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4 Nx25G-EPON architecture

4.1 Introduction

Clause 5 describes the overall architecture of an Nx25G-EPON system. The architecture defined in this clause is then used as the basis for the MAC Client reference model (see Clause 6), the connectivity configuration model (see Clause 7), and the management model (see Clause 13 and Clause 14).

A comparison of the EPON system architecture with the architecture models defined in BBF TR-200 and MEF 10.2 specifications is provided in IEEE Std 1904.1, Annex 5A.

Editorial Note (to be removed prior to publication):. DELETE Annex 5A

4.2 Optical Distribution Network

The term *passive optical network* (PON) generally refers to a network architecture where multiple devices at the edge of the network are interconnected via a passive *optical distribution network* (ODN).

A PON ODN comprises a structure made of a single strand of a single-mode optical fiber, spliced or connected together using specialized optical connectors. The ODN typically includes one or more passive splitter/coupler devices connected such that they form a point-to-multipoint (P2MP) topology, also called a *tree* or *trunk-and-branch* topology.

While in general, the ODN design is operator-specific and may vary from deployment to deployment, some operational aspects of Nx25G-EPON ODN, such as the maximum distance or the maximum channel insertion loss, are mandated by IEEE Std 802.3, Clause 141.

4.3 Nx25G-EPON devices

The device connected at the root of the tree is called an *optical line terminal* (OLT) and the devices connected as the leaves are referred to as *optical network units* (ONUs). The OLT architecture and various OLT categories are further defined in 4.7. The ONU architecture and various ONU categories are defined in 4.8.

4.4 Media access and transmission arbitration

The direction of transmission from the OLT to ONUs is referred to as the *downstream* direction, while the direction of transmission from the ONU to the OLT is referred to as the *upstream* direction. Upstream and downstream transmissions over an Nx25G-EPON ODN are wavelength division multiplexed into a single strand of fiber.

In the downstream direction, the OLT is the only device with the access to the transmission medium. The signals transmitted by the OLT pass through a 1:N passive splitter (or cascade of splitters) and reach each ONU.

In the upstream direction, the signal transmitted by an ONU reaches only the OLT, but not other ONUs. To avoid upstream data collisions, transmission windows (grants) for all ONUs are controlled in such a way that only a single ONU's transmission reaches the OLT at any given time.

The OLT is responsible for timing and arbitrating the ONU transmissions. This arbitration is achieved by allocating transmission windows (grants) to ONUs. An ONU defers its transmission until the start of its transmission window. When the transmission window starts, the ONU transmits its queued frames at full line rate for the duration of this transmission window.

Reporting of a queue occupancy state or congestion by the ONUs assists the OLT in optimal allocation of the transmission windows across the PON.

4.5 Concept of logical links

OLT and ONU devices instantiate multiple MAC instances. From a connectivity perspective, an Nx25G-EPON system can be viewed as a collection of logical point-to-point (P2P) and point-to-multipoint (P2MP) links. A logical link is created by binding a MAC instance at the OLT with a MAC instance at the ONU.

A P2P logical link connects a single MAC instance at the OLT to a single MAC instance at the ONU. A P2MP logical link takes advantage of the broadcasting nature of the PON tree topology and connects a single MAC instance at the OLT to multiple MAC instances in different ONUs.

The mechanism of establishing logical links relies on tagging each frame (or frame fragment) with a logical link identification (LLID) value and maping each instance of a MAC to a specific LLID value. See IEEE Std 802.3, 143.2.1 for the detailed explanation of the of logical link creation and operation.

The Nx25G-EPON architecture defines several types of LLIDs:

— The *Physical layer ID* (PLID) logical link carries messages used to control critical Nx25G-EPON operations, such as ONU registrations and arbitration of ONUs' access to the PON medium. All Multipoint Control Protocol data units (MPCPDUs) are transported using the PLID.

— *Management link ID* (MLID) logical link carries management traffic flows, such as OAM Protocol data units (OAMPDUS, see IEEE Std 802.3, 57.4) and Channel Control Protocol data units (CCPDUs, see IEEE Std 802.3, 144.4).

— *User link IDs* (ULIDs) carry subscriber traffic. It is expected that a single subscriber may be assigned one or more ULIDs to allow for separation of traffic classes and types. ULID values are assigned (provisioned) to an ONU by NMS.

— *Group link ID* (GLID) is used to consolidate several LLIDs into arbitrary groups for the purposes of bandwidth granting by the OLT and reporting by the ONU. The configuration and operation of GLID is specified in TBD.

