25GS-PON Specification
25 Gigabit Symmetric Passive Optical Network

7 October, 2020

Version 1.0

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TITLE: 25GS-PON / 25G TDM PON Specification

SUMMARY:
This specification describes a 25-Gigabit-capable asymmetric and symmetric passive optical network (25GS-PON) system in an optical access network for residential, business, mobile back/mid-haul and other applications. This system operates over a point-to-multipoint optical access infrastructure at the nominal data rate of 25 Gbit/s in the downstream and both 10 and 25 Gbit/s in the upstream directions. This specification contains the general requirements, physical media dependent layer requirements, transmission convergence layer requirements and management layer requirements of the 25GS-PON system.

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1 Document Revision History

Document Revision	Date	Revision Comments
V1.0	201007	25GS-PON Specification (initial version)

2 Scope and Introduction

This specification defines a 25-Gigabit-capable asymmetric and symmetric passive optical network (25GS-PON) system in an optical access network for residential, business, mobile back/mid-haul and other applications. 25GS-PON systems are able to operate on the same optical distribution network (ODN) as legacy PON systems. Co-existence of 25GS-PON with G-PON, XG-PON, XGS-PON and NG-PON2 is supported.

This specification re-uses existing industry standards, recommendations, and specifications (referred to as "standards" in this document) to the maximum extent possible. This specification is written as a delta-specification with respect to:
- IEEE P.802.3ca D3.1. for PMD layer and FEC
- ITU-T G.9807.1 for TC layer
- ITU-T G.988 for OMCI
- BBF TR-385 for Yang models.

The referenced standards each follow different formatting, style and document structure. This document, for purposes of clarity, will follow the structure used in ITU-T G.9807.1.

3 References

- ITU-T G.9807.1
- ITU-T G.988
- IEEE P.802.3ca D3.1
- BBF TR-385 Issue 1

4 Definitions

In addition to the definitions, abbreviations and acronymns documented in the references, this specification uses the following.

Terms

- **25GS-PON**: A passive optical network (PON) system that operates at a nominal line rate of 25 Gbit/s downstream and both 10 and 25 Gbit/s upstream.

Abbreviations and Acronyms

LDPC   Low Density Parity Check

5   Conventions

Many of the conventions in ITU-T G.9807.1 are followed. In addition this specification uses the following conventions:

- **Transmission order** - The order of transmission of information in all the diagrams is first from left to right and then from top to bottom unless explicitly called out as different. The most significant bit (bit 31) is illustrated at the left in all the diagrams (e.g. Row 1, Column 1).
- **Reserved bit(s)** - The value of a reserved bit or reserved bit for future standardization shall be set to "0".
- **Non-Sourced bit(s)** - The value of any non-sourced bit shall read back as "0".

The requirements for 25GS-PON are referenced to existing standards and simply extended to 25G as necessary. This "delta" document only documents the changes required to specify 25GS-PON. These "deltas" are noted with the "**Δ**" symbol.

6   Overview of the 25GS-PON Recommendation

Section 6 of ITU-T G.9807, "Overview of the XGS-PON Recommendation" applies to 25GS-PON, with the following modifications:

- Δ   References to the G.987 series are replaced with references to G.9807.1.
- Δ   References to IEEE 802.3 Clause 75 apply for 10G upstream in 25GS-PON.
- Δ   IEEE 802.3ca is the reference for 25G downstream and upstream.
- Δ   The wavelength bands mentioned are specified in Annex B of this document.

Annex B: Physical media dependent (PMD) layer specifications

The PMD requirements for 25GS-PON are contained in clause 141 of *IEEE P802.3ca™/D3.1, Draft Standard for Ethernet, Amendment: Physical Layer Specifications and Management Parameters for 25 Gb/s and 50 Gb/s Passive Optical Networks*, with several changes as noted herein.

25GS-PON will support the PHY links in P802.3ca Tables 141-1 and 141-2 for 25G asymmetric and 25G symmetric, for both "medium" (24dB) and "high" (29dB) loss budgets. There are four exceptions to these specifications, noted below.

