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

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

Gigabit-capable passive optical networks (GPON): Reach extension

Amendment 1: Wavelength-converting, continuous mode, and 1:N-protected range extenders

Recommendation ITU-T G.984.6 (2008) – Amendment 1

Recommendation ITU-T G.984.6

Gigabit-capable passive optical networks (GPON): Reach extension

Amendment 1

Wavelength-converting, continuous mode, and 1:N-protected range extenders

Summary

Amendment 1 to Recommendation ITU-T G.984.6 is aimed at defining several additional features or types of reach extender units, including:

- Wavelength-converting reach extenders.
- Continuous mode reach extenders.
- 1:N protected reach extenders.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T G.984.6	2008-03-29	15
1.1	ITU-T G.984.6 (2008) Amend. 1	2009-11-13	15

FOREWORD

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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.

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Gigabit-capable passive optical networks (GPON): Reach extension

Amendment 1

Wavelength-converting, continuous mode, and 1:N-protected range extenders

This amendment lists the changes necessary to accommodate the wavelength conversion (WC) function in the ITU-T G.984.6 architecture.

1)   Changes to clause 1 "Scope"

Add the following after the last paragraph of clause 1:

Optionally, optical-electrical-optical converter (OEO) type reach extender (RE) units may support a burst mode (BM) to continuous mode (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 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.

The optional support of type B protection in RE units is described in Appendix VI.

2)   Changes to clause 3 "Definitions"

Replace the text of clause 3 with the following:

This Recommendation defines the following term:

3.1   wavelength conversion (WC): Any type of technology used to convert the frequency (wavelength) of the incoming optical signal λ_{input} into any λ_{output} from a predefined wavelength grid. In case of $\lambda_{output} \neq \lambda_{input}$, true wavelength conversion takes place, while if $\lambda_{output} = \lambda_{input}$, a wavelength-transparent WC function is used, where the frequency of the optical signal does not change when passing through the WC function. Utilization of a wavelength-transparent WC function does not imply the optical path transparency to data rate modulation format. Several WC technologies are available, including wavelength-tuneable lasers, laser arrays, all-optical wavelength conversion and seed wavelength modulation.

CMGPON_D – The name given to the continuous mode GPON downstream bit-stream signal.

CMGPON_U – The name given to the continuous mode GPON upstream bit-stream signal.

3)   Changes to clause 4 "Abbreviations and acronyms"

Add the following to clause 4:

AWG   Arrayed Waveguide Grating

BC   Burst Mode

BLS   Broadband Light Source

BM-to-CM   Burst Mode to Continuous Mode

CID   Consecutive Identical Digits

CM   Continuous Mode

CM-to-BM   Continuous Mode to Burst Mode

DWDM   Dense wavelength Division Multiplexing

LC   Local Controller

NRZ   Non-Return to Zero

OWC   Optical Wavelength Conversion

RE   Reach Extender/Reach Extension

SNI   Service Node Interface

UNI   User Network Interface

WC   Wavelength Conversion

WC-RE   Wavelength Conversion-enabled Reach Extender unit

WDM   Wavelength Division Multiplexing

XGM   Cross-Grain Modulation

4)   Changes to clause 6 "Optical extension schemes and architectures"

Add the following text immediately after Figure 2:

An extended architecture considered in this Recommendation is presented in Figure 2a. 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 GPON-class ODNs, enabled by the wavelength division multiplexing (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.984.x-series compliant OLT interfaces.
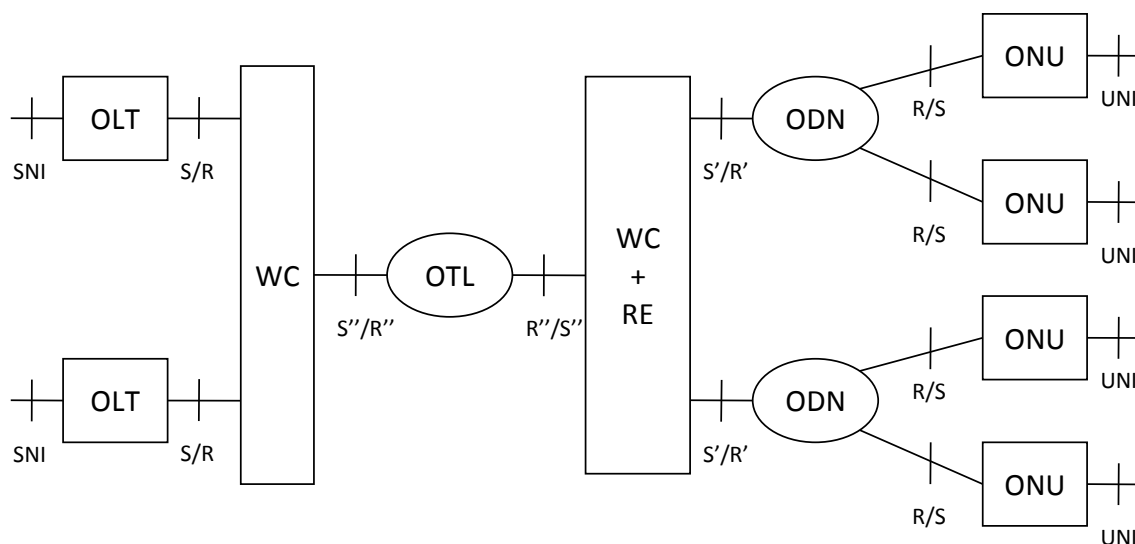
Figure 2a – Wavelength conversion reach extender architecture

An additional extended architecture considered in this architecture is shown in Figure 2b. 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 within the OLT itself.
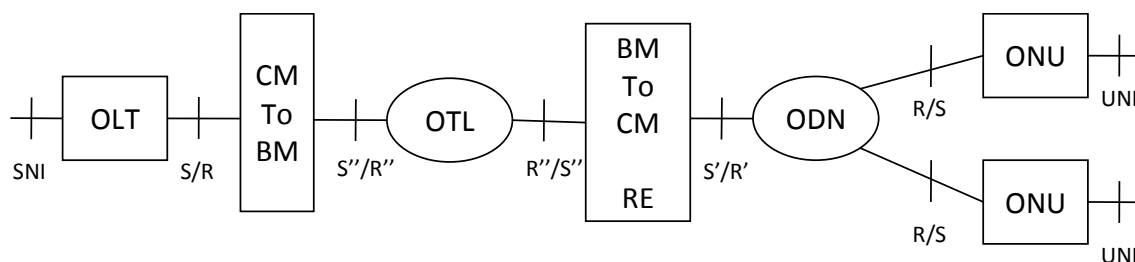

Figure 2b – BM-to-CM conversion reach extender architecture

Add the following text at the end of clause 6.2:

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 a continuous signal. The downstream signal (denoted CMGPON_D) 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). The upstream signal (denoted CMGPON_U) has a bit rate of 1.24416 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 CMGPON_U signal is composed of the regenerated upstream bursts and some 'filler' signal inserted between the bursts. The filler signal is a bit pattern that is well balanced in order to avoid long consecutive identical digits (CID). This continuous signal is transmitted by the R"/S" interface. The filling bit_pattern is configured by the management system at both the transmitter and receiver. The pattern is subject to the control of the OLT; 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 6a. 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.
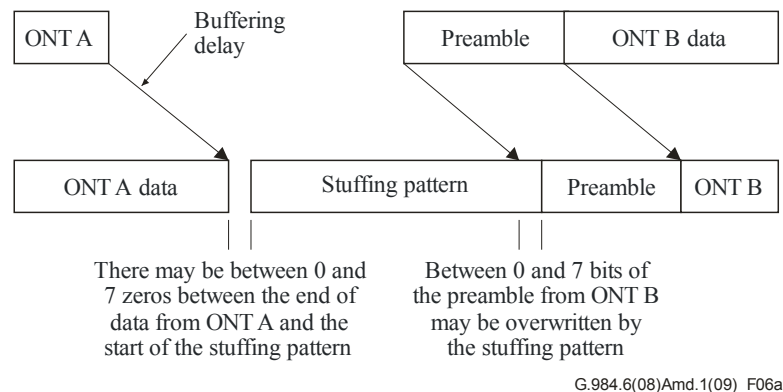

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Figure 6a – Frame of the upstream CMGPON_U signal

Specific techniques for implementing BM-to-CM are beyond the scope of this Recommendation; however, there are a couple of basic methods for detecting the gaps between bursts.

