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DIGITAL SYSTEMS AND NETWORKS

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

10 Gigabit-capable passive optical networks (XG-PON): Reach extension

Recommendation ITU-T G.987.4



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Recommendation ITU-T G.987.4

10 Gigabit-capable passive optical networks (XG-PON): Reach extension

Summary

Recommendation ITU-T G.987.4 outlines the architecture and interface parameters for 10 Gigabit-capable passive optical network (XG-PON) systems with extended reach using a physical layer reach extension device, such as a regenerator or optical amplifier in the fibre link between the optical line termination (OLT) and optical network unit (ONU). Wavelength converting, continuous mode, 1:N and combination type reach extenders are also described. The maximum reach is up to 60 km with loss budgets of in excess of 28.5 dB being achievable in both spans.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T G.987.4	2012-06-06	15

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.

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As of the date of approval of this Recommendation, ITU had not 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/>.

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Recommendation ITU-T G.987.4

10 Gigabit-capable passive optical networks (XG-PON): Reach extension

1 Scope

This Recommendation concerns 10 Gigabit-capable passive optical network (XG-PON) systems with optical link budgets up to the logical limits of the transmission convergence (TC) layer. The increased optical capability, which includes both increased overall fibre length and increased overall splitting ratio, is referred to in this Recommendation as "reach extension". The primary concerns addressed are the increase of the loss budget and the management of optical impairments.

This Recommendation considers mid-span extension, which uses an active extension node placed in the middle of the optical network. The recommended parameters for the optical distribution network(s) ODN(s) involved in this scheme are specified. Single-sided extension is considered as an improvement to the optical line terminal (OLT) interface.

The systems considered here must remain compatible with existing optical network units (ONUs). Furthermore, the approaches should maintain compatibility with existing OLTs to the maximum extent possible. It is recognized that some modification of the OLT equipment may be necessary, but this should be minimized.

Two system architectures are considered: optical amplification and opto-electronic regeneration. These can be viewed as providing reach extension at the physical layer. The key interfaces and functional blocks in each of these architectures are identified and specified.

Optionally, optical-electronic-optical (OEO) type reach extender (RE) units may support a burst mode to continuous mode (BM to CM) conversion function, as specified in clause 6.2. In this case, it is also necessary to introduce a CM to BM conversion function before the S/R interface at the OLT.

Optionally, both optical amplifier (OA) and OEO type RE units may support the wavelength conversion (WC) function, as specified in clause 6.4. In case of WC-enabled RE units, it is also necessary to introduce a WC-function block before the S/R interface.

Optionally, combination RE units may support all the functions described here in ITU-T G.987.4, and the G-PON RE functions described in [ITU-T G.984.6].

The optional support of a type-B type protection in RE units is described.

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.984.5] Recommendation ITU-T G.984.5 (2007), *Gigabit-capable Passive Optical Networks (G-PON): Enhancement band*.
- [ITU-T G.984.6] Recommendation ITU-T G.984.6 (2008), *Gigabit-capable passive optical networks (GPON): Reach extension*.
- [ITU-T G.987] Recommendation ITU-T G.987 (2010), *10-Gigabit-capable passive optical network (XG-PON) systems: Definitions, abbreviations, and acronyms*.

- [ITU-T G.987.1] Recommendation ITU-T G.987.1 (2010), *10-Gigabit-capable passive optical networks (XG-PON): General requirements*.
- [ITU-T G.987.2] Recommendation ITU-T G.987.2 (2010), *10 Gigabit-capable passive optical networks (XG-PON): Physical media dependent (PMD) layer specification*.
- [ITU-T G.987.3] Recommendation ITU-T G.987.3 (2010), *10 Gigabit-capable passive optical networks (XG-PON): Transmission convergence (TC) layer specification*.
- [ITU-T G.988] Recommendation ITU-T G.988 (2010), *ONU management and control interface (OMCI) specification*.
- [ITU-T L.66] Recommendation ITU-T L.66 (2007), *Optical fibre cable maintenance criteria for in-service fibre testing in access networks*.

3 Definitions

See clause 3 of [ITU-T G.987].

