5.8 Coexistence and Backward Compatibility

The requirement for backward compatibility and coexistence with 1G-EPON, 10G-EPON, and unidirectional / bidirectional RF overlay systems on the same ODN is critical for technical development of NG-EPON systems. There are several deployment scenarios for NG-EPON systems, with different coexistence and backward compatibility requirements. The resulting wavelength allocation for NG-EPON needs to account for these different deployment scenarios, while observing technical and economic feasibility.

Note that there are two main types of deployed RF overlay systems, namely:

- unidirectional (downstream-only, with center wavelength at 1550 nm) RF overlay with digital return channel,
- bidirectional (with downstream center wavelength at 1550 nm and upstream center wavelength at 1610 nm) RF overlay [SCTE] with analog return channel.

These two RF overlay types are compatible with EPON, i.e., they can coexist with 1G-EPON and 10G-EPON on the same ODN. A variation of the bidirectional RF overlay with the upstream channel centered at 1310 nm is not compatible with EPON, i.e., it cannot coexist on the same ODN with 1G-EPON or 10G-EPON, and it is excluded from the following analysis.

5.8.1 NG-EPON in green-field scenario

When deployed in the green-field scenario, NG-EPON does not have any specific coexistence and backward compatibility requirements. The wavelength allocation plan selected for NG-EPON for this scenario needs to make the most optimum use of the available SMF spectrum and provide sufficient number of wavelength channels to address the capacity requirements discussed in this report.

5.8.2 NG-EPON coexisting with 1G-EPON and optional RF overlay

When deployed in a brown-field scenario on the ODN carrying 1G-EPON and optional unidirectional / bidirectional RF overlay, there are several requirements that the NG-EPON needs to meet, as follows:

- NG-EPON downstream channel does not overlap with and impact the downstream 1G-EPON channel and downstream RF channel,
- NG-EPON upstream channel does not overlap with and impact the upstream 1G-EPON channel and optional RF upstream (return) channel,
- NG-EPON upstream and downstream channels do not require any changes in the design of wavelength blocking filters in 1G-EPON ONUs and RF overlay ONU already deployed in the field.

Effectively, the wavelength plan selected for NG-EPON needs to avoid the wavelength bands allocated to 1G-EPON and unidirectional / bidirectional RF overlay, and simultaneously use wavelength bands rejected by the wavelength blocking filters in deployed 1G-EPON and RF ONUs devices. TDM or WDM coexistence with 1G-EPON in the upstream direction is required, with preference for WDM coexistence. WDM coexistence with 1G-EPON in downstream is required.

5.8.3 NG-EPON coexisting with 10G-EPON and optional RF overlay

When deployed in a brown-field scenario on the ODN carrying 10G-EPON and optional unidirectional / bidirectional RF overlay, there are several requirements that the NG-EPON needs to meet, as follows:

- NG-EPON downstream channel does not overlap with and impact the downstream 10G-EPON channel and downstream RF channel,
- NG-EPON upstream channel does not overlap with and impact the upstream 10G-EPON channel and optional RF upstream (return) channel,
- NG-EPON upstream and downstream channels do not require any changes in the design of wavelength blocking filters in 10G-EPON ONUs and RF overlay ONU already deployed in the field.

Effectively, the wavelength plan selected for NG-EPON needs to avoid the wavelength bands allocated to 1G-EPON and unidirectional / bidirectional RF overlay, and simultaneously use wavelength bands rejected by the wavelength blocking filters in deployed 10G-EPON and RF ONUs devices. TDM or WDM coexistence with 10G-EPON in the upstream direction is required, with preference for WDM coexistence. WDM coexistence with 10G-EPON in downstream is required.

5.8.4 NG-EPON coexisting with 1G-EPON, 10G-EPON, and optional RF overlay

When deployed in a brown-field scenario on the ODN carrying 1G-EPON, 10G-EPON, and optional unidirectional / bidirectional RF overlay, NG-EPON needs to simultaneously meet requirements listed in 5.8.2 and 5.8.3.

5.8.5 NG-EPON and 10G-EPON ONUs

It is highly desired that NG-EPON OLT allows 10/10G-EPON to register and operate as if they were connected to a 10G-EPON OLT.