Detecting the gap at the optical layer (fibre to PHY interface). On the OEO RE, the optical power is detected, and a control signal is generated accordingly which can be used to control the insertion.

Detecting the gap at the logical layer (PHY to MAC interface). There are some regular patterns (typically the all-zeroes pattern) in the burst gaps which can be detected and used to generate the control signal. Upon the completion of data synchronization, the receiver accepts the burst data while at the same time it is searching for the end of the burst. When it detects the burst termination by finding the expected pattern, it can reset the burst receiver. Detecting the beginning of bursts requires 32 bit pattern matching, except for cases where the receiver produces random data between bursts, in which case 96 bit patterns are required for a reliable result. Also, 96 bit pattern matching is required to detect the end of bursts for a reliable result. These numbers of required digits are based on statistical calculations of the probability of missing a burst event or creating a false burst event. Shorter or longer pattern matching is possible, with the concomitant change in error probability.

The gap detector will require a logical buffer to store the upstream data to compensate for the non-zero response time of the gap detector, so as to avoid long gaps of all-zero data. However, the stuffing pattern is typically byte-oriented, while the aligned bursts can be at any arbitrary bit timing. Therefore, in this case an integral number of 0 to 7 bits of zeroes should be expected at the end of each burst, and the last byte of the stuffing pattern will overwrite an integral number of 0 to 7 bits of the following burst's preamble.

The CM-to-BM converter can find the boundaries of the bursts using the logical layer detection method. Importantly, the pattern between the bursts is known to be filled with the stuffing pattern, and so the detection algorithm can be quite simple and should require only 32 bits of pattern matching to detect the start of a burst, and 96 bits to detect the end of a burst. The comment given above on lengths of bit pattern matching apply here as well.

As with the ordinary OEO RE, the RE system clock is driven by the downstream signal, and the upstream signal from the ONUs is locked synchronously to the downstream signal that the RE sends to them. The frequency, jitter and jitter tolerances of the OLT and ONU equipment are given in [ITU-T G.984.2].

The converted CM signal can optionally be transported over an OTN path. See Appendix VIII for more information.

5)   New clause 6.4 "Wavelength conversion reach extenders"

Add the following text as a new clause 6.4:

6.4   Wavelength conversion reach extenders

A WC-RE unit has the capability of performing the WC function in the upstream and downstream channels. The functional architecture of a WC-RE unit is presented in Figure 7a. The WC function in the upstream channel converts λ_U to λ_{U_OTL} and the WC function in the downstream channel converts λ_{D_OTL} to λ_D. The RE function could either be the OA or OEO type reach extension function as described in clauses 6.1 to 6.3.

The functional blocks in Figure 7a only represent logical functions rather than a specific physical implementation. The functional blocks in Figure 7a can be implemented in a variety of ways; as a separate physical element, component or subassembly performing the desired functions, including implementations whereby the WC function may be implemented as an integral part of the existing elements of the RE unit, as discussed in Appendix VII.

There are several optional elements in this architecture:

•   In some implementations, the local controller (LC), used optionally in remotely managed RE units, may need to control additionally the WC function implementation, selecting the target transmission wavelength (in case of WC-enabled OEO-type REs) or controlling the operating point for all optical wavelength converters (in case of both OA-type and OEO-type REs equipped with WC function). The LC is served by an EONT, which in the figure is connected to one of the outputs of the WC-RE. Other methods of connecting the EONT to the PON signal paths are possible, as well as providing protection for the management channel.

•   Some implementations may optionally utilize optical seed signals provided over the R"/S" interface.

•   One or two fibres can be employed for the OTL.

•   In certain implementations of the RE unit, it may be also necessary to guarantee that a clock signal is exchanged between the upstream and downstream channels for proper bit alignment and phase detection.

Figure 7a – Internal structure of a WC-RE unit with optional WC function shown for both upstream and downstream channels

6) New clause 6.5 "Wavelength re-conversion at OLT"

Add the following text as a new clause 6.5:

6.5 Wavelength re-conversion at OLT

The OLT WC function block is required to ensure that the existing ITU-T G.984.2-compatible optical interfaces at the OLT do not need to be redefined.

Figure 7b presents the functional architecture of the WC-OLT unit, with optional WC function implementation for both downstream and upstream channels. An optional management function based on an EONT function is also presented; however, since this equipment is likely located in the central office, other management mechanisms may be used.
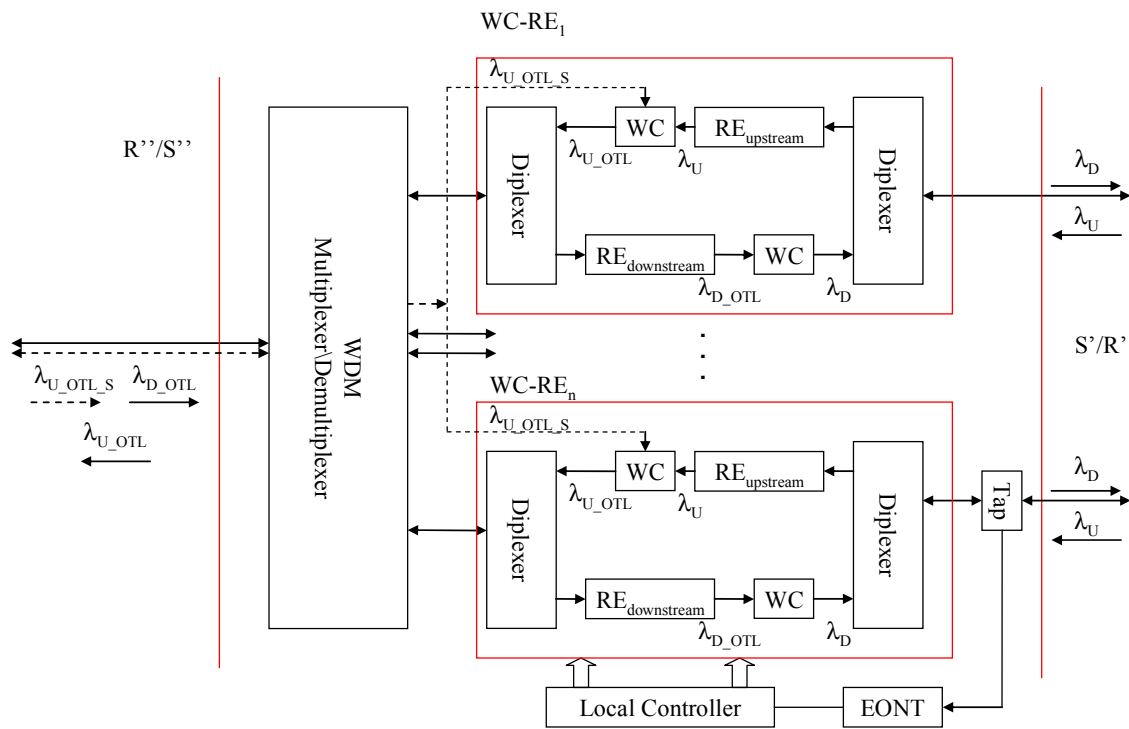
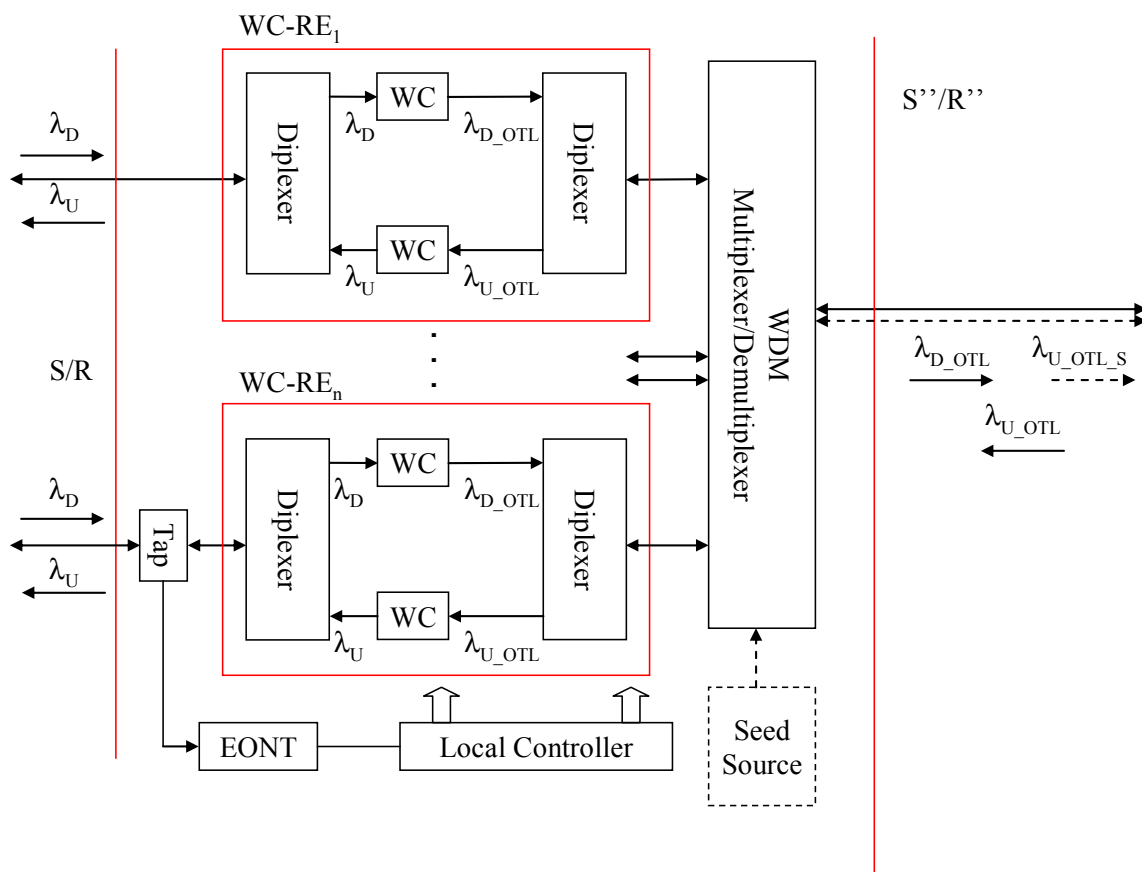One or two fibres can be employed for the OTL.