4 Abbreviations and acronyms

See clause 4 of [ITU-T G.987].

5 Conventions

See clause 5 of [ITU-T G.987].

6 Optical extension schemes and architectures

The basic PON architecture is shown in Figure 1. The OLT interfaces with multiple ONUs via the ODN. The OLT also provides interfaces to one or more service node interfaces (SNIs), as well as the management system. The ONU interfaces with various UNIs. The only interfaces of interest to this Recommendation are those that face the ODN. The XG-PON physical medium dependent (PMD) specification [ITU-T G.987.2] specifies the loss profile for the ODN to be 14 ~ 29 dB, 16 ~ 31 dB, 18 ~ 33 dB, or 20 ~ 35 dB. The OLT-ODN and ONU-ODN interfaces for XG-PON are specified in [ITU-T G.987.2]. Indeed, most ITU-compliant PONs deployed today adhere to these Recommendations.

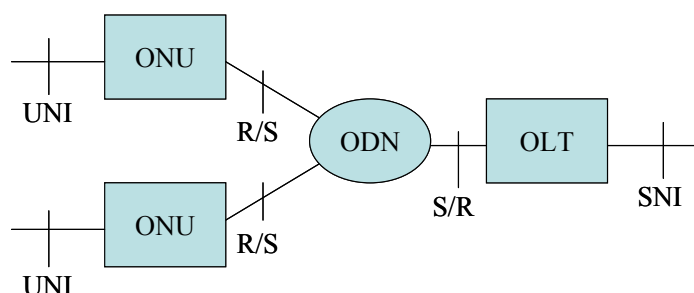


Figure 1 – Basic PON architecture

The architecture considered in this Recommendation is illustrated in Figure 2. A mid-span extender device is inserted between the ODN (compliant with existing PON Recommendations) and an optical trunk line (OTL), which is connected to the OLT. This architecture extends the reach of the PON by the length of the OTL, and may also increase the split ratio of the PON. However, it does require electrical power for the mid-span extender.

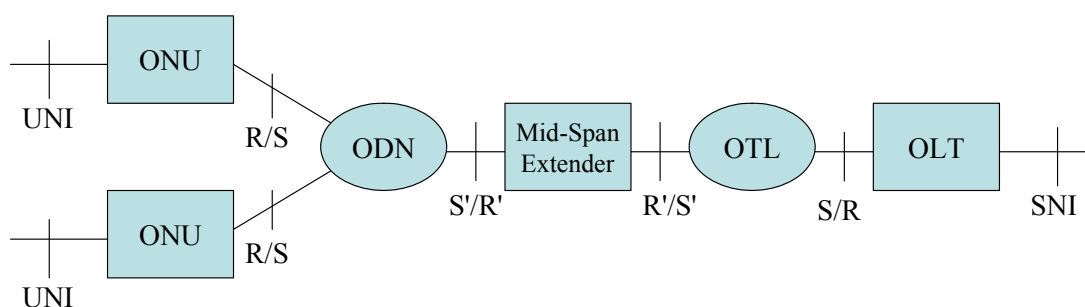


Figure 2 – Mid-span reach extension

An extended architecture considered in this Recommendation is presented in Figure 3. A WC-enabled RE-unit is inserted between the ODN (compliant with existing PON recommendations) and an optical trunk line (OTL), which is connected to the OLT. This architecture extends the reach of the PON by the length of the OTL, and may also increase the split ratio of the PON. Additionally, the WC-RE unit may aggregate several XG-PON-class ODNs, enabled by the WDM multiplexing over OTL to achieve more cost-efficient use of existing fibre infrastructure. The WC function block inserted before the S/R interface at the OLT performs adaptation between the WDM optical signals transmitted over the OTL and the ITU-T G.987 series-Recommendations compliant OLT interfaces.