5.8.6 Coexistence requirements

Given the ongoing migration from RF delivery systems towards all-IP delivery paradigm, it is likely that by the time NG-EPON is deployed in the field, RF overlay will not be actively deployed anymore. The aggregate capacity of NG-EPON will further stimulate the removal of any existing RF overlay systems, resulting in all-digital optical access, releasing the downstream and upstream RF overlay channels for the use by digital transmission systems.

NG-EPON shall support coexistence with 10G-EPON on the same ODN in the following manner:

- WDM coexistence in the downstream direction, i.e., NG-EPON operates in a wavelength band that does not overlap or impact downstream 10G-EPON wavelength band,
- WDM or TDM coexistence in the upstream direction, where the WDM coexistence is preferred. The TDM coexistence mode builds on the principle of dual-rate burst-mode operation supported by 10G-EPON when sharing the upstream channel with broad-spectrum 1G-EPON ONU transmitters. The WDM coexistence mode builds on the principle of wavelength filtering when narrow-band (40 nm or even 20 nm) optics is used in deployed 1G-EPON ONU transmitters.

NG-EPON shall support coexistence with 1G-EPON on the same ODN in the following manner:

- WDM coexistence in the downstream direction, i.e., NG-EPON operates in a wavelength band that does not overlap or impact downstream 1G-EPON wavelength band,
- WDM or TDM coexistence in the upstream direction, where the WDM coexistence is preferred. The TDM coexistence mode builds on the principle of dual-rate burst-mode operation supported by 10G-EPON when sharing the upstream channel with broad-spectrum 1G-EPON ONU transmitters. The WDM coexistence mode builds on the principle of wavelength filtering when narrow-band (40 nm or even 20 nm) optics is used in deployed 1G-EPON ONU transmitters.

6.4.5 Wavelength Allocation Plans for NG-EPON

There are several potential wavelength allocations plans available for NG-EPON, depending on the required coexistence with 1G-EPON, 10G-EPON, unidirectional and/or bidirectional RF overlay systems on the same ODN (see 5.8 for details). Examples of potential wavelength allocations plans are presented in the following sections, and shown in Figure 1.