Δ **Exception 1.** 25GS-PON supports slightly different line rates, as specified in Table B.1. (For 25GS-PON, the line rate for nominal 25 Gbit/s downstream and upstream signals is 2.5 times the XGS-PON line rate [ITU-T G.9807.1]. The line rate for the nominal 10 Gbit/s upstream signal is the same as the XGS-PON.)

Nominal line rate [Gbit/s]	Direction	P802.3ca line rate [Gbit/s]	25GS-PON line rate [Gbit/s]
25	downstream	25.78125	24.8832
25	upstream	25.78125	24.8832
10	upstream	10.3125	9.95328

Table B.1: 25GS-PON line rates.

Δ **Exception 2.** As indicated in P802.3ca Tables 141-1 and -2, 25G EPON PHY links support a 14 dB range of ODN loss: the difference between the minimum and the maximum channel insertion loss. ITU-T PONs support a wider range, 15 dB. To ensure that 25GS-PON can operate on 29 dB ODNs designed for ITU-T PONs, the minimum channel insertion losses specified in Tables 141-1 and -2 for the "high" power class are decreased by 1 dB for 25GS-PON, as indicated in Table B.2. As a result, the 25GS-PON "high" power class will support the exact same loss range as the XGS-PON N1 class loss budget.

PHY link name	P802.3ca minimum channel insertion	25GS-PON minimum channel insertion
25/10-PQ30*	15 dB	14 dB
25/25-PQ30*	15 dB	14 dB

Table B.2: 25GS-PON minimum channel insertion loss, deltas to P802.3ca Tables 141-1 and -2.

*denotes either G (using upstream wavelength UW0) or X (using upstream wavelength UW1).

To accommodate this, the Damage Threshold and Average receive power, each channel (max) parameters in P802.3ca Tables 141.17, 141.18, 141-21 and 141-22 shall be increased by 1 dB.

). The specific values are indicated in Table B.3.

P802.3ca Table	Damage threshold		Average receive power, each channel (max.)	
	P802.3ca	25GS-PON	P802.3ca	25GS-PON
141-17	-2	-1	-3	-2
141-18	-5	-4	-6	-5
141-21	-4	-3	-5	-4
141-22	-6.2	-5.2	-7.2	-6.2

Table B.3: 25GS-PON damage threshold and average receive power (max.), deltas to P802.3ca Tables 141-17, -18, 21 and -22.

Δ Exception 3: WDM co-existence with XGS-PON and GPON.

For 25GS-PON, a new third upstream wavelength is defined, UW3, to support simultaneous WDM co-existence between 25GS-PON, XGS-PON and GPON. This wavelength is 1286 +1/-2 nm[1]. See Figure B.1. Except for the wavelength, all other PMD values for UW3 are the same as for UW0 and UW1. Implementation of this wavelength is optional.
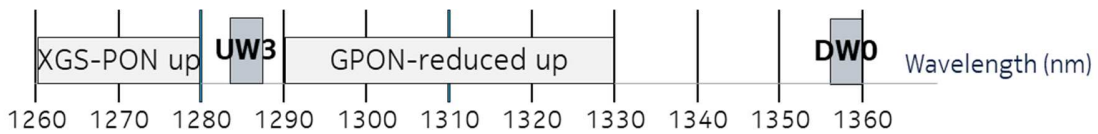
Figure B.1. Upstream wavelength UW3 to support triple co-existence.

Δ Exception 4: Versatile WDM configuration (ONU blocking filter for co-existence)

25GS-PON ONUs shall tolerate interferers from legacy GPON, XG(S)-PON and future PON systems. The specified X/S tolerance mask is indicated in Figure B.2, which is a modification of Fig. B.10.1 in ITU-T G.9807.1. The value, Y, is 9 dB.

