5 Requirements for NG-EPON

5.8 Backward ~~compatibility~~ Compatibility and Coexistence

Commented [MH1]: Capitalization change for consistency

Backward compatibility and coexistence with earlier generations of Ethernet have always been considered key requirements for the development of any PHY within the IEEE 802.3 Working Group. It is therefore expected that NG-EPON maintains the ability to support coexistence and backward compatibility with the two previous generations of EPON.

A gradual evolution from 1G-EPON systems towards 10G-EPON, while allowing operators to take full advantage of deployed active equipment, was one of the cornerstone requirements during the development of 10G-EPON technology [cfi1]. The resulting development of a dual-rate OLT (capable of operating in 1G-EPON and 10G-EPON mode in the upstream and downstream directions) provided a clear evolution and migration path to 10G-EPON.

5.8.1 Coexistence of 1G EPON and 10G-EPON

Figure 1~~Figure 14~~ presents the starting point for the evolution from 1G-EPON to 10G-EPON, where all active devices in the TDM-PON are of the 1G-EPON type. During a maintenance window, an operator would replace the line card on the OLT, converting a dedicated 1G-EPON line card to a dual-rate line card capable of operating at 1G-EPON and 10G-EPON modes simultaneously. This situation is presented in Figure 2~~Figure 15~~. All ONUs connected to this port continue to operate in 1G-EPON-mode only.

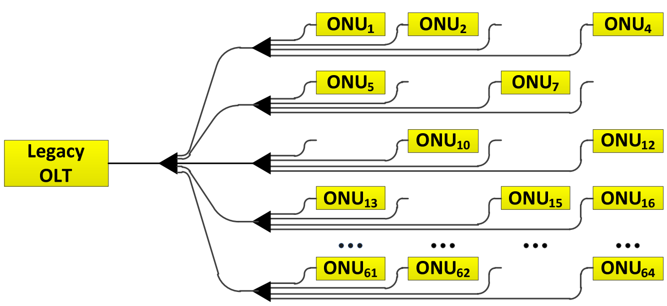

Figure 1~~14~~: EPON access: starting point with 1G-EPON devices

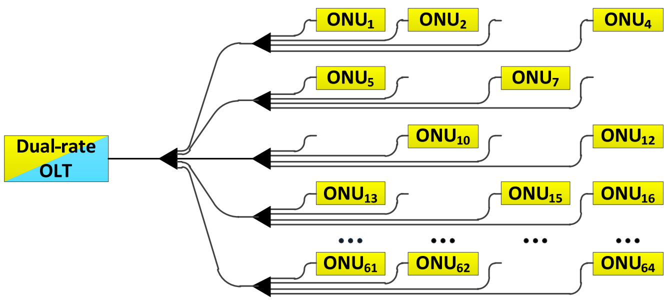

Figure 2~~15~~: EPON access: dual-rate OLT port

Once the maintenance on the OLT port has been completed, new customers may be connected to currently unoccupied ports on the splitter(s) and be served with 10G-EPON ONUs. It is also possible to upgrade some of the existing customers served with 1G-EPON ONUs to higher speed 10G-EPON ONUs. Such a decision is typically driven by a demand for higher tier services purchased by selected customers. This scenario is shown in Figure 3~~Figure 16~~, where 1G-EPON and 10G-EPON ONUs coexist on the same PON.

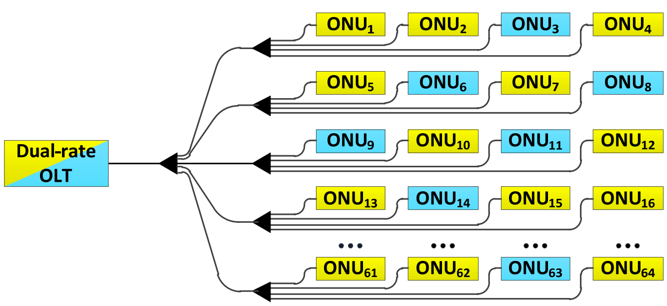

Figure 3~~16~~: EPON access: 1G-EPON and 10G-EPON ONUs coexist on the same ODN

Over time most of the existing ONUs get upgraded to 10G-EPON, as the cost of 10G-EPON devices decreases and approaches the cost of 1G-EPON devices. This scenario is shown in Figure 4~~Figure 17~~. Note that the resulting network may operate in a dual-rate mode for a very long time, since the transition from 1G-EPON to 10G-EPON is primarily motivated by the service upgrades for existing customers, as well as cost decrease of 10G-EPON devices.