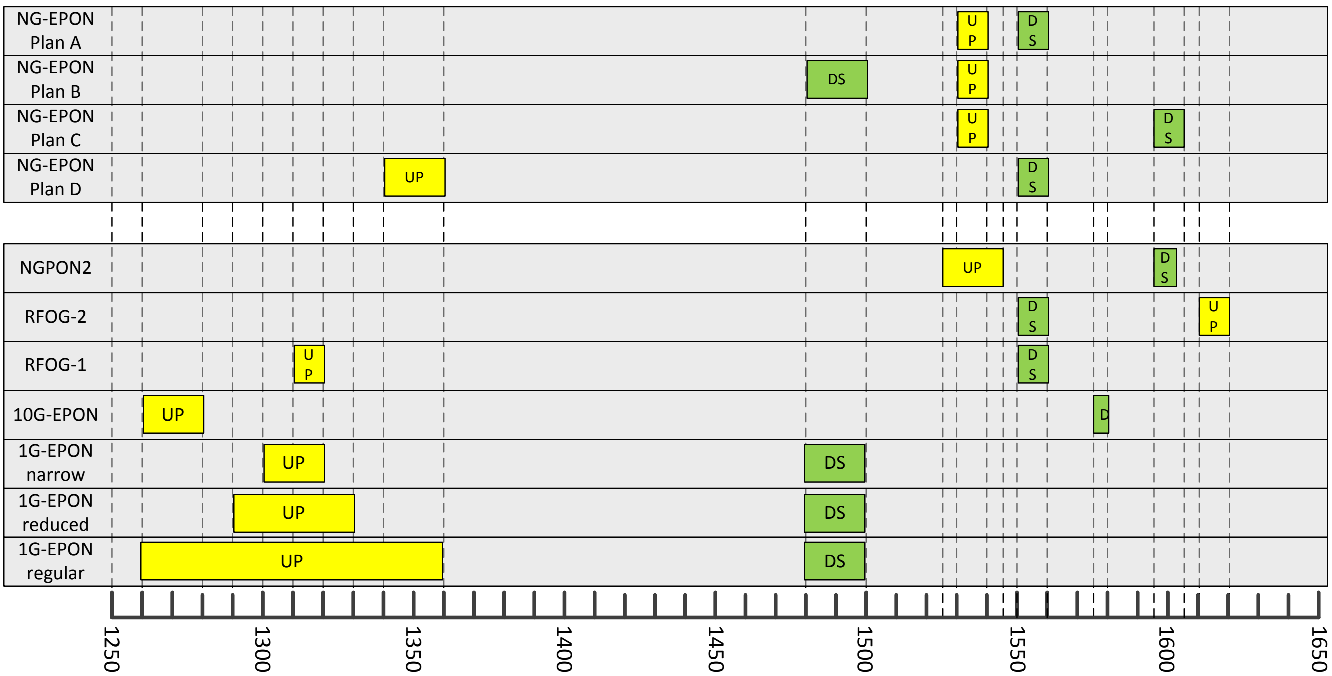

Figure 1: Wavelength allocation plans for 1G-EPON, 10G-EPON, ITU-T PON, SCTE RFOG, and NG-EPON

6.4.5.1 Plan A: Coexistence with 1G-EPON and 10G-EPON [xref]

Figure 1 presents the wavelength plan for NG-EPON (Plan A) guaranteeing coexistence for 1G-EPON, 10G-EPON, and NG-EPON, when operated on the same ODN. The downstream NG-EPON wavelength band is 10 nm wide and placed between 1550 nm and 1560 nm, while the upstream NG-EPON wavelength band is also 10 nm wide and placed between 1530 nm and 1540 nm. Effectively, in this particular wavelength allocation plan, the spectrum band currently reserved for the downstream RF overlay is reused for NG-EPON.

Both downstream and upstream NG-EPON wavelength bands can carry up to 10 separate channels if 100 GHz channel spacing is used.

Optical components for C-band are technically mature and are expected to be cost-efficient at this time, though they are typically designed for transport systems and support very limited power budgets. The dispersion in C-band is much higher when compared with O-band, and thus typically EML transmitters are used. There were also announcement of DML transmitters developed for O-band as well [TBD, reference missing]. However, there are no confirmed C-band components supporting power budgets in excess of 29 dB, capable of operating over the most common ODN designs deployed today.

6.4.5.2 Plan B: Coexistence with RF overlay and 10G-EPON [xref]

Figure 1 presents the wavelength plan for NG-EPON (Plan B) guaranteeing coexistence for RF overlay, 10G-EPON, and NG-EPON, when operated on the same ODN. The downstream NG-EPON wavelength band is 20 nm wide and placed between 1480 nm and 1500 nm, while the upstream NG-EPON wavelength band is 10 nm wide and placed between 1530 nm and 1540 nm. Effectively, in this particular wavelength allocation plan, the spectrum band currently reserved for the downstream 1G-EPON is occupied by the downstream NG-EPON, while the upstream NG-EPON band is placed between downstream 1G-EPON band and RF overlay, effectively changing requirements for existing wavelength filters on 1G-EPON devices with RF overlay.

The upstream NG-EPON wavelength band can carry up to 10 separate channels if 100 GHz channel spacing is used, just like in Plan A. The downstream NG-EPON wavelength band can carry up to 20 separate channels, if 100 GHz channel spacing is used. Alternatively, lower cost 200 GHz grid can be used if only 10 channels are needed.

Observations about maturity of C-band components in section 6.4.5.1 are also applicable to NG-EPON upstream band in this plan. The S-band optical PON-specific components are much more mature, given the long-term deployment of 1G-EPON operating in the same wavelength band in downstream. The transition from 1G to 10G lasers should be relatively straightforward, given the maturity of laser drivers for 10G-EPON transceivers.

6.4.5.3 Plan C: Coexistence with RF overlay, 1G-EPON, and 10G-EPON [xref]

Figure 1 presents the wavelength plan for NG-EPON (Plan C) guaranteeing coexistence for RF overlay, 1G-EPON, 10G-EPON, and NG-EPON, when operated on the same ODN. The downstream NG-EPON wavelength band is 10 nm wide and placed between 1595 nm and 1605 nm, while the upstream NG-EPON wavelength band is also 10 nm wide and placed between 1530 nm and 1540 nm. Effectively, in this particular wavelength allocation plan, the NG-EPON wavelength bands are located in areas currently not used by 1G-EPON, 10G-EPON, or RF overlay.

Both downstream and upstream NG-EPON wavelength bands can carry up to 10 separate channels if 100 GHz channel spacing is used.