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[1] The rationale for this wavelength choice is explained in contribution D042 to ITU-T SG15/Q2 interim meeting, October 2019. In summary, the short wavelength end of the O-band is chosen for low dispersion and for sufficient downstream-upstream wavelength separation.

Figure B.2. X/S tolerance mask for ONU

Annex C Transmission convergence layer spec. of 25GS-PON
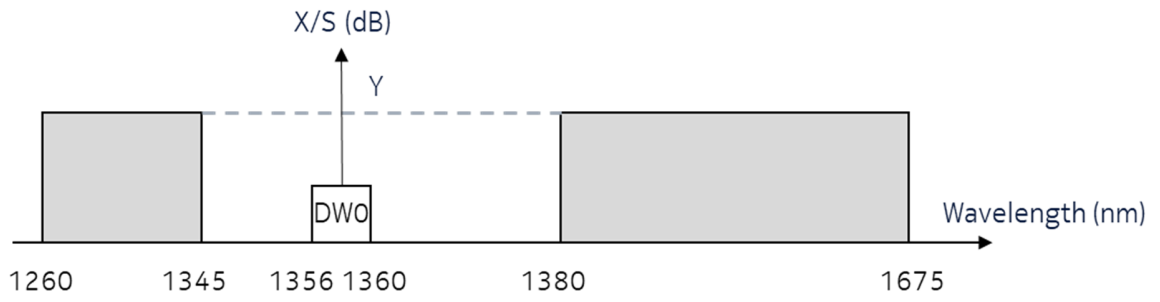
The TC-Layer requirements for 25GS-PON are contained in ITU-T G.9807.1 [1]. Changes required for an implementation to comply with the 25GS-PON specification are noted herein. This includes the substitution of G.9807 R-S FEC with P802.3ca LDPC FEC.

C.6 25GS-PON transmission convergence layer overview

C.6.1.1 Supported nominal line rates

Δ A 25GS-PON OLT supports the following line rates:

Downstream line rate (Gbit/s)	Upstream line rate (Gbit/s)
24.8832	24.8832
24.8832	9.95328
24.8832	24.8832 and 9.95328

Table C.6.1. 25GS-PON OLT Supported line rates

Δ A 25GS-PON ONT supports the following line rates:

Downstream line rate (Gbit/s)	Upstream line rate (Gbit/s)
24.8832	24.8832
24.8832	9.95328

Table C.6.2 25GS-PON ONU Supported line rates

C.6.1.5.7 Allocation identifier (Alloc-ID)

Δ A 25GS-PON OLT uses broadcast Alloc-ID 1020 to signal any DS-25Gbit/s and US-25Gbit/s capable ONU that it can use this allocation to transmit the serial number response.

Δ A 25GS-PON OLT uses broadcast Alloc-ID 1019 to signal any DS-25Gbit/s and US-10Gbit/s capable ONU that it can use this allocation to transmit the serial number response.

Alloc-ID 0…1018 is the available default Allocation-ID range.
Note: for co-existence with XGS-PON, the Alloc-ID's 1019 & 1020 shall not be used.

C.6.1.6 Media access control

Δ The start pointers and grant size locations in the BWmap are expressed in units of:

16 Bytes for an ONU transmitting at 10 Gbit/s in the upstream direction.
40 Bytes for an ONU transmitting at 25 Gbit/s in the upstream direction.

C.7 25GS-PON Resource allocation and quality of service

No deltas.

C.8 25GS-PON transmission convergence framing sublayer overview

C.8.1.1. Downstream 25GS-PON TC framing

Δ The 25GS-PON downstream FS frame is 330536 bytes.
- The total PHY frame size is: 388800 Bytes
- PSBd is not included in the FS frame: -   24 Bytes
- FEC-parity is not included in the FS frame: - 58240 Bytes
                                  330536 Bytes

C.8.1.1.2.3 StartTime field
Same 9720 equally spaced time intervals.
One interval accommodates 16 bytes at 10 Gbit/s.
Δ One interval accommodates 40 bytes at 25 Gbit/s.