Figure 7b – Internal structure of a WC-OLT unit with optional WC functions shown for both upstream and downstream channels

The functional blocks in Figure 7b only represent logical functions rather than a specific physical implementation. The functional blocks in Figure 7b can be implemented in a variety of ways as a separate physical element, component or subassembly performing the desired functions, including implementations, whereby the WC function may be implemented as an integral part of the existing elements of the RE unit, as discussed in Appendix VII.

The WC function performs conversion of the frequency of the optical signal carried over OTL in the downstream and upstream directions, adjusting it to the conditions required at the S/R and S"/R" interfaces. The WC function in an RE unit may also be implemented in a wavelength-transparent way in the downstream and/or upstream direction, depending on the user requirements.

6.5.1 Operation of WC function in downstream channel

Implementation of the WC-OLT function in the downstream channel is optional and depends on the implementation of the WC function in the RE unit.

If the WC-OLT function is implemented, the optical signal received from the OLT at λ_D is converted into λ_{D_OTL}, which is then transmitted towards the WC-enabled RE over the OTL. In practice, that means that the optical signal received at λ_D, compliant with the ITU-T G.984.x-series can be converted into any wavelength λ_{D_OTL}.

Detailed information about the wavelength-transparent WC function is provided in clause 8.6.

Values of λ_{D_OTL} are given in clause 8.6.

6.5.2 Operation of WC function in upstream channel

Implementation of the WC-OLT function in the upstream channel is optional and depends on the implementation of the WC function in the RE unit.

The optical signal received from the OTL at λ_{U_OTL} is converted into λ_U compliant with the ITU-T G.984.x-series and then delivered to the OLT connected to the S/R interface of the WC function. This way, the WC function adapts the optical signal received from the ONU over the OTL into the existing ITU-T G.984.2/ITU-T G.984.5-compliant OLT receiver.

Detailed information about the wavelength transparent WC function is provided in clause 8.6.

Values of λ_{U_OTL} are given in clause 8.6.

6a) Modifications to tables in clause 8 "Specifications for mid span extenders"

Add the following lines to Table 1:

Items	Unit	Specification
Attenuation range for C-band applicable for WC types of extenders	dB	14-27.5 (Note 1)
Maximum attenuation for L-band applicable for WC types of extenders	dB	14-27.5 (Note 1)

In Table 2a, add Note 4 to the item "operating wavelength":

"NOTE 4 – For WC-type reach extenders, the operating wavelength may be changed; see clause 8.6."

And Note 5 to the item "line code":

"NOTE 5 – For some optical wavelength converters, the non-return to zero (NRZ) data is inverted in the OTL section between the WC-RE and the WC-OLT."

Add the following lines to Table 2a immediately after the row "Dispersion reach at 1 dB penalty":

Mean launched seed light power MIN (per channel) (Note 4)	dBm	FFS	FFS
Mean launched seed light power MAX (per channel) (Note 4)	dBm	FFS	FFS

Add Note 4 to Table 2a:

NOTE 4 – Typical seed light sources have a spectral power density of 6 dBm/nm.

In Table 2b, add Note 7 to the item "operating wavelength":

"NOTE 7 – For WC-type reach extenders, the operating wavelength may be changed; see clause 8.6."

And Note 8 to the item "line code":

"NOTE 8 – For some optical wavelength converters, the NRZ data is inverted in the OTL section between the WC-RE and the WC-OLT."

7)   New clause 8.6 "WDM wavelength allocation plan for OTL"

Add the following text as a new clause 8.6:

8.6   WDM wavelength allocation plan for OTL

The wavelength allocation plans for the OTL between the S"/R" and R"/S" interfaces are defined in this clause. Since the various technical options have different requirements on the wavelength allocation, we arrive at several channel plans. Examples of the application of these plans are shown in Appendix VII.

8.6.1   Transparent OTL wavelength allocation plan

The transparent OTL wavelength allocation plan is presented in Table 5a. The basic design principle here is to use the central 20 nm of the GPON wavelengths, and employ the usual 100 or 50 GHz channel grid. This arrangement should facilitate forward compatibility with the maximal set of GPON equipment.

Table 5a – Transparent OTL wavelength allocation plan
for upstream and downstream channels

	Upstream		Downstream	
Minimum channel spacing	100 GHz	50 GHz	100 GHz	50 GHz
Minimum central frequency	227.70 THz 1316.61 nm	227.70 THz 1316.61 nm	200.10 THz 1498.21 nm	200.05 THz 1498.59 nm
Maximum central frequency	230.00 THz 1303.45 nm	230.05 THz 1303.16 nm	202.40 THz 1481.19 nm	202.40 THz 1481.19 nm
Spectral excursion	±20 GHz	±10 GHz	±20 GHz	±10 GHz
Total number of supported channels	24	48	24	48

8.6.2   Conventional OTL wavelength allocation plan

The conventional OTL wavelength plan is presented in Table 5b. The basic design concept here is to use conventional wavelength assignments from [ITU-T G.694.1] or [ITU-T G.694.2]. In dense wavelength division multiplexing (DWDM) applications using two fibres, the "C-band" allocations are used for both transmission directions. In DWDM applications using a single fibre, the "C-band" is used for the upstream and the "L-band" is used for the downstream.