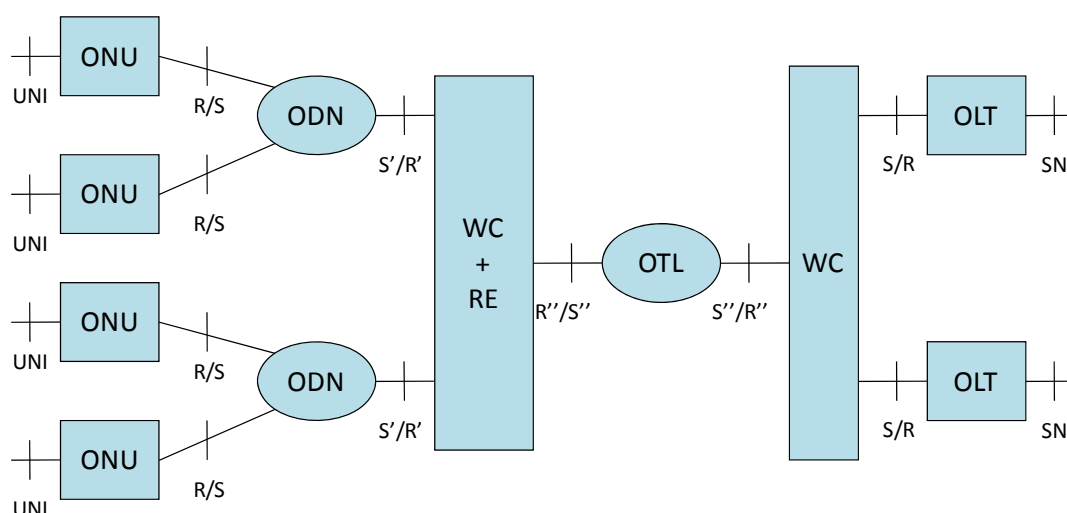


Figure 3 – Wavelength conversion reach extender architecture

An additional extended architecture considered in this architecture is shown in Figure 4. "BM-to-CM" means burst mode to continuous mode converter, and vice versa. A BM to CM converter is used at the remote PON reach extender to convert the bursty upstream signal into a conventional continuous mode signal. A CM to BM converter is theoretically present at the OLT location, although it will most likely be integrated with the OLT itself.

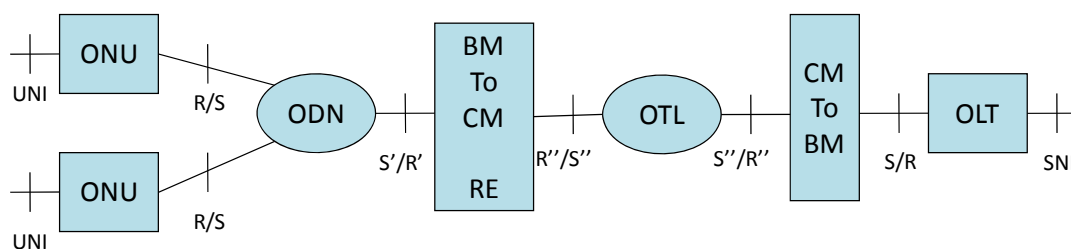


Figure 4 – BM-to-CM conversion reach extender architecture

An additional aspect of XG-PON systems is their coexistence with the ITU-T G.984 G-PON systems. The reach extender function can be combined to support both systems simultaneously, as shown in Figure 5. The "combo" reach extender fulfils the roles of both an ITU-T G.984.6 RE and an ITU-T G.987.4 RE.