C.8.1.1.2.4 GrantSize field
The granularity of the GrantSize field varies with the upstream linerate:
For ONU's transmitting at 10 Gbit/s, the GrantSize refers to 16 bytes. The minimum non-zero value of GrantSize is 1, which can be used for a DBRu-only transmission (4 byte DBRu field, followed by a 12 byte idle) and for minimum size payload allocations (16 bytes)
Δ For ONU's transmitting at 25 Gbit/s, the GrantSize refers to 40 bytes.The minimum non-zero value of GrantSize is 1, which can be used for a DBRu-only transmission (4 byte DBRu field, followed by a 36 byte idle) and for minimum size payload allocations (40 bytes)

C.8.1.1.3 BWmap construction and parsing rules
Maximum GrantSize value of any individual allocation:
Same 9720 equally spaced time intervals.
For 10 Gbit/s upstream rate – 9 719 (referring to 16-byte blocks).
Δ For 25 Gbit/s upstream rate – 9 719 (referring to 40-byte blocks).

The maximum FS burst size, that is, the sizes of all allocations within the burst allocation series together with the FS burst overhead:
For 10 Gbit/s upstream rate – 155 520 bytes.
Δ For 25 Gbit/s upstream rate – 388 800 bytes.

For 10 Gbit/s, the FS burst has the following constraint:

$$\text{StartTime} + \Sigma n\text{GrantSizen} \leq 14580$$

Δ For 25 Gbit/s, the FS burst has the following constraint:

$$(\text{StartTime} + \Sigma n\text{GrantSizen}) * 2.5 \leq 30990$$

C.9 25GS-PON encapsulation method

C.9.1.1 FS payload structure

Δ The size of the FS payload in a given downstream FS frame is equal to the FS frame size (which is fixed 330 536 bytes) less the sum of the sizes of its FS frame header and FS frame trailer.

C.10 25GS-PON PHY adaptation sublayer

C.10.1.1 Downstream PHY frame

Δ The duration of a downstream PHY frame is 125 μs, which corresponds to the size of 388 800 bytes (97 200 words) at the downstream line rate of 25 Gbit/s.
The PSBd is 24 bytes and the remaining Phy frame payload is 388 776 bytes.

C.10.1.1.3 ONU downstream synchronization
Δ The downstream synchronization statemachine is updated to be able to reliably operate under high (1E-2) BER conditions. The following diagram (Figure C.10.4) shows the reference statemachine.

Hunt state: The initial synchronization state is the Hunt state. In the Hunt state, the synchronization function of the ONU searches for the Psync pattern over all bit alignments in the downstream data pattern. When the exact Psync pattern has been detected, the statemachine transitions to the Pre-Sync state.

Pre-Sync state: When in the Pre-Sync state both the Psync pattern as the LDPC-decoder results are used to determine the synchronization state: when more than N_{eps} errors are detected in the Psync pattern, the state machine falls back to the Hunt state. When in the Pre-Sync state a LDPC-codeword is correctly decoded, the statemachine further transitions to the Sync state. At each frame start, the SFC is latched then HEC-13 corrected and used to descramble the data for that frame. When the statemachine transitions to the Sync state, the current SFC value is latched into an Internal Frame Counter (IFC) which is then used by the ONU in all states except the Hunt and Pre-Sync states.

Sync state: When in the Sync state and the decoding of a LDPC-codeword fails, the statemachine transitions into the Re-Sync state.