Table 5b – Conventional OTL wavelength allocation plan

	CWDM option	DWDM options for upstream and two-fibre downstream		DWDM options for single-fibre downstream	
Minimum channel spacing	20nm	100 GHz	50 GHz	100 GHz	50 GHz
Maximum central frequency	1471 nm	196.0 THz 1529.55 nm	196.05 THz 1529.16 nm	190.3 THz 1575.37 nm	190.35 THz 1574.95 nm
Minimum central frequency	1611 nm	192.1 THz 1560.61 nm	192.1 THz 1560.61 nm	186.4 THz 1608.33 nm	186.4 THz 1608.33 nm
Spectral excursion	±6.5 nm	±20 GHz	±10 GHz	±20 GHz	±10 GHz
Total number of supported channels	18	40	80	40	80

8.6.3　Optically-converted OTL wavelength allocation plan

The optically-converted wavelength allocation plan is presented in Table 5c. This wavelength plan is suitable for certain wavelength conversion technologies that have a limitation in the change of wavelength. For this reason, the wavelength bands are placed close to (but not overlapping) the central 20 nm bands of the GPON wavelengths.

Table 5c – Optically-converted OLT wavelength plan

	Upstream		Downstream	
Minimum channel spacing	100 GHz	50 GHz	100 GHz	50 GHz
Minimum central frequency	231.30 THz 1296.12 nm	231.25 THz 1296.40 nm	197.40 THz 1518.71 nm	197.35 THz 1519.09 nm
Maximum central frequency	233.60 THz 1283.36 nm	233.60 THz 1283.36 nm	199.70 THz 1501.21 nm	199.70 THz 1501.21 nm
Spectral excursion	±20 GHz	±10 GHz	±20 GHz	±10 GHz
Total number of supported channels	24	48	24	48

8.6.4　Cyclic OTL wavelength allocation plan

The cyclic OTL wavelength allocation is presented in Table 5d. This wavelength plan is suitable for implementations that employ a single wavelength multiplexing device for both directions, and each direction uses a different diffractive order of the multiplexer. The upstream "C-band" uses the conventional ITU-T G.694.1 grid assignments, and the downstream "L-band" uses the cyclically-related grid assignments.

Table 5d – Cyclic OLT wavelength plan

	Downstream			Upstream		
Minimum channel spacing	194.7 GHz	97.35 GHz	48.675 GHz	200 GHz	100 GHz	50 GHz
Minimum central frequency	187.4234 THz 1599.49 nm	187.4234 THz 1599.49 nm	187.4234 THz 1599.49 nm	192.4 THz 1558.17 nm	192.4 THz 1558.17 nm	192.4 THz 1558.17 nm
Maximum central frequency	190.3439 THz 1575.04 nm	190.4413 THz 1574.21 nm	190.49 THz 1573.79 nm	195.4 THz 1534.25 nm	195.5 THz 1533.46 nm	195.55 THz 1533.07 nm
Spectral excursion	±40 GHz	±20 GHz	±10 GHz	±40 GHz	±20 GHz	±10 GHz
Total number of supported channels	16	32	64	16	32	64

8)　New Appendix VI "Extender-based type B protection scheme"

*Add the following text as a new Appendix VI*:

Appendix VI

Extender-based type B protection scheme

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

VI.1   OEO extender-based type B protection architecture

Figure VI.1 shows the architecture of an OEO-based RE PON with type B protection function. The protection switch function is done by an integrated MUX module within the EONT MAC. Once the EONT is powered on, the inner MUX module, controlled by the EONT MAC, chooses to pass the signal from the Tx/Rx set at the R'/S' side connecting with the working OLT. Then the EONT registers to this OLT as any other normal ONT does. On completion of the EONT's registration, the OLT could issue its local EqD information of every connected ONT to this EONT on a real time basis. Once protection switching occurs, the backup OLT issues the request of re-ranging the EONT. On receiving the ranging request signal, the EONT changes its MUX status immediately and then chooses to pass the signal from the backup link transmission. Once successfully registered, it is the responsibility of the backup OLT to work out all the EqDs and then drive all the ONTs into an operational state by sending out the ranging-time messages. Then the system enters the normal working state as usual.
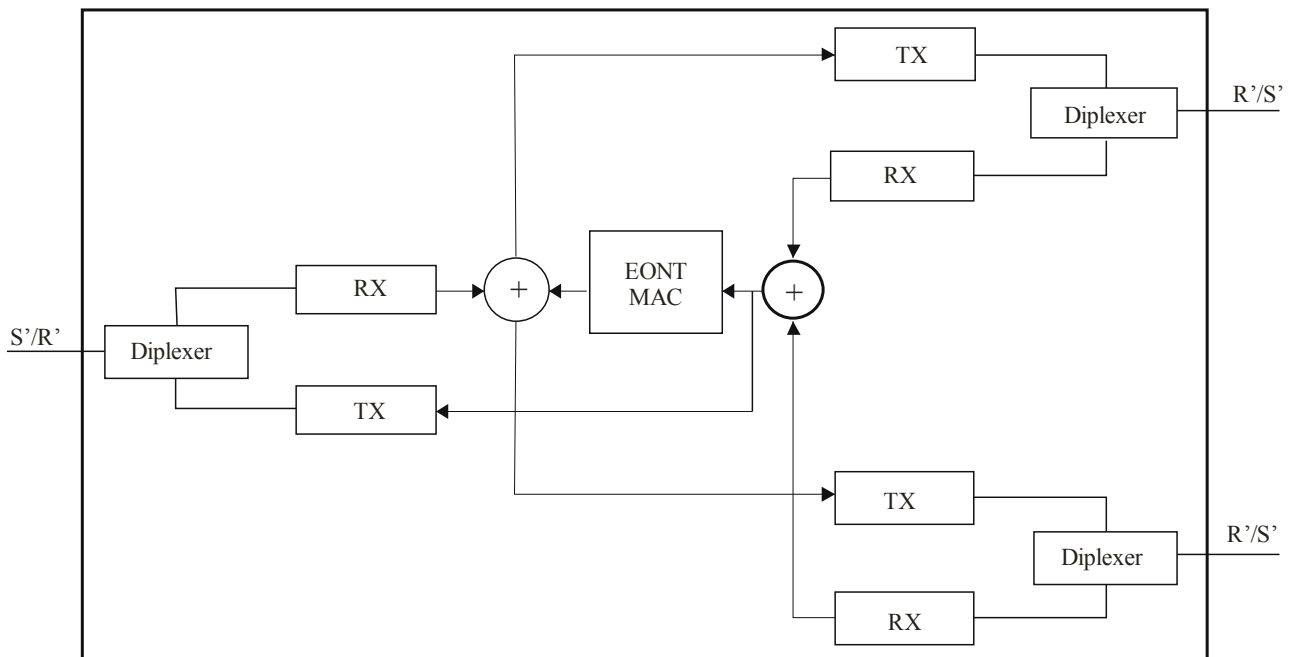
G.984.6(08)Amd.1(09)_FVI.1