Observations about maturity of C-band components in section 6.4.5.1 are also applicable to NG-EPON upstream band in this plan. The placement of the downstream NG-EPON wavelength channel in L-band requires redesign of the existing 10G-EPON transceivers to place their operating wavelength above 1595 nm. While technically feasible, a new class of 100 GHz grid lasers will need to be designed.

6.4.5.4 Plan D: Coexistence with 1G-EPON and 10G-EPON, reuse of downstream RF overlay band [xref]

Figure 1 presents the wavelength plan for NG-EPON (Plan D) guaranteeing coexistence for 1G-EPON, 10G-EPON, and NG-EPON, when operated on the same ODN. The downstream NG-EPON wavelength and is 10 nm wide and placed between 1550 nm and 1560 nm, effectively reusing the downstream RF overlay band. The upstream NG-EPON wavelength band is 20 nm wide and placed between 1340 nm and 1360 nm, overlapping with stand-defined 1G-EPON upstream wavelength band.

The coexistence with 1G-EPON and 10G-EPON in the downstream direction is achieved via WDM, where 1G-EPON, 10G-EPON, and NG-EPON wavelength bands are non-overlapping, and separated sufficiently to implement low-cost wavelength filters. Furthermore, given the reuse of downstream RF overlay band, 1G-EPON and 10G-EPON ONUs are already equipped with the appropriate wavelength rejection filters to make sure that downstream NG-EPON transmissions not affect their receivers.

The coexistence with 10G-EPON in the upstream direction is achieved via WDM, where 10G-EPON and NG-EPON wavelength bands are non-overlapping, and separated sufficiently to implement low-cost wavelength filters. The coexistence with 1G-EPON in the upstream direction is achieved via WDM or TDM schemes. The TDM coexistence mode extends to the concept of TDM coexistence defined for 1G-EPON and 10G-EPON to a triple-rate burst mode operation mode. This mode of operation is only required when the operator uses 1G-EPON ONUs with broad-band spectrum (100 nm) transmitters. The WDM coexistence mode is supported when the operator uses 1G-EPON ONUs with reduced-band or narrow-band transmitters, and 1G-EPON and NG-EPON transmissions can be WDM-filtered.

The downstream NG-EPON wavelength band can carry up to 10 separate channels if a 100 GHz channel spacing is used. The upstream NG-EPON wavelength band can carry up to 10 separate channel if a more relaxed 200 GHz channel spacing is used.

The optical components for the downstream channel are available today, requiring minimum changes to the manufacturing process to support the required power budgets. The optical components for the upstream channel can build on upstream components for 10/10G-EPON, requiring minimum changes to shift the transmission wavelength from 1260 – 1280 nm band to 1340 – 1360 nm band.

6.4.5.5 Comparison of Different Wavelength Allocation Plans

Table 2 presents a comparison of different wavelength allocation plans for NG-EPON, summarizing the key characteristics of specific plans presented in the previous sections.

Table 1: Comparison of Different Wavelength Allocation Plans for NG-EPON

<table>
<tr><th>Wavelength Plan</th><th>A</th><th>B</th><th>C</th><th>D</th></tr>
<tr><td>Downstream band [nm]</td><td>1550-1560</td><td>1480-1500</td><td>1595-1605</td><td>1550-1560</td></tr>
<tr><td>Upstream band [nm]</td><td>1530-1540</td><td>1530-1540</td><td>1530-1540</td><td>1340-1360</td></tr>
<tr><td>Number of channels
[in 100 GHz grid]</td><td>10 / 10</td><td>20 / 10</td><td>10 / 10</td><td>10 / 20</td></tr>
<tr><td>Raman effects</td><td>No N/A</td><td>Yes</td><td>Yes</td><td>N/A</td></tr>
<tr><td>Maturity of optics
Downstream / Upstream</td><td>Moderate / Moderate</td><td>High / Moderate</td><td>High / Moderate</td><td>High / High</td></tr>
<tr><td>Coexistence with 1G-EPON</td><td>Yes</td><td>No</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Coexistence with 10G-EPON</td><td colspan="3">Yes</td><td>Yes</td></tr>
<tr><td>Coexistence with RF overlay</td><td>No</td><td>Yes</td><td>Yes</td><td>No</td></tr>
<tr><td>Coexistence with OTDR</td><td colspan="3">Yes</td><td>Yes</td></tr>
</table>

6.4