Re-Sync state: When in the Re-Sync state and a LDPC-codeword is correctly decoded, the statemachine transitions back into the Sync state. When it detects M-1 consecutive LDPC-decoding fails of the first LDPC-codeword, the statemachine state changes to the Hunt state. The recommended value of M is 3.
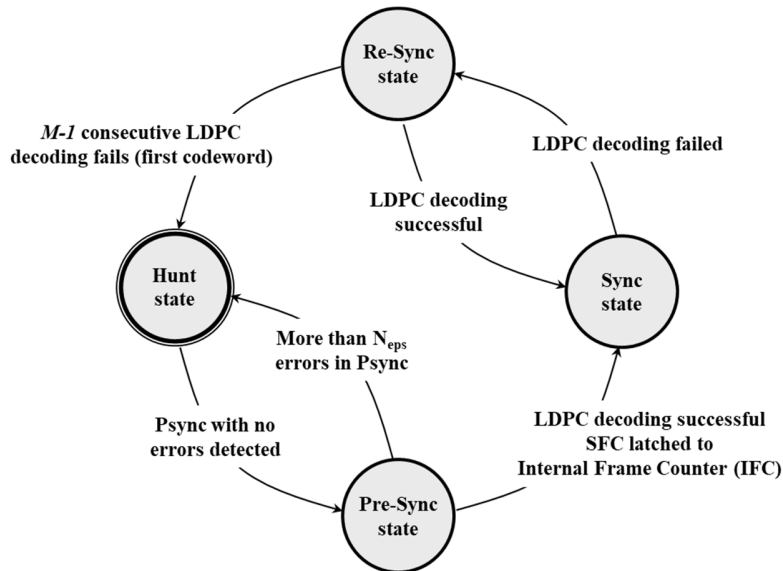
Figure C.10.4 DS reference synchronization statemachine

C.10.1.1.4 Downstream PHY frame payload

Δ The payload of a downstream PHY frame has the size of 388 776 bytes.

C.10.1.2 Upstream PHY frames and upstream PHY bursts

Δ The duration of an upstream PHY frame is 125 μs, which corresponds to the size of 388 800 bytes (97 200 words) at the downstream line rate of 25 Gbit/s.

C.10.1.3 Δ Forward error correction

Δ For a line rate of 10 Gbit/s, in upstream direction, the FEC code is RS(248,216) which is the truncated form of RS(255,223). RS(248,216) is described in Annex C.B of ITU-T G.9807.1 [1].

Δ For a line rate of 25Gbit/s, in both downstream and upstream directions, the FEC code is LDPC(17152,14592) which is the punctured form of LDPC(17664,14592). The LDPC(17152,14592) and LDPC(17664,14592) codes are formally described in Annex C.B of this specification.

C.10.1.3.1.1 Downstream FEC codeword

Δ For 25 Gbit/s nominal line rate, the downstream FEC code is LDPC(17152,14592). Each downstream PHY frame contains 182 FEC codewords. The first 181 codewords are 2144 bytes long, the last one is a short codeword of 712 bytes.

Δ Within a full codeword, 1824 data bytes are followed by 320 parity bytes. The last short codeword is 712 bytes: 392 bytes of data, followed by 320 parity bytes.

Δ In a downstream PHY frame, the first codeword starts with the 25th byte of the PHY frame (the first byte of the downstream FS header section), the second codeword starts from the 2169th byte of the PHY frame, and the third codeword starts from the 4313th byte of the PHY frame, etc.

C.10.1.3.1.1 Upstream FEC codeword

For 10 Gbit/s, the upstream FEC code is RS(248, 216).

Δ For 25Gbit/s, the upstream FEC code is LDPC(17152,14592).

C.10.1.3.2.4 Upstream FEC on/off control

Δ For 25Gbit/s, FEC is always enabled.

C.11 25GS-PON PLOAM messaging channel

C.11.2.1 ONU-ID

Δ The value 1020 (0x3FC) is reserved for broadcasting messages to ONUs with 25Gbit/s Downstream and 25Gbit/s Upstream burst-rate capability.

Δ The value 1019 (0x3FB) is reserved for broadcasting messages to ONUs with 25Gbit/s Downstream and 10 Gbit/s Upstream burst-rate capabilities.