Figure VI.1 – OEO-based RE PON with type B protection: Integrated MUX module

VI.2   OA extender-based type B protection architecture

Figure VI.2 shows the architecture of an OA-based RE PON with type B protection function. However, the protection switching function is done by an external MUX module at the R'/S' side. Though the extending feature is implemented through an optical amplifier, it works quite similarly to the architecture shown in Figure VI.1 during protection switching.
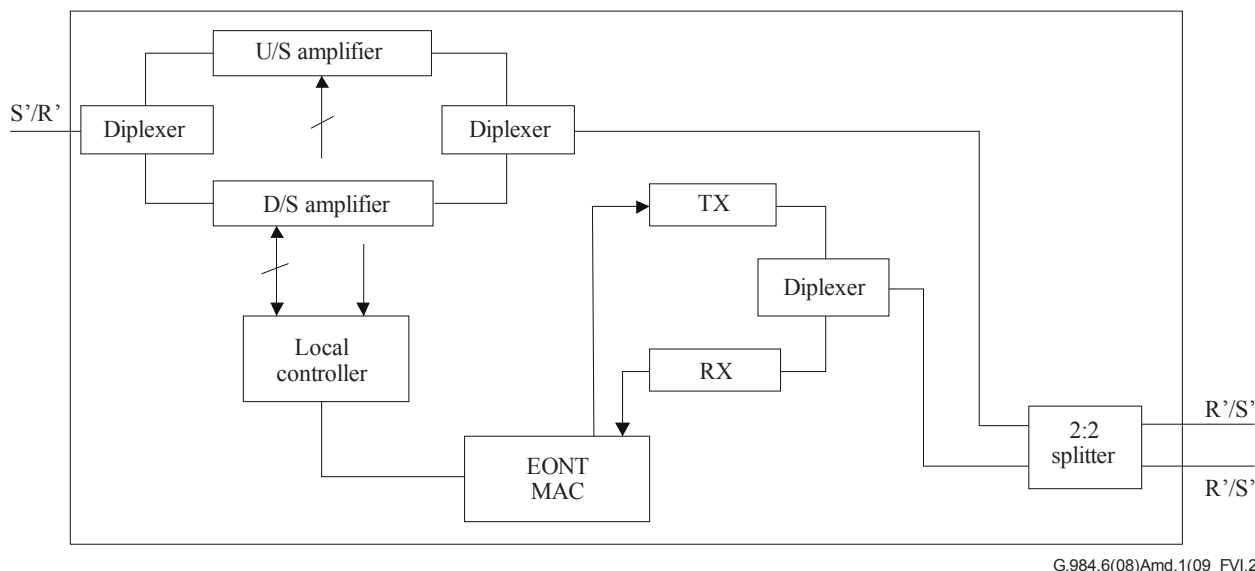
G.984.6(08)Amd.1(09_FVI.2

Figure VI.2 – OA-based RE PON with type B protection: External MUX module

9) **New Appendix VII "Possible realization of OA and OEO-based extenders using wavelength conversion"**

Add the following text as a new Appendix VII:

Appendix VII

Possible realization of OA and OEO-based extenders using wavelength conversion

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

This appendix illustrates examples of several implementations of wavelength conversion extenders.

VII.1 A transparent wavelength plan extender realization

Figures VII.1 and VII.2 show example optical schematic diagrams for the wavelength conversion reach extender and wavelength conversion OLT for a transparent wavelength conversion design.
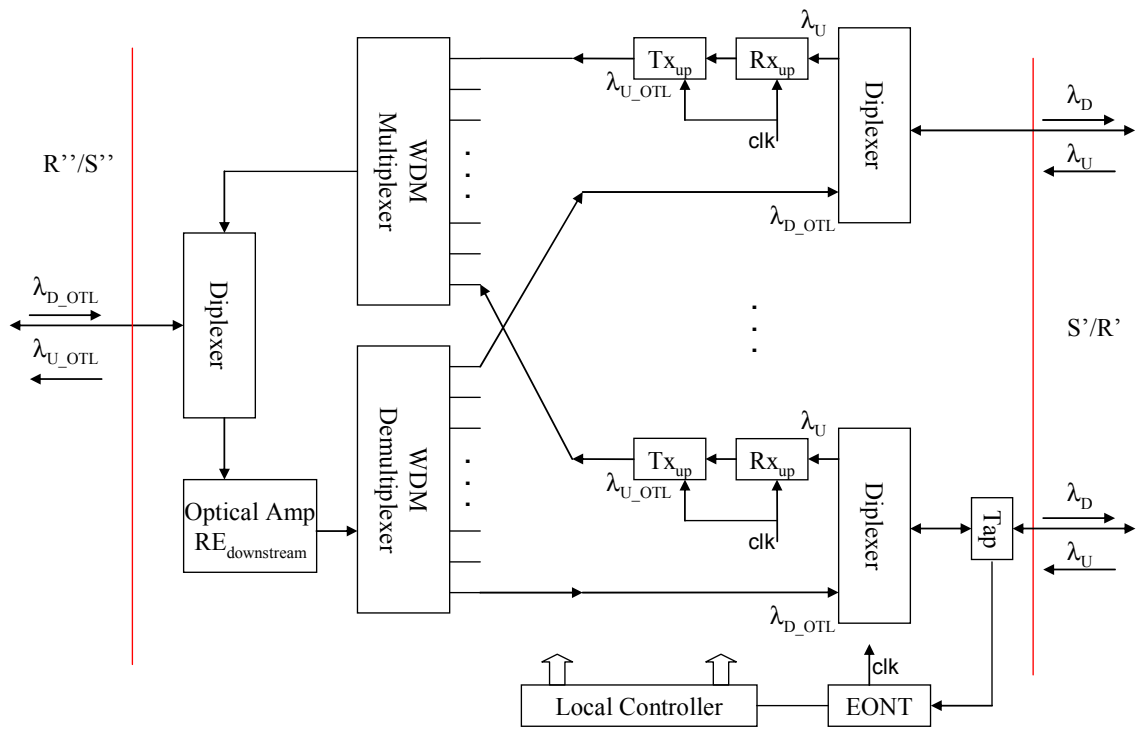
Figure VII.1 – Example of a transparent wavelength conversion reach extender
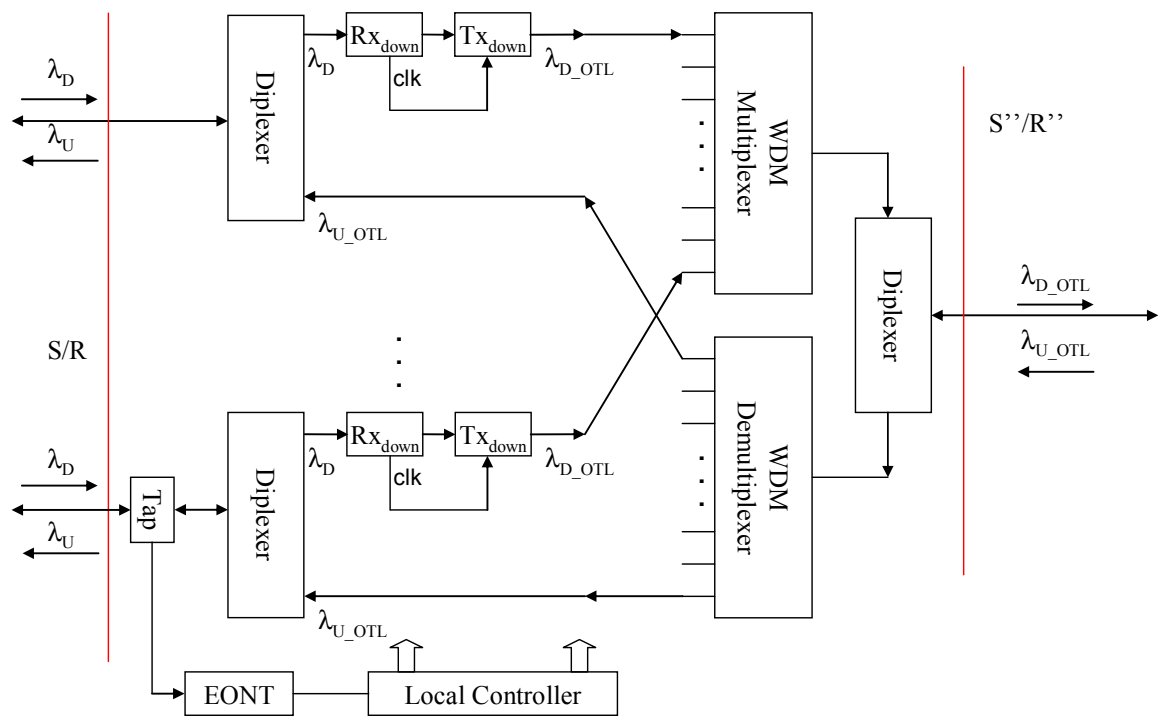

Figure VII.2 – Example of a transparent wavelength conversion OLT

The chief advantage of the transparent wavelength conversion system is that the wavelength re-conversion at the receiving end of the OTL is avoided. In the downstream, all that is needed at the reach extender is an optical amplifier. This is particularly advantageous in cases where this amplifier can handle all of the wavelength channels at once. In the upstream direction at the WC-OLT, only passive WDM demultiplexing is used to direct the channels to the appropriate OLT port. On the transmitting end of the OTL, any means of wavelength conversion is possible; in the example here, OEO conversion is used.

