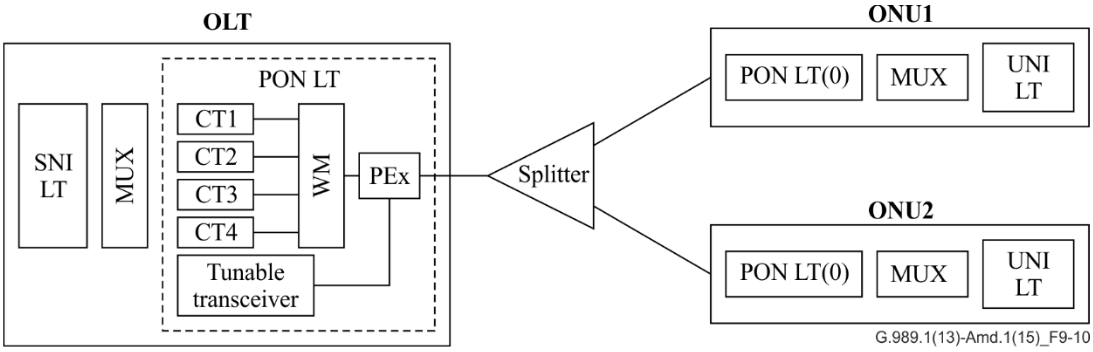

Figure 9-10 – Type W protection – (n+1):n model

The (n+1):n model of type W protection is shown in Figure 9-10. A dedicated OLT CT with a tunable transceiver is configured to be the backup OLT CT. When a working OLT CT fails, the backup OLT CT (tunable transceiver) tunes to the same wavelength channel as the working OLT CT. In order to avoid rogue OLT behaviors, the backup OLT CT tunes its wavelengths only after recognizing the working OLT CT failure. The model does not require any ONU operation in protection switchover.

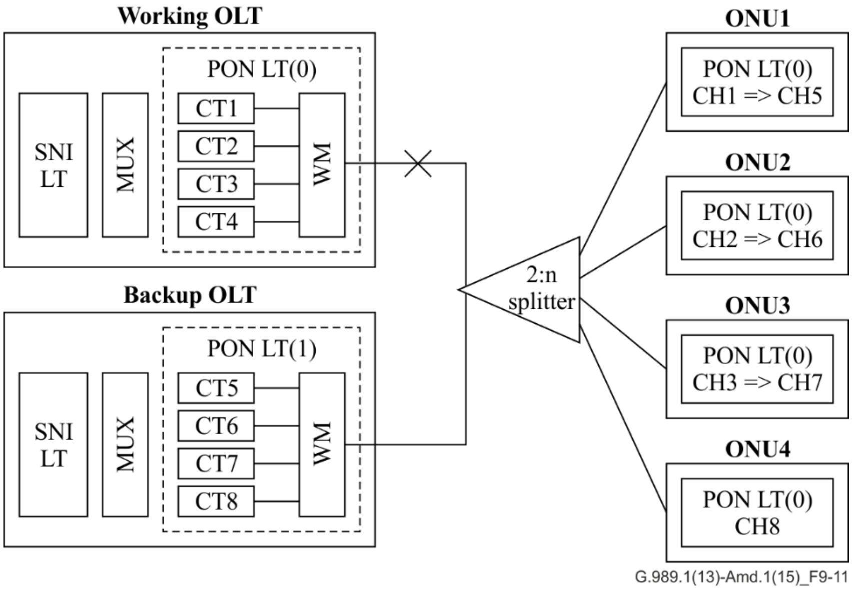

Figure 9-11 – Type W protection – 2n:n model with dual parenting

Figure 9-11 shows the architecture of 2n:n type W protection with dual parenting. The OLT CTs are divided into two groups: a working group and a backup group. When faults occur to the working group, the backup group can protect the transmission by instructing the affected ONUs to tune their wavelengths into the wavelengths of the backup group. This architecture has the same feature as type B protection as its OLT and feeder fibre are duplicated. Note that the major difference between the type B protection in Figure 9-2 and the 2n:n type W protection in Figure 9-11 is that the backup group in the 2n:n type W protection can be active to carry extra traffic with wavelengths other than those of the working group when no fault occurs, while the backup group in type B protection stands by with the same wavelengths as the working group.