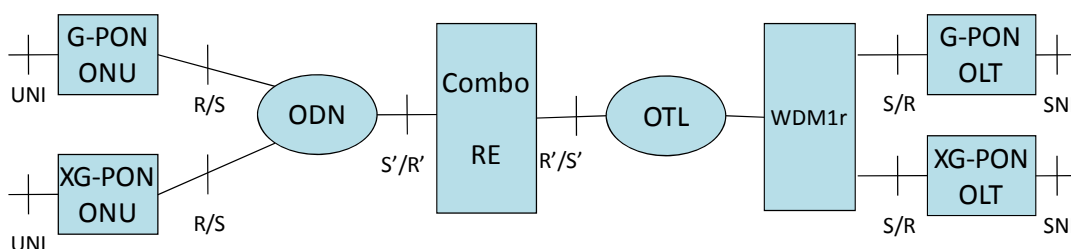


Figure 5 – Combination G-PON/XG-PON reach extender

Reach extenders can also incorporate additional fanout within the RE, as shown in Figure 6. In this case, the RE has multiple S'/R' interfaces that are combined with the usual PON logical connectivity (downstream broadcast, upstream combining) to a single R'/S' interface. However, it is not the same as placing a splitter next to the RE, as the loss budget constraints would prevent this. A couple of physical methods to achieve this are described in clause 6.7. The motivation for such a scheme is to increase the sharing of the OLT port, OTL fibre and RE R'/S' interface over more ODNs. This can particularly be useful in the XG-PON overlay application.

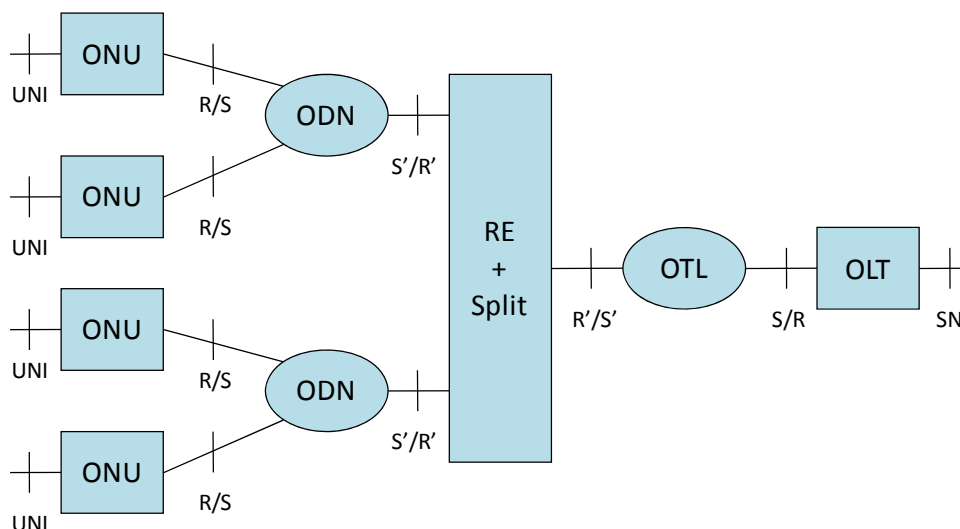


Figure 6 – Reach extender with additional fanout in the RE

Another topology of reach extenders is to allow point-to-multipoint connectivity between the RE and the OLT, as shown in Figure 7. In this case, the optical trunk line is replaced by an optical trunk network (OTN), which is composed of fibres and splitters and which combines the output of several R'/S' interfaces into a single S/R interface to the OLT. The motivation here is similar to the previous case: to increase the sharing of the OLT interface. This method also allows for physically diverse placement of the subtending RE units. However, it does not increase the sharing of the RE R'/S' interfaces, and it then requires that the R'/S' interfaces must be able to operate in burst mode.