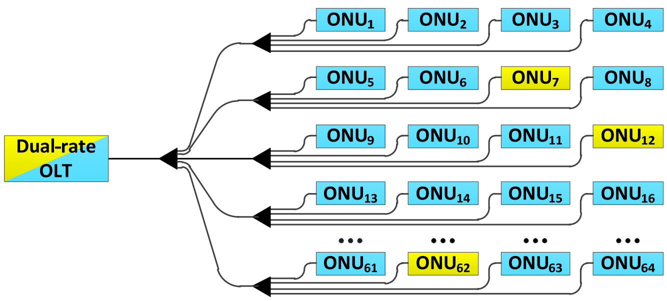

Figure ~~4~~~~17~~4: EPON access: 1G-EPON and 10G-EPON ONUs coexist on the same ODN

The evolution scenario described above assumes the deployment of a dual-rate OLT, capable of operating at 1G-EPON and 10G-EPON modes simultaneously. This requires that 1G-EPON and 10G-EPON transmissions be time-interleaved in the upstream using a dual-rate burst mode receiver at the OLT as described in Annex 75A in [802.3].

A drawback of this approach is that the ability to support 1G-EPON is essentially paid for twice - once with the purchase of the 1G-EPON ports and then with the purchase of the dual-rate port capable of supporting 1G-EPON and 10G-EPON. The other potential drawback is the practical aspect of dual-rate 1G-EPON/10G-EPON OLT ports, which provide lower port density per line card when compared with dedicated 1G-EPON or 10G-EPON line cards.

However, it is also possible for an operator to deploy separate 1G-EPON and 10G-EPON OLT ports, and then combine downstream 1G-EPON and 10G-EPON wavelengths and split the respective upstream wavelengths using a discrete wavelength splitter / combiner device external to the OLT ports. This solution provides a higher OLT port density per line card, and eliminates the need to repurchase the OLT ports, though the operator needs to make sure that 1G-EPON and 10G-EPON upstream wavelengths can be WDM-separated into dedicated OLT ports. In practice, this requires the use of 1G-EPON ONUs equipped with more narrow-band upstream transmitters, typically centered around 1310 nm with 40 nm or even 20 nm band rather than 100 nm band allowed by ~~the~~ 1G-EPON ~~standard~~equipment compatible with [802.3].

Commented [MH2]: Clarification on what standard 1G-EPON equipment here really means.

5.8.2 Migration to NG-EPON and coexistence with 1G-EPON and 10G-EPON

The migration to NG-EPON needs to assume that at the time NG-EPON becomes commercially available, the access network is expected to include a mixture of 1G-EPON and 10G-EPON devices, operating with either dual-rate OLT ports, or dedicated 1G-EPON and 10G-EPON OLT ports with external wavelength splitter / combiner. Assuming that 1G-EPON ONUs remain in the network and coexist on the same ODN with both 10G-EPON as well as NG-EPON ONUs, a triple-rate OLT may need to be deployed first, preparing the given ODN for NG-EPON ONUs. Only when the NG-EPON OLT port becomes available, may NG-EPON ONUs be connected to the ODN, occupying previously unoccupied drop fibers, or replacing 1G-EPON or 10G-EPON ONUs, as service requirements for selected customers exceed the capacity of 1G-EPON or 10G-EPON systems. This evolutionary approach becomes increasingly complex, especially because of the exhaustion of the fiber spectrum. It is also inefficient for the operator to repurchase 1G-EPON and 10G-EPON OLT port that has been already paid for by the time 1G-EPON and 10G-EPON have been deployed.

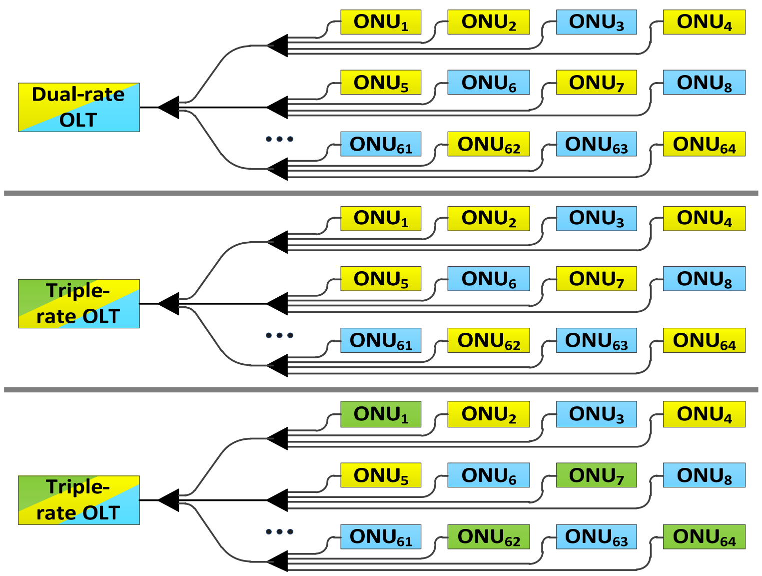

Figure 5~~18~~: Evolution from 1G-EPON and 10G-EPON network to three generation EPON access