9.4.4 Protection category

The protection category is summarized in Table 9-1. Categorization criteria are based on the subject to be protected. For type A, only a feeder fibre is protected while type B offers protection for an OLT (or OLT CTs or OLTs) and feeder fibres. Type C is referred to as a full duplex system, which protects the OLT, a feeder fibre, drop fibres and ONUs. Type W is the new category which offers protection only for an OLT CT (or OLT). In some cases, type W uses wavelength tuning in ONUs for protection.

Table 9-1 – Protection category

Type	Sub category	Dual parenting	Protected subject	ONU tuning	Extra equipment for protection	Figure number
A	1:1	No	Feeder fibre	No	Spare fibre [ITU-T G.983.1] Optical switch and 2:n splitter [b-ITU-T G.suppl.51]	Not shown
B	1:1	No	OLT and feeder fibre	No	Backup OLT, 2:n splitter, and extra feeder fibre	9-3 (with one OLT)
		Yes				9-2
	1:n	No	OLT CT and feeder fibre	No	Backup OLT CT, 2:n splitter and extra feeder fibre	9-4
		Yes	OLTs and feeder fibres	No	Backup OLT, 2:n splitters, 1:n optical switch and extra feeder fibres	9-5 (with fibre added)
C	1+1	No	OLT, feeder fibre, drop fibres and ONUs	No	Backup OLT, 2:n splitters, extra feeder fibres, extra drop fibres and extra LTs (ONUs).	9-6 9-7
W	1:n	No	OLT CT	Yes	None	9-8 9-9
	(n+1):n			No	Tunable TRx, 2:n splitter, and extra fibre	9-10
	2n:n	Yes	OLT	Yes	Backup OLT, feeder fibre	9-11

6) Clause 9.6, Power reduction

Replace clause 9.6 with the following text:

9.6 Power reduction

Power saving in telecommunication network systems has become an increasingly important concern in the interest of reducing operational costs and reducing the network contribution to greenhouse gas emission. NG-PON2 systems must be designed in the most energy-efficient way. This applies to the OLT side and even more to the ONU side since the energy consumption is not shared at the ONU except for FTTC/B. In some instances, the primary objective of the power saving function in access networks is to maintain the lifeline service(s), such as a voice service, as long as possible through the use of a backup battery when electricity service goes out. A lifeline interface must be sustainable for at least eight hours after mains power outage, and options such as allowing four hours of talk time while an ONU is in sleep mode for an extended period (e.g., one week) should be offered. Therefore, the NG-PON2 system shall support improving energy efficiency whilst maintaining compatibility with the service requirements.

For time and wavelength division multiplexing (TWDM) channels, the mechanisms to attain better power savings at the ONU side, shall include the watchful sleep mode, which allows network operators to adjust the balance between the impact on the performance and the power-saving effect. Mechanisms at the OLT side shall include the wavelength re-tuning. Control protocols for realizing these mechanisms shall be supported in an NG-PON2 system.

The OLT-port sleep mode can offer power savings because when there is less traffic in the TWDM PON system (4 Type W wavelengths) as shown in Figure 9-12, all the OLT-ports will keep working even though the total traffic could be accommodated by a single OLT-port. However, by connecting all of the ONUs to the same OLT-port (CT1) with the use of wavelength re-allocation, the other OLT-ports (CT 2, CT 3 and CT 4) can be forced into sleep mode as shown in Figure 9-13.