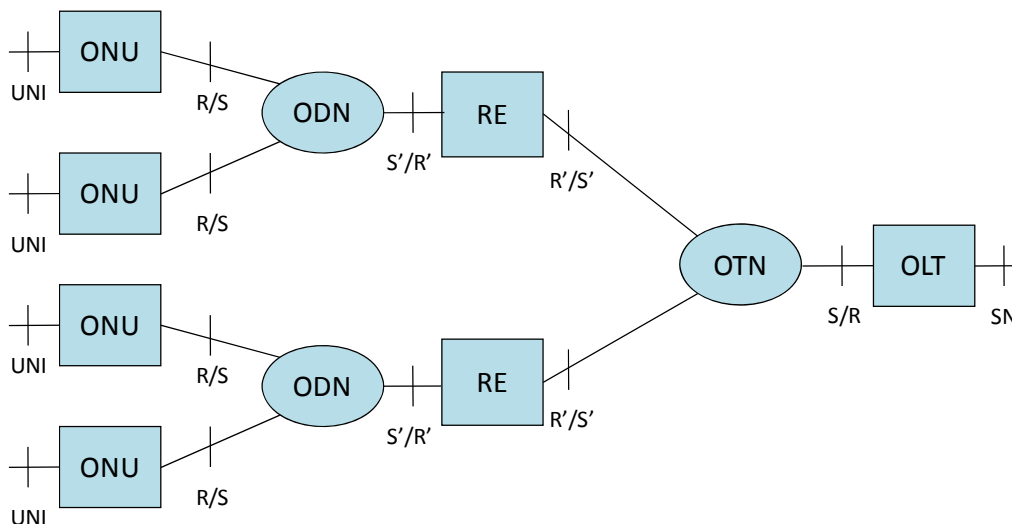
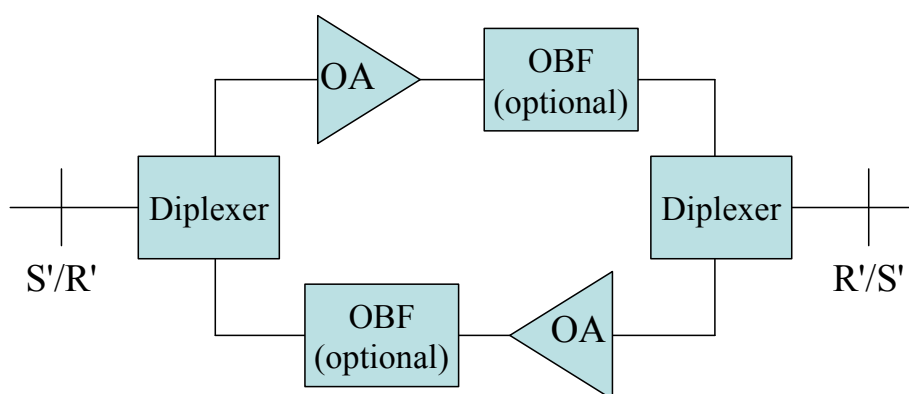


Figure 7 – Reach extender with an optical trunk network

There are several ways to implement an optical reach extender. There are two general classes of extenders. The first is an optical amplifier (OA), shown in Figure 8a, which provides gain in optical power. The second is an optical-electrical-optical (OEO) regenerator (Figure 8b), which receives an optical signal, reshapes and retimes it in the electrical domain and retransmits in the optical domain. Further hybrid schemes are possible, for example, to use optical amplification in the downstream and regeneration in the upstream, as shown in Figure 9a, or the reverse as shown in Figure 9b.

a)



b)

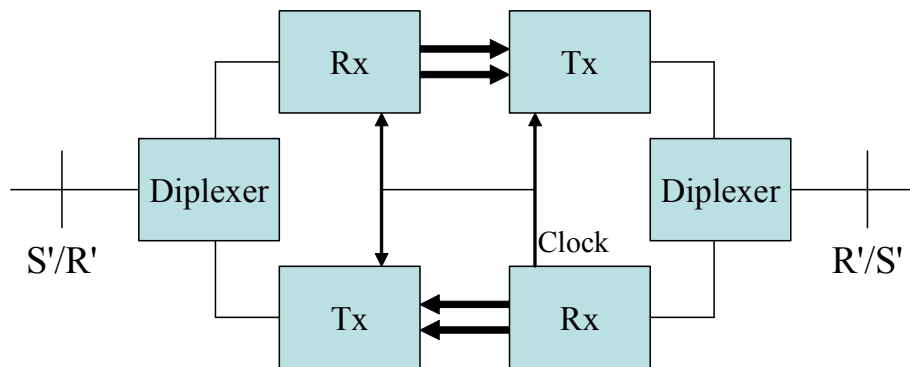
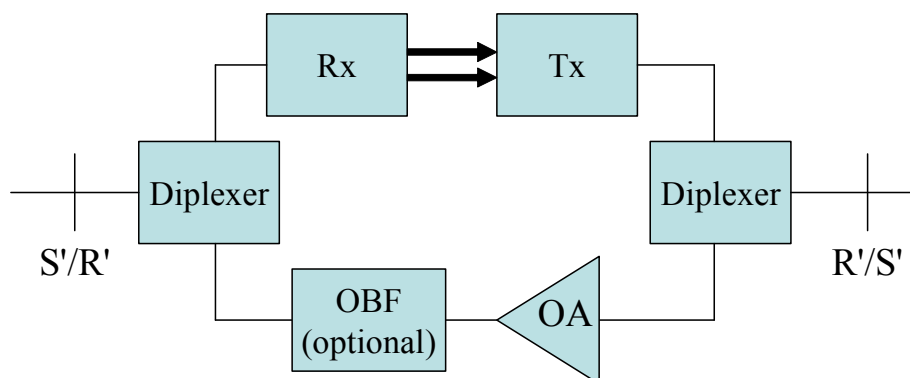