C.11.3.3 Downstream PLOAM message formats

C.11.3.3.1 Burst_Profile message

Table C.11.4 – Burst_Profile message
- Octet 1-2: ONU-ID extra reserved values:
  - o **Δ** ONU-ID = 0x03FC identifies a message to all 25 Gbit/s downstream and 25 Gbit/s upstream capable ONUs.
  - o **Δ** ONU-ID = 0x03FB identifies a message to all 25 Gbit/s downstream and 10 Gbit/s upstream capable ONUs.
- Octet 5: the rate bit only applies for 10 Gbit/s downstream capable ONU's.
- Octet 6: only applies for 10 Gbit/s upstream capable ONU's.

C.12 25GS-PON ONU activation

No deltas.

C.13 25GS-PON OLT and ONU timing relationships

C.13.1.6 In-service equalization delay adjustment

	In integer bit periods for specified line rate	
	9.95328 Gbit/s	**Δ 24.8832 Gbit/s**
DOW$_i$	± 32 bits	± 32 bits
TIW$_i$	± 64 bits	± 64 bits

Table C.13.1 Suggested thresholds for DOWi and TIWi

C.14 25GS-PON performance monitoring, supervision and defects

No deltas

C.15 25GS-PON security

C.15.4.3 Initial counter block

Δ In the downstream direction, the FS frame of the framing sublayer (see Figure C.8.1) is partitioned into 16-byte blocks, and these blocks are sequentially numbered from 0 to 20658 (25G, FEC on), the last block being half-size. The size of the sequence number is 15 bits.

Δ At 25 Gbit/s upstream line rate, the largest StartTime is 8264.

Δ At 25 Gbit/s upstream line rate, the largest possible 16-byte block number in an upstream burst is determined by the FS burst specification constraint (see clause C.8.1.1.3)

$$\Delta \ (StartTime + \Sigma nGrantSizen)*2.5 \leq 30990 < 2^{16}$$

Please note that FEC for 25G in the upstream direction is always enabled.

Δ For 25Gbit/s rates, the 128-bit initial counter block as input for the AES calculation is structured as follows:

Initial counter(127..80) :   Superframe Counter (47..0)
Initial counter(79..64)   :   Intra frame Counter (15..0)
Initial counter(63..16)   :   Superframe Counter (47..0)
Initial counter(15..0)   :   Intra frame Counter (15..0)

C.16 25GS- PON power management

No deltas

C.17 25GS-PON channel management

Not applicable to 25GS PON.

C.18 25GS-PON system protection

No deltas

C.19 25GS-PON Rogue behaviour and its mitigation

No deltas

Annex C.B LDPC based Forward error correction used in 25GS-PON.

The used low-density parity check (LDPC) FEC mothercode used for 25GS-PON is based on the mothercode specified by the IEEE P802.3ca™/D3.1 [2].

The mothercode is a 12×69 quasi-cyclic matrix with a circulant size of 256. As a result, a codeword is 69x256 = 17664 bits in size of which payload is 57x256 bits = 14592 bits and parity is 12×69 bits = 3072 bits. This is then noted as LDPC(17664,14592).

The selected LDPC code for 25GS-PON is a non shortened and 2 column (512bits) punctured code, based on the IEEE 802.3ca task force mothercode.
The puncturing is applied from the right side of the Matrix.

Optionally, interleaving/de-interleaving can be applied following P802.3ca™/D3.1 [2].

As a result, the selected code for 25GS-PON is LDPC(17152,14592), which has the following characteristics:
- Codeword length: 17152 bits
- Payload length: 14592 bits
- Parity length: 2560 bits

Golden vectors to be added for reference

7 OMCI Specification

25GS PON has minimal impact on the ITU-T G.988 Recommendation for OMCI. The following two new plug-in unit types to represent 25GS-PON needs be added to the Table 9.1.5-1 in G.988 OMCI specification:
- Values 224..234 are kept as reserved, in line with the G.988 Specification.
- Values 235 and 236 are then assigned for 25G/10G and 25G/25G plug-in types respectively.