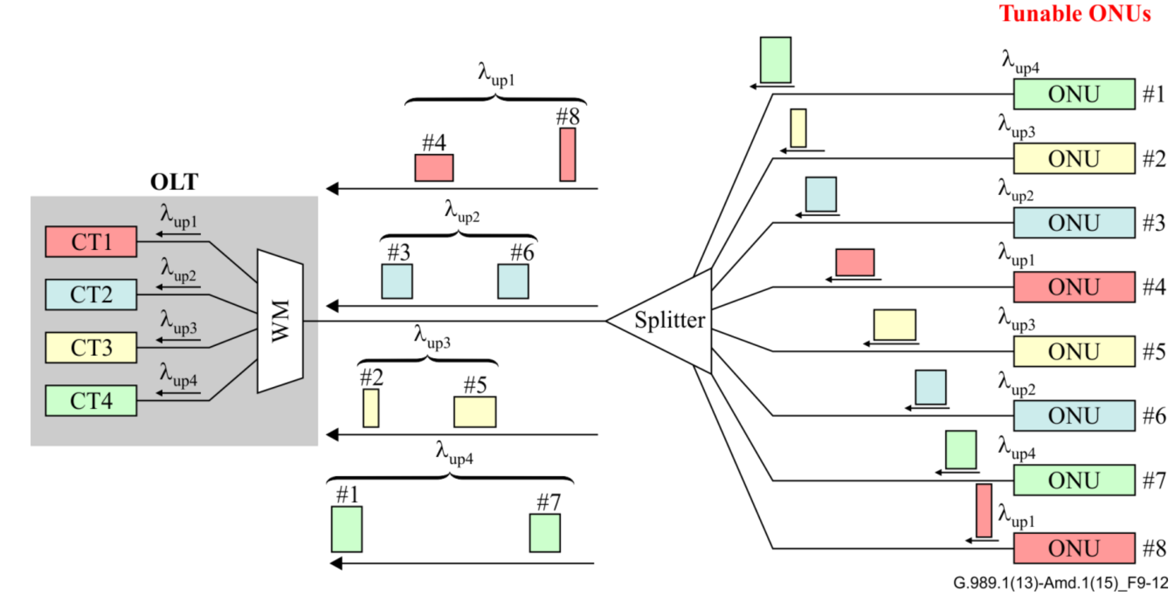

Figure 9-12 – Example of OLT-port sleep mode (before starting sleep mode)

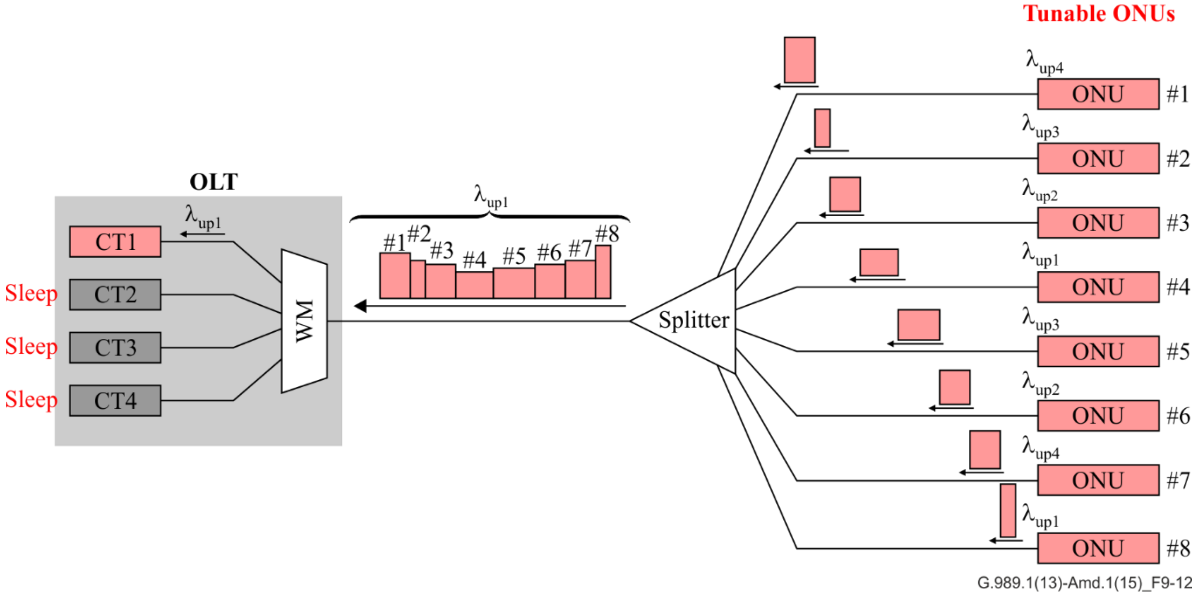

Figure 9-13 – Example of the OLT-port sleep (CT 2, CT 3 and CT 4 are in the sleep mode)

For PtP WDM channels, mechanisms to address power reduction capabilities at the ONU side shall include:

− the silent start function to reduce power in the standby state and to reduce risks upon resuming operation, see [ITU-T G.986];

− a sleep mode to reduce power when the traffic is low or when there is zero traffic.