Figure 8 – The two basic extender architectures: Optical amplifier, repeater

a)



b)

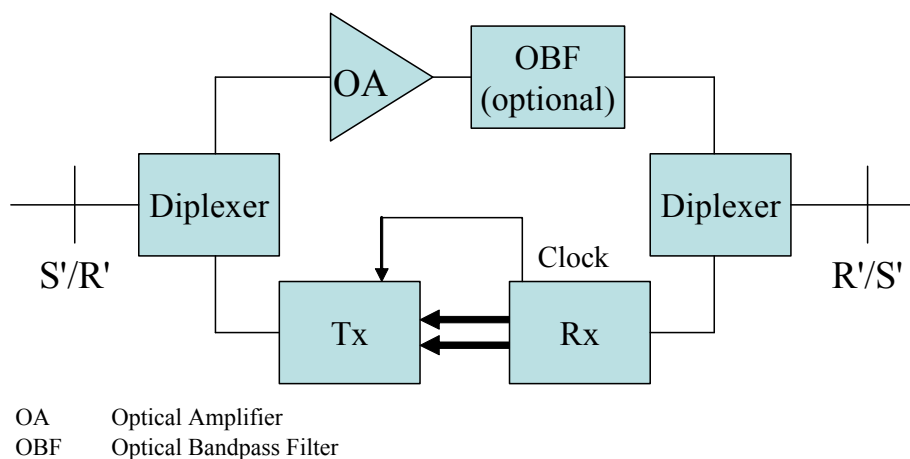


Figure 9 – Examples for hybrid extender architectures

6.1 OA-based reach extenders

Reach extenders based on optical amplifiers optionally may include optical bandpass filters (OBFs) in order to restrict the bandwidth of amplified spontaneous emission (ASE) generated by the optical amplifier, and thus reduce ASE-ASE beat noise and ASE-based power-offset (see Appendix I) in the optical receiver and achieve higher performance.

Due to the nature of OA-based reach extenders, the application range (useable trunk and ODN loss range) varies according to the parameters of the optical amplifiers used. The vendor has to provide sufficient data showing the key parameters (such as, e.g., maximum gain, minimum gain, and saturated output power), the application range and applicable penalties due to ASE.

As there is no signal regeneration provided by OA-based reach extenders, ONU and OLT transmitters must provide a dispersion reach of up to 60 km.

An optical amplifier-based extender should include a complete embedded ONU (EONU) for management purposes, as shown in Figure 10. The EONU is connected internally by means of an optical tap coupler at the interface facing the OLT in order to keep the RE accessible even in case an optical amplifier fails.

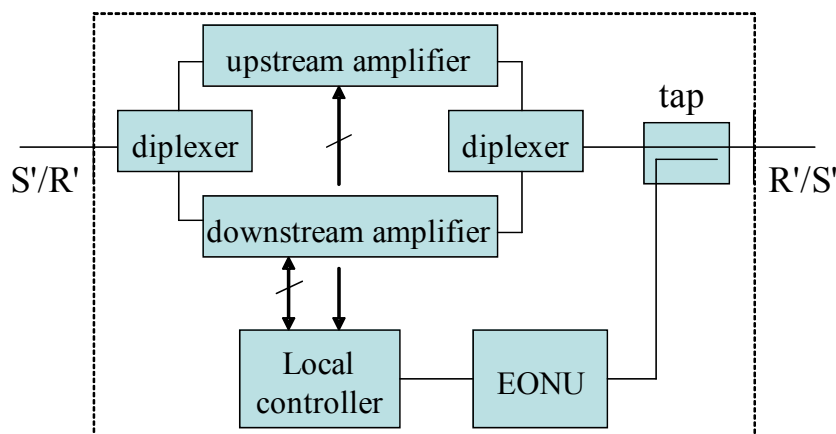


Figure 10 – OA-type reach extender with embedded ONU (EONU) for management purposes