VII.2 A conventional wavelength plan extender realization

Figures VII.3 and VII.4 show example optical schematic diagrams for the wavelength conversion reach extender and wavelength conversion OLT for a conventional wavelength conversion design. This is perhaps the most straightforward type of wavelength conversion, where both directions of the PON signals are converted to the conventional ITU-T G.694 wavelengths and back again. This example shows OEO wavelength conversion technology, but other types of conversion are possible. This example also shows the use of BM-to-CM conversion and re-conversion. This allows for the use of more common CM optics, but this is not essential.
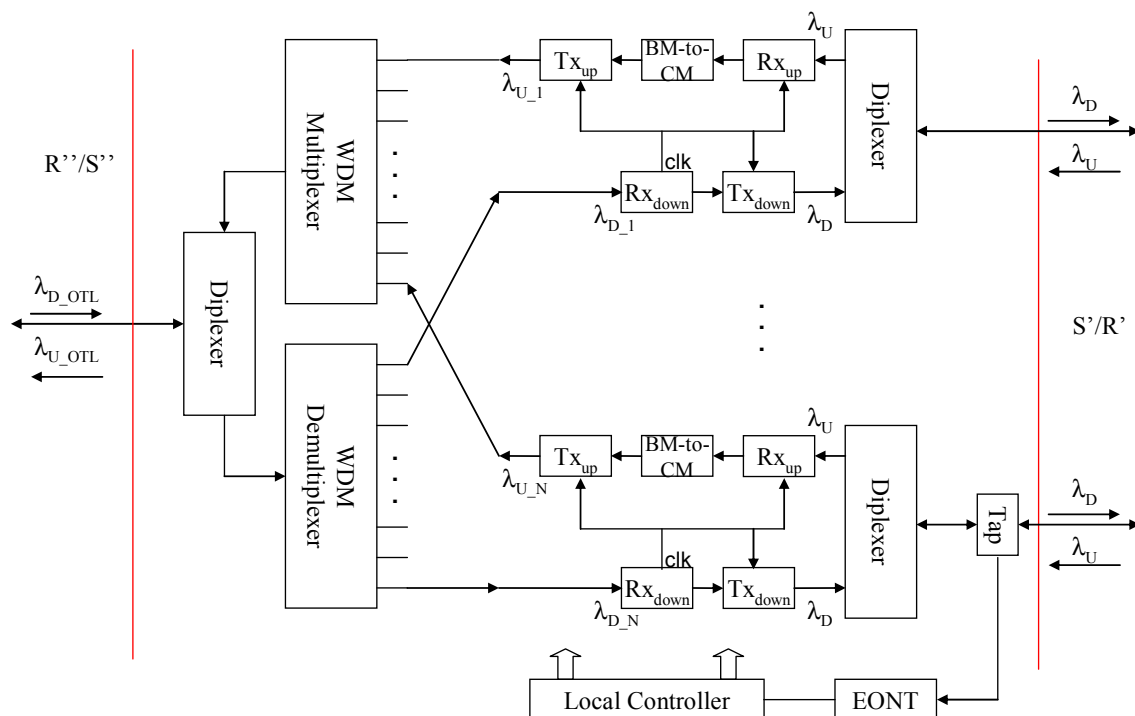

Figure VII.3 – Example of a conventional wavelength conversion reach extender
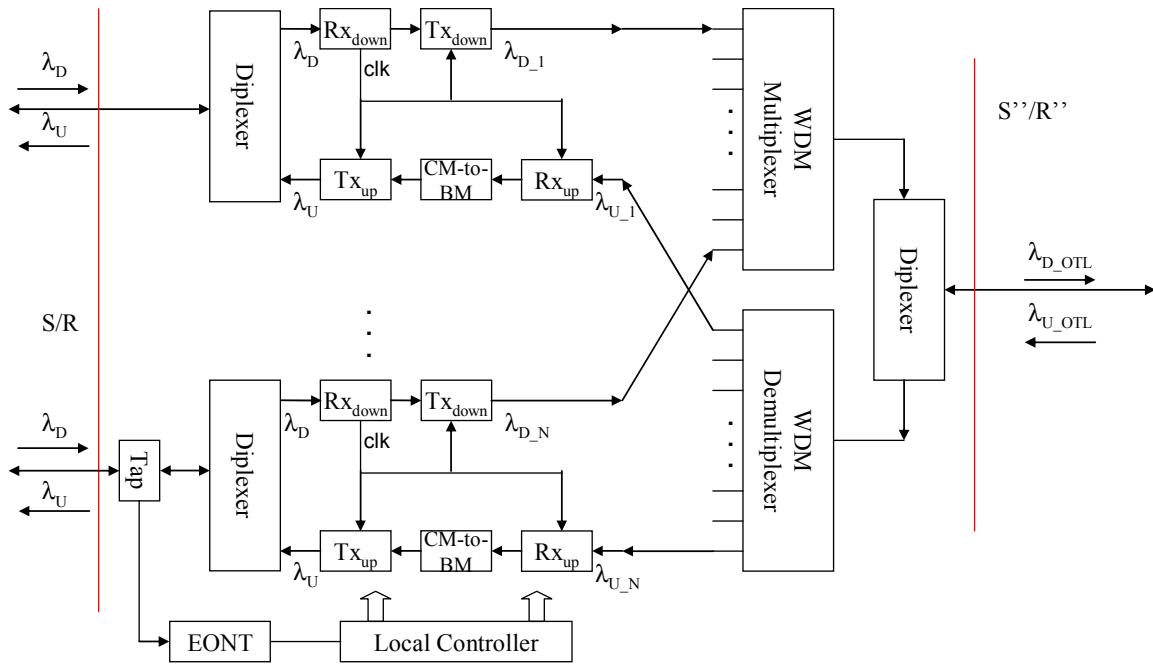
Figure VII.4 – Example of a conventional wavelength conversion OLT

VII.3 An OWC-based extender realization

Figures VII.5 and VII.6 show example optical schematic diagrams for the wavelength conversion reach extender and wavelength conversion OLT for an optical wavelength conversion (OWC) design. The main advantage of optical wavelength conversion is that it can be independent of PON signal data rate and protocol format. From a certain point of view, this is more "passive" than other types of wavelength conversion.
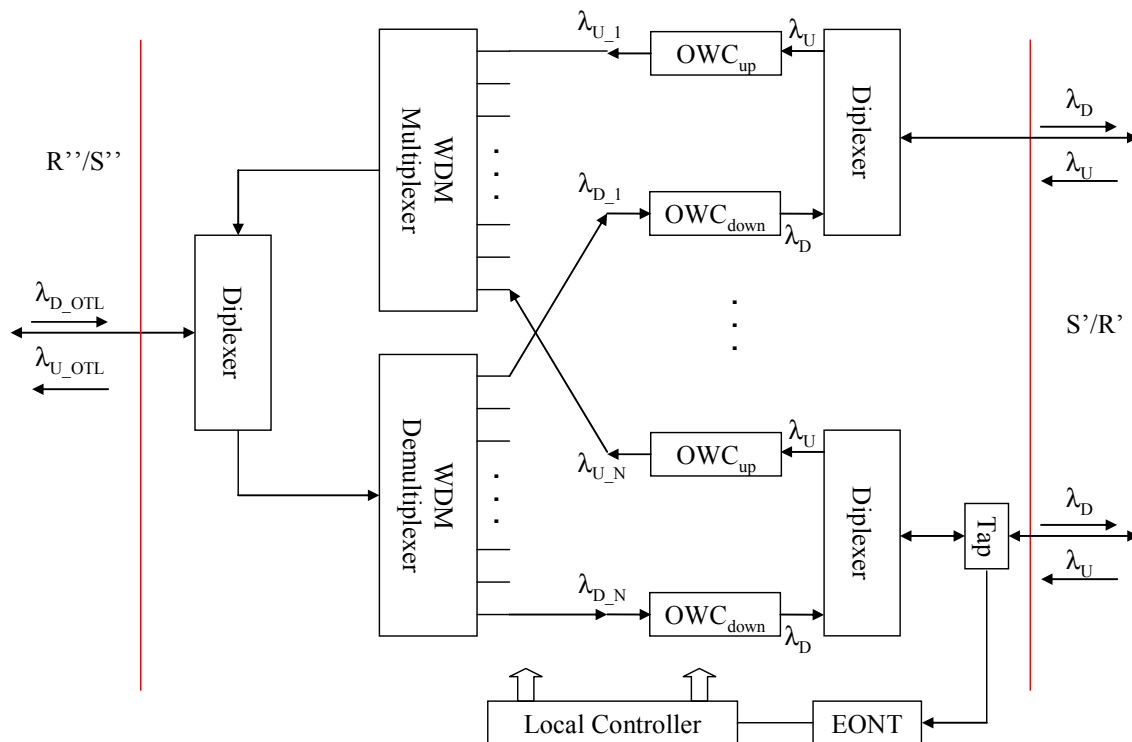