Methods to address power reduction capabilities for both of the OLT and ONU sides shall include:

− line-rate switching to reduce the power when traffic and service parameters permit, for link or service sets that do not allow the use of sleep mode.

7) Clause 9.12, Transport of wireless fronthaul links over the access system

Add new clause 9.12 with the following text:

9.12 Transport of wireless fronthaul links over the access system

To achieve a fronthaul transport solution over the access system, three fronthaul protocols should be taken into consideration: namely CPRI, OBSAI and ETSI-ORI. In all of these fronthaul protocols the radio signal is digitized radio over fibre (D-RoF).

NG-PON2 systems are required to fully support the various fronthaul services for mobile applications. Furthermore, for these mobile applications, NG-PON2 must achieve:

− Capability to support a fixed and continuous symmetrical bandwidth allocation capacity compatible with any fronthaul bit rate between 614.4 Mbit/s to 10.1376 Gbit/s.

− The fronthaul latency considered applies to the round trip time between SNI to UNI to SNI. It is required to be less than 500 µs including the fibre propagation time. A more stringent delay requirement is preferred when fronthauling legacy base station equipment.

− The accuracy of the measurement of the round trip delay on the transmission medium (including fibre, ONT and OLT) shall meet the following requirement of ±16.276 ns. Between two periodic measurements of the round trip delay by base band unit, the variation of the transmission medium must not exceed ±16.276 ns with a preference to be strictly less than this value.

− Preferably, the fronthaul latency for upstream and downstream should be symmetrical. An asymmetrical trip delay between the upstream and downstream fronthaul transmission medium (including fibre, ONT and OLT), should impact the accuracy of the timing calculation between the user equipment and base band units. The fronthaul transmission medium time difference shall not exceed 65ns with a preference to be strictly less than this value.

− The maximum contribution *df*/*f*0 of jitter from the fronthaul link to the radio base station frequency accuracy budget must not exceed ±2 ppb (2.10-9). The RRH clock shall be traceable to the BBU clock. This implies that the fronthaul link must not introduce any constant frequency error. The link timing accuracy for the transport system will be specified with concrete values which will be defined in a further study.

− The extended outside temperature range may be needed in many of the envisaged fronthaul applications for the ONU, with a similar requirement as that already expressed in clause 9.9 of [ITU-T G.989.1].

− Optionally, the OLT should also be able to operate over the extended outside temperature range and compact packaging based on pluggable receptacle footprint.

− Optionally, an antenna site management interface could be transported over the access system.

− Optionally, an additional synchronization signal (e.g., a GPS signal) could be transported over the access transmission.

− Optional capability to support the multiplexed transport of fronthaul protocols (e.g., CPRI over OTN).

8) Appendix I, OLT resilience configuration

Add new Appendix I with the following text:

Appendix I

OLT resilience configuration

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

I.1 OLT resilience configuration

The NG-PON2 OLT can be configured to protect line card faults. Figure I.1 shows the optical line terminal (OLT) resilience configuration with individual port design. An OLT is formed by taking one port from each line card and aggregating the ports using a 4x1 wavelength Mux/DeMux. When faults occur in a line card, the corresponding wavelength channel pair is impaired. The other three wavelength channel pairs maintain transmission. The OLT can instruct the affected optical network units (ONUs) to tune to the wavelengths supported by the other OLT ports.