An alternative approach (see Figure 6~~Figure 19~~) assumes coexistence of only two EPON generations on the same ODN. Before deploying NG-EPON devices, the operator upgrades all 1G-EPON ONUs to 10G-EPON ONUs, replacing the dual-rate OLT port operating in 1G-EPON and 10G-EPON with a dual-rate OLT port capable of operating in 10G-EPON and NG-EPON modes. Once the OLT port upgrade is done and all 1G-EPON active devices have been removed from the given ODN, the NG-EPON ONUs can be deployed. In this particular scenario, the NG-EPON may partially or completely reuse 1G-EPON downstream and/or upstream spectrum, assuming that TDM or WDM separation between 10G-EPON and NG-EPON upstream channels is possible.

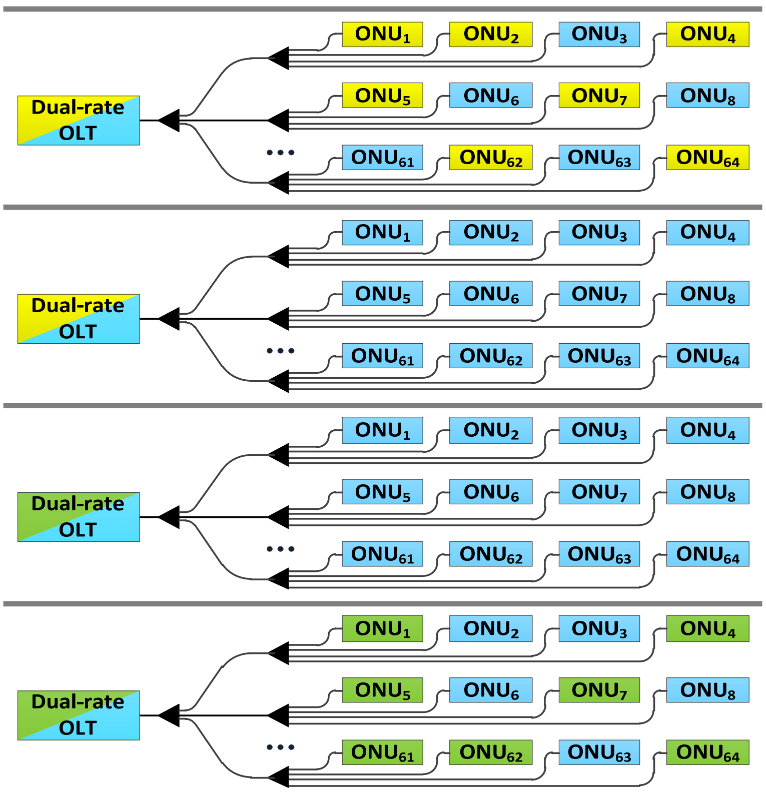

Figure ~~19~~6: Evolution from 1G-EPON and 10G-EPON network to two generation EPON access

5.8.3 Requirements for NG-EPON Coexistence and Compatibility

Commented [MH3]: Moved material from 5.11, which also spoke about coexistence and backward compatibility into one section to keep similar text in the same subclause.

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 development of a 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:

- 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.

~~5.8.2.1~~5.8.3.1 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.

~~5.8.2.2~~5.8.3.2 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.

~~5.8.2.3~~5.8.3.3 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.

~~5.8.3~~5.8.3.4 NG-EPON coexisting with 1G-EPON, 10G-EPON, and optional RF overlay

Formatted: Heading 4

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 5.8.3.25.10.2~~5.11.1~~ and 5.8.3.3~~5.11.2~~.

~~5.8.4~~5.8.3.5 NG-EPON and support for 10G-EPON ONUs

Formatted: Heading 4

It is highly desired that an NG-EPON OLT allow a 10/10G-EPON ONU to register and operate as if it were connected to a 10G-EPON OLT.

~~5.8.5~~5.8.3.6 Coexistence requirements

Formatted: Heading 4

Given the ongoing migration from RF delivery systems towards all-IP delivery paradigm in some networks, it is likely that by the time NG-EPON is deployed in the field, RF overlay is not likely to be actively deployed anymore in such networks. The aggregate capacity of NG-EPON is expected to further stimulate the migration to all-IP delivery model, and in case of some operators this process would release the downstream and upstream RF overlay channels for the use by digital transmission systems.

NG-EPON is expected to 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, for example, when narrow-band (40 nm or even 20 nm) optics is used in deployed 1G-EPON ONU transmitters.

NG-EPON is expected to 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.