Upon successful registration, the ONU is connected to the OLT via two point-to-point logical links: primary PLID and primary MLID. Additionally, two broadcast logical links are pre-defined: `BCAST_PLID` and `BCAST_MLID` (see IEEE Std 802.3, Table 144–1). Together, the two primiary LLIDs and the two predefined broadcast LLIDs are refered as *system* LLIDs.

Additional P2P and/or P2MP logical links between the OLT and ONUs may be provisioned by the NMS based on specific access network configuration and service requirements. Provisioning of such additional logical links is accomplished using the eOAM action *acConfigLlid* (see 14.6.2.8).

Although at the PON-facing port the OLT and ONUs instantiate multiple MAC entities, each device may use a single MAC address. Within the EPON Network, MAC instances are uniquely identified by their LLID.

4.6 Family of Nx25G-EPON architectures

Nx25G-EPON operates at 25 Gb/s or 50 Gb/s in the downstream direction, and at 10 Gb/s, 25 Gb/s or 50 Gb/s in the upstream direction. The 50 Gb/s downstream or upstream throughput is achieved by bonding two Physical Layer channels. Various flavors of Nx25G-EPON architectures are distingushed based on the specific combination of downstream/upstream data rates supproted by the OLT and ONUs:

- 25/10G-EPON – an EPON architecture supporting a maximum sustained throughput of 25 Gb/s in the downstream direction and 10 Gb/s in the upstream direction (asymmetric rate).

- 25/25G-EPON – An EPON architecture supporting a maximum sustained throughput of 25 Gb/s in both downstream and upstream directions (symmetric rate).

- 25G-EPON – An EPON architecture supporting a maximum sustained throughput of 25 Gb/s in either downstream or both downstream and upstream directions. This term collectively refers to 25/10G-EPON and 25/25G-EPON architectures.

- 50/10G-EPON – An EPON architecture supporting a maximum sustained throughput of 50 Gb/s in the downstream direction and 10 Gb/s in the upstream direction (asymmetric rate).

- 50/25G-EPON – An EPON architecture supporting a maximum sustained throughput of 50 Gb/s in the downstream direction and 25 Gb/s in the upstream direction (asymmetric rate).

- 50/50G-EPON – An EPON architecture supporting a maximum sustained throughput of 50 Gb/s in both downstream and upstream directions (symmetric rate).

- 50G-EPON – An EPON architecture supporting a maximum sustained throughput of 50 Gb/s in either downstream or both downstream and upstream directions. This term collectively refers to 50/10G-EPON, 50/25G-EPON, and 50/50G-EPON architectures.

4.7 OLT architecture

The OLT is the central network controller in EPON, providing connectivity between the EPON and the metro/aggregation network across Network-to-Network Interface (NNI). The OLT controls all connected ONUs, and it is in turn controlled by the NMS.

Historically, in various contexts (i.e., in different specifications), the term OLT has been used to represent different functionalities. To avoid potential ambiguities, this standard defines several OLT categories based on what functional elements are included in the OLT. The following OLT categories are defined:

- Line OLT (4.7.1),
- Client OLT (4.7.2),
- Service OLT (4.7.3).

The OLT categories together with the functional elements included in each category are illustrated in Figure 4-1.