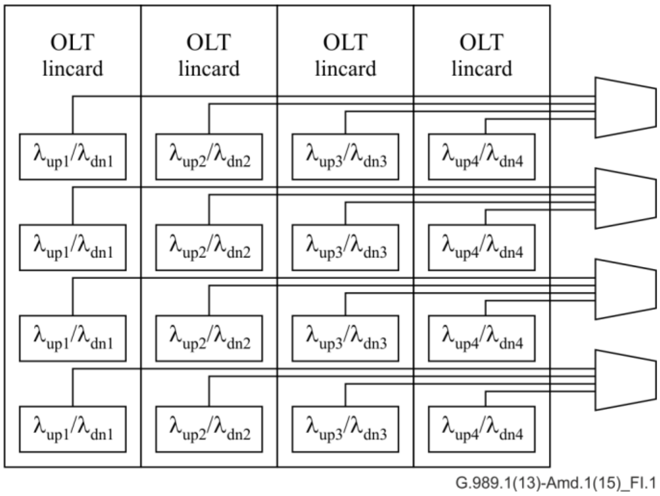

Figure I.1 – OLT resilience configuration with individual port design

Figure I.2 shows the OLT resilience configuration with integrated port design. An NxN component (e.g., 4x4 AWG, wavelength router) is used to rearrange the wavelength pairs. The wavelength pairs of an OLT are from/to different line cards. Faults to a line card only impair one wavelength pair in an OLT. The OLT can protect transmission by tuning the ONU wavelengths.

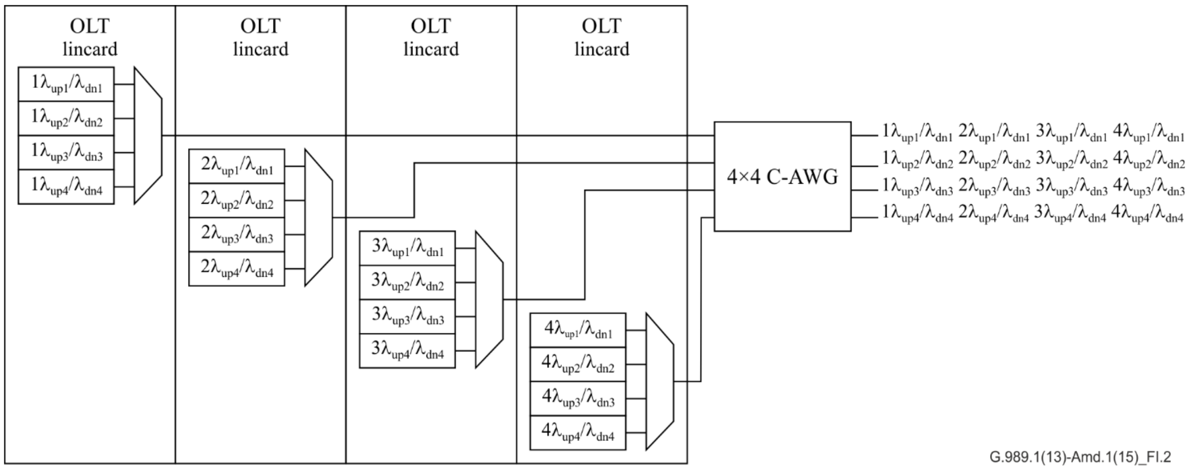

Figure I.2 – OLT resilience configuration with integrated port design

9) Appendix II, Transmission technique for mobile fronthaul

Add new Appendix II with the following text:

Appendix II

Transmission technique for mobile fronthaul

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

II.1 Definitions

For the definitions of mobile fronthaul (MFH) and mobile backhaul (MBH), see [b-MEF 22.1.1 Amd1].

II.2 Transmission technique for mobile fronthaul

When an optical fibre communication technology is applied to the mobile fronthaul link, the transmission technique becomes a kind of radio-over-fibre (RoF) technology. On the basis of the difference in the subcarrier frequency of the signal transmitted over a fibre-optic link, three types of RoF transmissions can be identified: (a) radio-frequency-band (RF-band) signal transmission, (b) intermediate-frequency-band (IF-band) signal transmission and (c) equivalent low-pass or equivalent baseband signal transmission. In addition, RoF technologies can be classified into two groups, which are analogue RoF and digital RoF. Specifically, when a digitized radio signal is transmitted over a digital fibre-optic link, it is called digitized RoF (D-RoF). The European Telecommunications Standards Institute (ETSI) open radio equipment interface (ORI), the common public radio interface (CPRI) and the open base station architecture initiative (OBSAI) which are considered as candidates for the transmission technique for mobile fronthaul over optical access networks, are known as typical D-RoF applications.

10) Bibliography

Add the following documents in Bibliography:

[b-ITU-T G.Sup.55] ITU-T G-series Recommendations – Supplement 55 (2015), *Radio-over-fibre (RoF) technologies and their applications.*

[b-MEF 22.1.1 Amd1] MEF 22.1.1 (2014), *Mobile Backhaul Phase 2 Amendment1 – Small Cells*.

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