~~5.8.5.1~~5.8.3.7 Wavelength allocation for NG-EPON

Requirements for backward compatibility and coexistence are also expected to drive the process of selecting the target wavelength allocation plan for NG-EPON. In order to alleviate inventory and logistical tasks for service providers, it is highly desirable that the allocation of the downstream and/or upstream wavelength channels to an ONU be configurable dynamically via the OLT. The operation of the wavelength configuration protocol should be reliable and prevent a situation in which an ONU after a reboot / reset impacts other customers by transmitting on incorrect upstream wavelength channels.

The specific number of downstream and upstream channels allocated within the selected wavelength windows depends on the aggregated bandwidth per OLT port, wavelength grid spacing, as well as wavelength stability at the ONU. The allocation of transmission windows and individual channel assignments would be addressed by the future NG-EPON Task Force, taking into consideration many aspects of PHY operation, including requirements for coexistence and backward compatibility, aggregate capacity, etc.

5.9 Pluggable Optics

For a residential-class and a business-class ONU, it is highly desirable that pluggable PON optics is supported.

In case of fixed wavelength optics, pluggable PON optics limits inventory problems, allowing an operator to reuse the same ONU model in different locations and equip it with required fixed wavelength transceivers on demand.

In case of tunable optics, pluggable PON optics simplifies the deployment process and limits inventory problems, allowing to upgrade the ONU to support larger number of wavelength channels (provided that electronic front end is designed accordingly).

5.10 Power Saving

Power conservation and reduction of the carbon footprint of access networks is globally recognized as one of the technical targets for the optical access networks. The objectives of the power-saving mechanisms are to reduce ecological impact, reduce operating cost, and extend battery backup time (if supported by the given product), while minimizing any degradation of network performance to maintain the configured SLA.

It is expected that NG-EPON supports power-saving mechanism available today for 1G-EPON and 10G-EPON systems, defined in [1904.1], providing decreased power consumption for ONUs while maintaining the configured SLA. The power-saving mechanism should be fully configurable on per ONU or OLT port basis, providing the operator with full control of the sleep period, detection threshold for ONU inactivity, etc. The NG-EPON OLT should support a mix of ONUs with enabled power-saving mechanism and with disabled power-saving mechanism on the same OLT port. The NG-EPON OLT should support different configuration parameters for the power-saving mechanism for different groups of ONUs on the same OLT port.

At the same time, it is also expected that NG-EPON OLT implement more advanced power-saving mechanisms, disabling inactive OLT ports, inactive wavelengths on OLT ports, whole line cards (when inactive), etc. OLT power saving mechanism become increasingly important for high-density optical access platforms to avoid substantial increase in drawn power, but also in cooling / ventilation necessary to keep the OLT within its operating conditions.

~~5.11 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 development of a 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:

- 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.

5.11.15.10.1 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.

5.11.25.10.2 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.

5.11.35.10.3 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.

5.11.45.10.4 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 5.11.1 and 5.11.2.

Field Code Changed

Field Code Changed

5.11.55.10.5 NG-EPON and 10G-EPON ONUs

It is highly desired that an NG-EPON OLT allow a 10/10G-EPON ONU to register and operate as if it were connected to a 10G-EPON OLT.

5.11.65.10.6 Coexistence requirements

Given the ongoing migration from RF delivery systems towards all-IP delivery paradigm in some networks, it is likely that by the time NG-EPON is deployed in the field, RF overlay is not likely to be actively deployed anymore in such networks. The aggregate capacity of NG-EPON is expected to further stimulate the migration to all-IP delivery model, and in case of some operators this process would release the downstream and upstream RF overlay channels for the use by digital transmission systems.

NG-EPON is expected to 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, for example, when narrow-band (40 nm or even 20 nm) optics is used in deployed 1G-EPON ONU transmitters.

NG-EPON is expected to 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.

5.11.75.10.7 Wavelength allocation for NG-EPON

Requirements for backward compatibility and coexistence are also expected to drive the process of selecting the target wavelength allocation plan for NG-EPON. In order to alleviate inventory and logistical tasks for service providers, it is highly desirable that the allocation of the downstream and/or upstream wavelength channels to an ONU be configurable dynamically via the OLT. The operation of the wavelength configuration protocol should be reliable and prevent a situation in which an ONU after a reboot / reset impacts other customers by transmitting on incorrect upstream wavelength channels.

The specific number of downstream and upstream channels allocated within the selected wavelength windows depends on the aggregated bandwidth per OLT port, wavelength grid spacing, as well as wavelength stability at the ONU. The allocation of transmission windows and individual channel assignments would be addressed by the future NG-EPON Task Force, taking into consideration many aspects of PHY operation, including requirements for coexistence and backward compatibility, aggregate capacity, etc.

5.125.11