224..234	Reserved	
235	25G-PON25G10	25G-PON interface, 25G downstream and 10G upstream
236	25G-PON25G25	25G-PON interface, 25G downstream and 25G upstream

8 xPON YANG model

Because 25GS-PON is 'linear' extrapolation of the XGS-PON standard, the data model structure of TR-385 Issue 1 nicely fits with only minimal extensions required for 25GS-PON specificities. The analysis shows that TR-385 only needs to define a new xPON type identity "25gs-pon" and apply it to a very limited places in the TR. All changes are backward compatible or captured by editorial updates.

Identified changes

The 25GS-PON type requires a new identity to be added to **WT-385/bbf-xpon-types.yang**:

```
identity 25gs-pon {
  base channel-pair-type-base;
  description
    "This identity is used to denote a 25GS-PON
     channel-pair,per ITU-T <tbd>.";
}
```

The new 25GS-PON type needs to be taken in to account at the following places:

- WT-385/body/bbf-xpon-channel-pair-body.yang
  - The "wavelength-prof-ref" is also applicable to 25GS-PON
  - Update the description of the "channel-pair-line-rate" YANG leaf to tell that it is not applicable to 25Gs-PON. This is no more than an editorial update.

- WT-385/body/bbf-xpon-channel-termination-body.yang
  - Add "leaf 25gspon-pon-id" YANG leaf; contents expected to be similar to "xgs-pon-id" YANG leaf.

- WT-385/body/bbf-xpon-channel-partition-body.yang
  - Update the description of the "downstream-fec" YANG leaf; similar with XGS. Add also ITU-T reference.
  - Add ITU-T references for the "multicast-aes-indicator" YANG leaf

- WT-385/body/bbf-xponani-ani-body.yang
  - Update "upstream-fec" YANG leaf: always on for 25 Gbit/s

- WT-385/body/bbf-xponvani-v-ani-body.yang
  - Update "upstream-fec" YANG leaf: always on for 25 Gbit/s

- Update description field of ONU-ID, Gemport-IDs and Alloc-IDs to cope with the case of 25GS-PON type. This is no more than an editorial update.
  - WT-385/body/bbf-xpon-channel-group-body.yang
  - WT-385/body/bbf-xponani-ani-body.yang
  - WT-385/body/bbf-xponvani-v-ani-body.yang

9 Appendix: General statements on the relationship with XGS-PON TC layer requirements.

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

25GS-PON will be a 'linear' extrapolation of the XGS-PON standard with mainly the following characteristics:

In the downstream direction:
- Rate 24.8832 Gbit/s – further referred to as 25Gbit/s (10x GPON, 2.5x XGS-PON).
- Keeping the 125us frame structure.
- XGS-PON Compatible SDU mapping.
- Identical PSBd, FSheader,XGEM, FStrailer structure and bit definitions.
- Identical ONU ID, Alloc-ID, XGEM Port-ID.
- New reserved broadcast alloc-IDs for 25G ONUs are needed.
- New reserved broadcast ONU-IDs for 25G ONUs are needed.
- Blocks are defined as 40 bytes (XG-PON 4 bytes, XGS-PON 16 bytes).
- Identical BWmap partition definition and function.
- Block size means compatibility with 2.5G / 10G DBA, identical 9720 allocation start locations in a frame.
- 25Gbit/s DS uses LDPC FEC (using shorted/punctured codeword based on IEEE Mothercode).

In the upstream direction:
- Rate 24.8832 Gbit/s – further referred to as 25Gbit/s (10x GPON, 2.5x XGS-PON).
- Blocks are defined as 40 bytes (XG-PON 4 bytes, XGS-PON 16 bytes).
- XGS-PON Compatible SDU mapping.
- Identical PSBu, FSheader, Allocation overhead, XGEM, FStrailer structure and bit definitions.
- Identical ONU-ID, Alloc-ID, XGEM Port-ID.
- 25Gbit/s US uses LDPC FEC (using shorted/punctured codeword based on IEEE Mothercode)

10 Bibliography

No further additions.