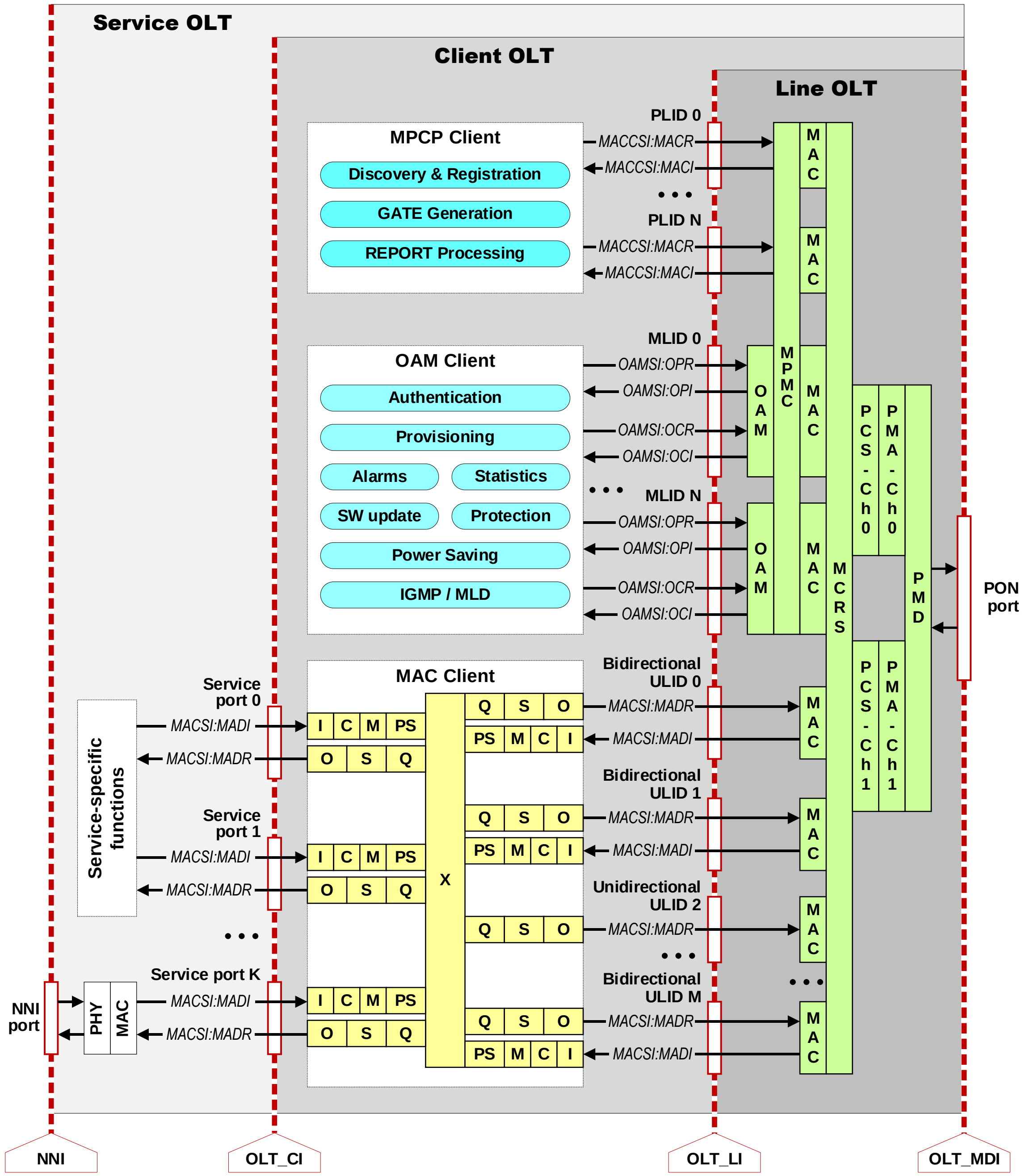

Figure 4-1—OLT architecture

4.7.1 Line OLT

A Line OLT (L-OLT) represents the functionality specified in IEEE Std 802.3 for 25G-EPON or 50G-EPON. This functionality includes the physical layer and portions of data link layer. Figure 4-2 illustrates the ralation of the L-OLT to the reference layering model defined in IEEE Std 802.