6.2 OEO-based reach extenders

The signals passing through the OEO extender are re-timed (2R regenerators are not specified by this Recommendation). The timing reference for this function is the downstream receiver of the extender (see Figure 11). This timing is used to drive both transmitters and as a reference for the other receiver. This arrangement is identical to that used in SDH regenerator devices.

The presence of an OEO-based extender may require extension of burst overhead, which is automatically handled by the OLT via PLOAM messages (refer to clause 8.5). As the increase of burst overhead is bandwidth-relevant, upstream burst detection is supported by the aid of an embedded ONU (EONU, see Figure 11) which is used for management (see clause 7.2). In addition to the managing functions, the EONU may analyse the downstream signal and read the BW map in order to calculate burst-timing. In this way, a reset signal to the upstream burst-mode receiver can be provided, and the required burst overhead extension is kept to minimum.

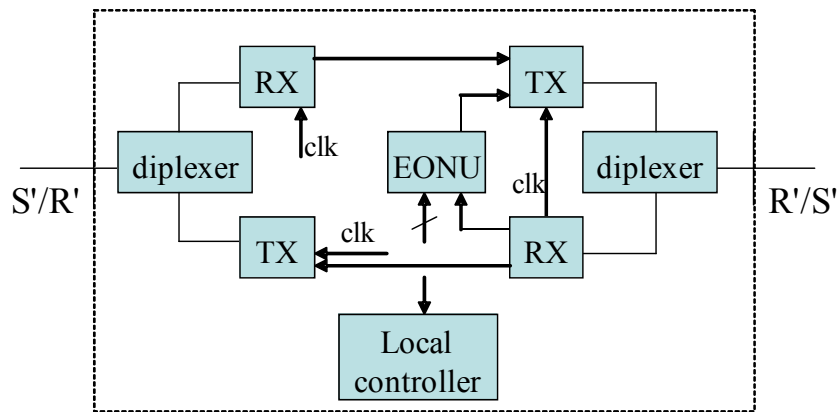


Figure 11 – OEO-type reach extender with embedded ONU for management purposes

The continuous mode OEO RE is a subtype of OEO RE. The S'/R' interface of CM OEO RE is the same as the one of OEO RE. In CM RE, a BM-to-CM converter is used to convert the burst signal to continuous signal. The downstream signal (denoted CMXGPON_D) has a bit rate of 9.95328 Gbit/s, and a frequency accuracy of 32 ppm in the worst case (where the OLT is in free running mode). The upstream signal (denoted CMXGPON_U) has a bit rate of 2.48832 Gbit/s, and a frequency accuracy of 32 ppm in the worst case (where the OLT is in free running mode). It must be noted, however, that the upstream signal is always synchronous to the downstream signal.

The CMXGPON_U signal is composed of the regenerated upstream bursts and some stuffing signal inserted between the bursts. The stuffing signal is a bit pattern that is well balanced in order to avoid long CID. This continuous signal is transmitted by the R"/S" interface. The stuffing bit_pattern is configured at both the transmitter and receiver. The means for such configuration is for further study. The pattern is somewhat arbitrary; however, it does need to satisfy a few basic requirements to avoid impacting the physical layer: it should have approximately a 1:1 mark to space ratio, and it should have approximately a 50% transition density. The OEO RE regenerates the received data from ONUs, and therefore does not unscramble the data from the ONUs.

The upstream frame is depicted in Figure 12. It is important to note that the incoming upstream bursts each have a unique and independent bit clock phase. The BM-to-CM converter produces at its output a signal that has a single continuous bit clock phase. Therefore, the BM-to-CM converter must buffer each incoming burst of data and re-time it with its output clock.