Figure VII.5 – Example of an optical wavelength conversion reach extender
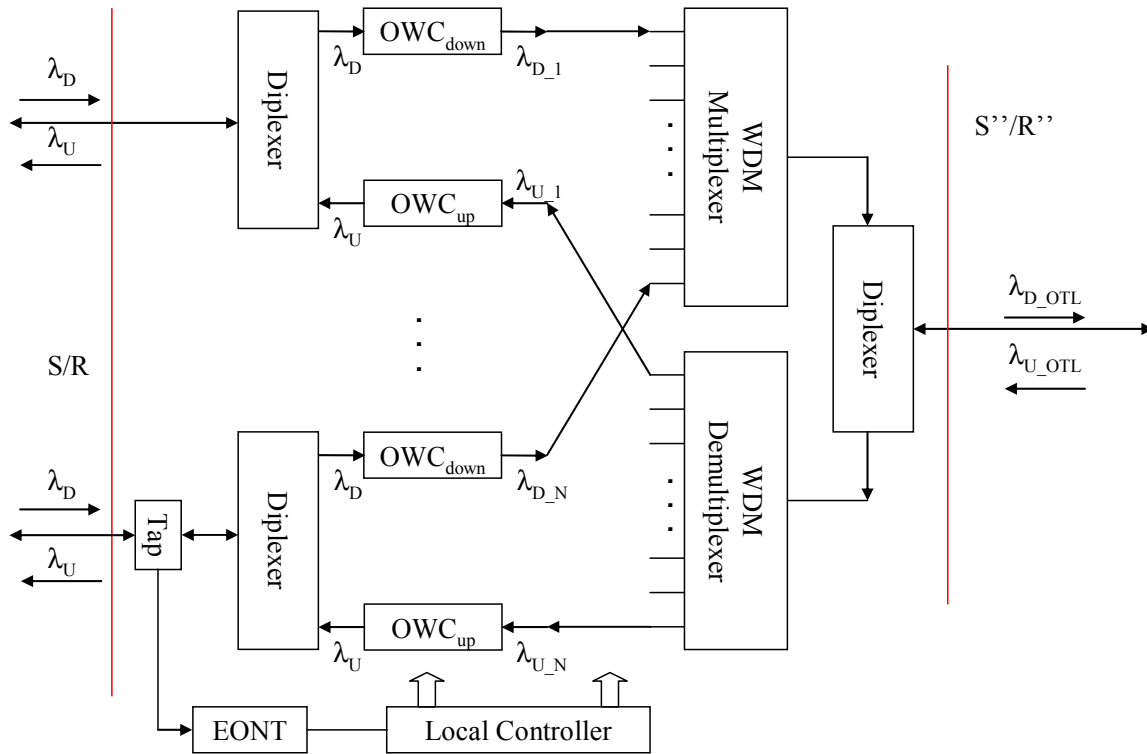
Figure VII.6 – Example of an optical wavelength conversion OLT

One possible implementation of an optical wavelength converter is the so-called "AOWC" device. The AOWC device can be constructed from the following components:

- **Input fibre**, which guides the input signal into the AOWC.
- **SOA-based fibre-grating external-cavity laser**, operating at wavelength λ_2, responsible for the wavelength conversion function.
- **Output fibre**, which guides the wavelength-converted signal out of the AOWC unit.

The operating principle can be described as follows:

The input optical fibre guides the non-return to zero (NRZ) input signal at wavelength λ_1 into the SOA unit. The amplitude-modulated NRZ input signal at wavelength λ_1 is amplified and the output optical power at wavelength λ_2 is suppressed simultaneously by cross-gain modulation (XGM) effect. The output optical power at wavelength λ_2 is modulated by the input signal power and the input NRZ signal is wavelength converted from wavelength λ_1 to wavelength λ_2 with reversed digital levels (logical "1" is equivalent to low light level). The output fibre guides the wavelength-converted signal at wavelength λ_2 out of the AOWC. An WDM multiplexer/demultiplexer or arrayed wavelength grating (AWG) located outside of the AOWC, acting as a wavelength-selective filter, blocks the input signal at wavelength λ_1 and only allows the wavelength-converted signal at wavelength λ_2 to pass through.

VII.4 A cyclic seeded wavelength plan extender realization

Figures VII.7 and VII.8 show example optical schematic diagrams for the wavelength conversion reach extender and wavelength conversion OLT for a cyclic wavelength conversion design, that also happens to use a seeded transmitter at the RE.
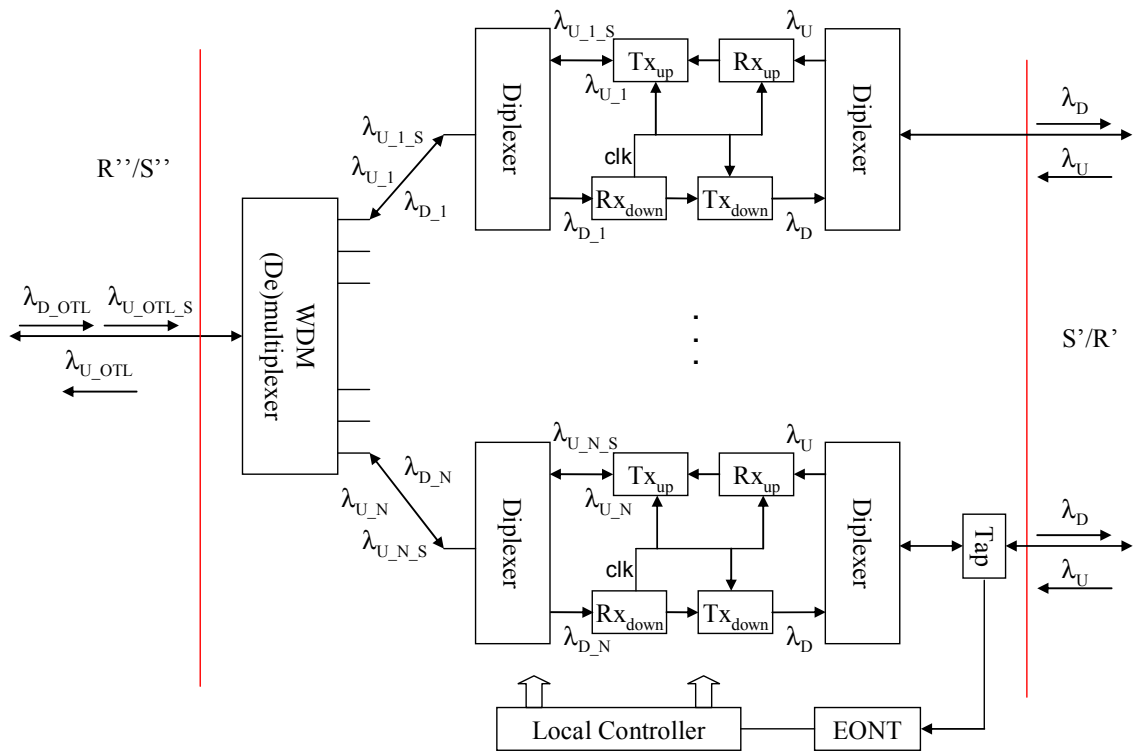
Figure VII.7 – Example of a cyclic seeded wavelength conversion reach extender

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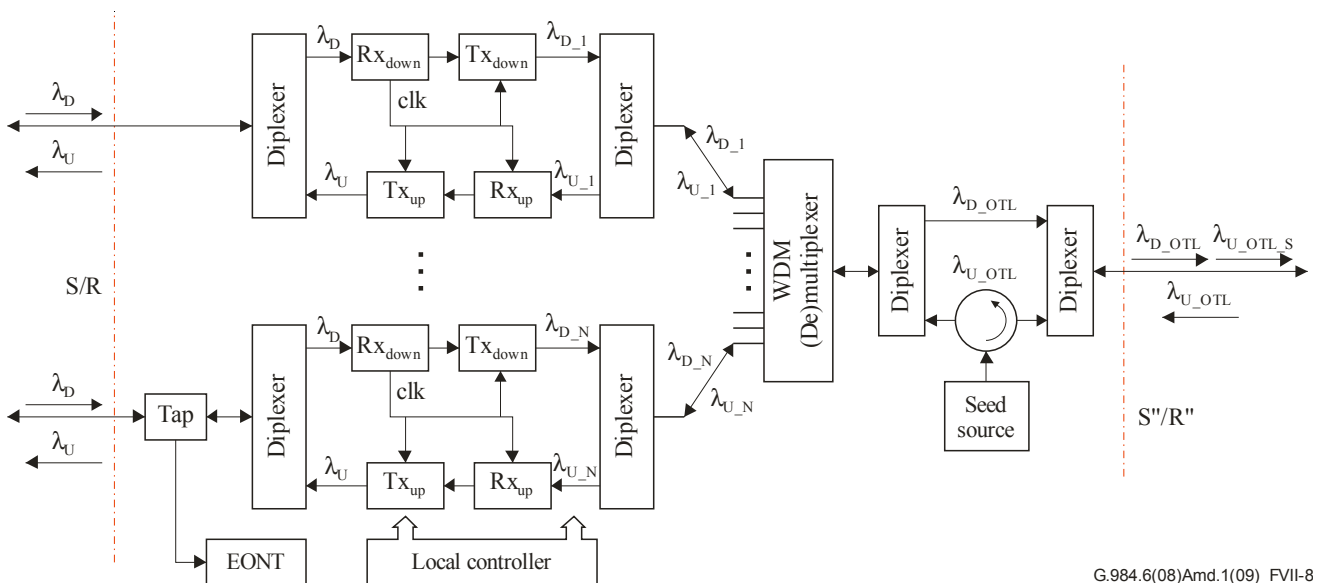**Figure VII.8 – Example of a cyclic wavelength conversion OLT**

A major value of the seeded WC-OEO-RE is that transmitters at RE units are colourless. "Colourless" means that RE transmitters do not have wavelength-specific characteristics, and therefore need not be plugged into specific wavelength ports of the mux/demux. This saves both inventory and administrative tracking costs for the operating company.

The seed signals are generated by a broadband light source (BLS) located in the WC-OLT. The unmodulated broadband light source (BLS) signal is spectrally sliced by the WC-RE AWG demultiplexer into multiple narrow-band seed signals for each of the identical seeded transmitters. The seed signal injection into each OEO transmitter module forces it to operate in a narrow wavelength range for transmission through the WDM filters.

The use of a separate upstream and downstream communication band is possible through the use of cyclic AWGs designed to be periodic in wavelength in order to operate in multiple bands. The AWG can simultaneously support two communication wavelength bands on each of its input and output fibres. This allows an AWG to perform multiple functions, for example, the reach extender AWG serves three functions, which are:

1)   demultiplexes the downstream data traffic;

2)   demultiplexes the seeding signals;

3)   multiplexes the upstream data traffic.

The operation of the cyclic AWG uses the principles of bulk-optics diffraction grating that operates at a high diffraction order. This allows both a downstream and upstream wavelength to be diffracted into the same output fibre by using the different diffraction orders within the AWG. This results in multiple wavelengths being coupled into each output fibre that are spaced by the free-spectral-range of the cyclic AWG. While the channel-plan for the upstream propagation direction aligns exactly on the ITU frequency grid, the "run out" in the cyclic band for the opposite direction will have a channel-plan that would not be aligned to the ITU grid in that band. In this implementation, the C-band is used for the upstream direction and is defined on the ITU grid, whereas the L-band is used in the downstream direction and is not on the ITU grid.

10)   New Appendix VIII "Transport of BM-to-CM converted signals over OTN"

Add the following text as a new Appendix VIII:

Appendix VIII

Transport of BM-to-CM converted signals over OTN

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

The use of BM-to-CM-enabled reach extender functions opens a new possibility: transporting the resulting continuous mode signals over the optical transport network (OTN). The basic system arrangement is shown in Figure VIII.1.
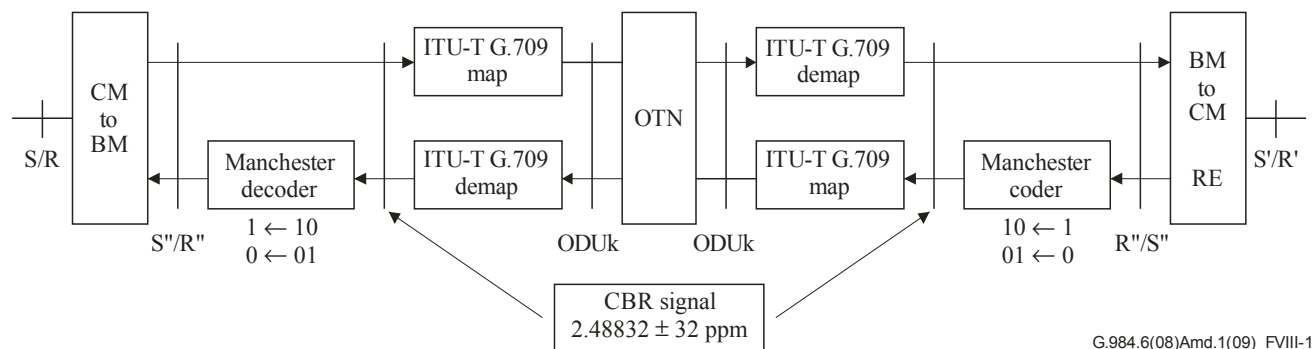

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Figure VIII.1 – The transport of BM-to-CM signals over OTN

In the downstream direction, the CM-to-BM unit performs a null function (that is, the output of the OLT is already a continuous mode signal). The CMGPON_D signal is a 2.48832 Gbit/s constant bit rate signal, and it has a frequency accuracy no worse than 32 ppm (corresponding to an OLT that is operating in free-running mode, per clause 8.2.3.1 of [ITU-T G.984.2]. In fact, in normal operation the frequency accuracy should be 4.6 ppm or better. Recommendation ITU-T G.709 describes how to map the CMGPON_D signal into an ODUk, and how to de-map (recover) the signal back again on the other side. The BM-to-CM unit performs a null function again, and merely passes the continuous mode signal onto the optical interface.

In the upstream, the BM-to-CM unit converts the upstream bursts into a continuous mode signal (CMGPON_U), as described in clause 6.2. The CMGPON_U signal is a 1.24416 Gbit/s constant bit rate signal that is synchronous to the downstream signal, and it has a frequency accuracy no worse than the downstream signal (per clause 8.2.3.2 of [ITU-T G.984.2]). A Manchester coder is used to convert the 1.24416 Gbit/s signal into a 2.48832 Gbit/s signal (denoted CMGPON_U2), where an input "1" produces an output "10", and an input "0" produces an output "01". Recommendation ITU-T G.709 describes how to map the CMGPON_U2 signal into an ODUk, and how to recover it on the other side. The CM-to-BM unit converts the upstream continuous mode signal back into a burst-like signal, and passes this to the OLT.

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