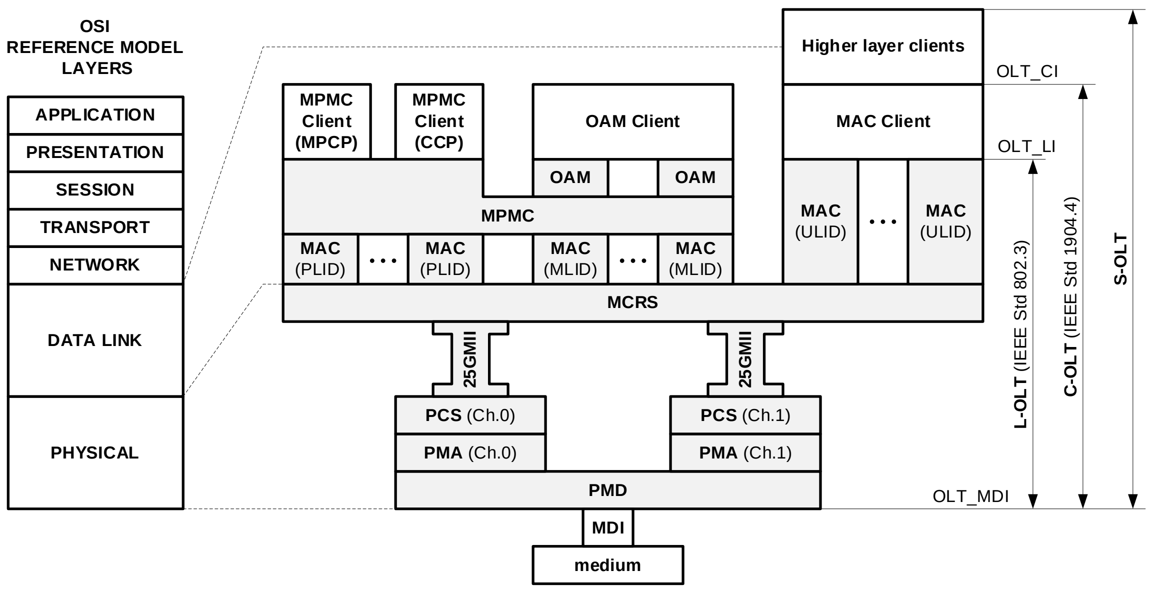

Figure 4-2—Relationship of OLT interfaces to the OLT layering model defined in IEEE Std 802.3

The location of the L-OLT in the OLT architecture is presented in Figure 4-1.

An L-OLT represents the basic logical entity that is responsible for the Physical Layer connectivity in EPON. As such, the L-ONU is capable of sending and receiving various types of Ethernet frames: data frames, OAM frames, or MPCP frames, where the payload is provided via the C-OLT. The L-OLT does not initiate the process of MPCP discovery and registration of ONUs. It does not have frame buffers to store frames received from or destined to the ONUs.

As shown in Figure 4-1, the L-OLT interfaces with the PON media at the OLT_MDI (see4.9.1) and it interfaces with the higher-layer clients at the OLT_LI (see 4.9.3). The OLT_LI instantiates a number of logical ports, where each such port represents a single logical link (LLID).

By itself, the L-OLT is not capable of establishing bidirectional connectivity with the OLT and requires the support of the C-OLT functions defined in this standard.

4.7.2 Client OLT

A Client OLT (C-OLT) combines an L-OLT with higher-layer functions, such as the following:

- *OAM Client* functions: Provisioning, Statistics, Alarms, and Power Saving agents, Internet Group Management Protocol/Multicast Listener Discovery (IGMP/MLD), Authentication agents, etc.
- *MAC Control Client* functions: discovery and registration, *GATE* MPCPDU generation and *REPORT* MPCPDU processing agents
- *MAC Client* functions: see Clause 6 for details on these data path functions

These functions reside above the OLT_LI (see4.9.3) but below the OLT_CI (see4.9.5). The C-OLT is capable of establishing bidirectional connectivity with the ONU, sending and receiving subscriber frames (and providing all the necessary processing), and participating in the MPCP and OAM frame exchanges and related processes (e.g., discovery and registration, OAM discovery).

Each of the OLT_LI logical ports, which represent LLIDs, is connected to one of the avalaible clients. Depending on resources alloacted to each LLID within its respective client, the LLID may operate as a bidirectional logical link or as a unidirectional (downstream-only) logical link. For example, in Figure 4-1, the ULID 1 is connected to MAC Client input [I] and output [O] blocks and it supports both the *MA_DATA.Indication* and *MA_DATA.Request* primitives Therefore ULID 1 is a bidirectional LLID. In contrast, the ULID 2 is connected only to MAC Client output block and supports only the *MA_DATA.Request* primitive. This makes the ULID 1 a unidirectional (downstream-only) LLID.

The C-OLT interfaces with the Service OLT at the OLT_CI. The OLT_CI instantiates a number of service ports (see Figure 4-1).

4.7.3 Service OLT

An S-OLT combines one C-OLT together with a number of functions residing above the OLT_CI (see4.9.5) and one or more NNI ports. The specific type, structure, and data rates supported by NNI ports are outside the scope of this standard.

Examples of additional functionalities residing above the OLT_CI include service initiation protocols, network address translation, switching, POTS, and other elements appropriate for delivery of specific subscriber services. These elements are typically subject to separate specifications and remain outside the scope of this standard.

Elements residing above the OLT_CI within the S-OLT are typically managed using solutions outside the scope of this standard.

4.8 ONU architecture

The ONU represents the client unit in EPON, providing connectivity between CPE devices across the user network interface (UNI) and the EPON.

Historically, in various contexts (i.e., in different specifications), the term ONU has been used to represent different functionalities. To avoid potential ambiguities, this standard defines several ONU categories based on what functional elements are included in the ONU. The following ONU categories are defined:

— Line ONU (4.8.1),

— Client ONU (4.8.2),

— Service ONU (4.8.3).

The ONU categories together with the functional elements included in each category are illustrated in Figure 4-3.

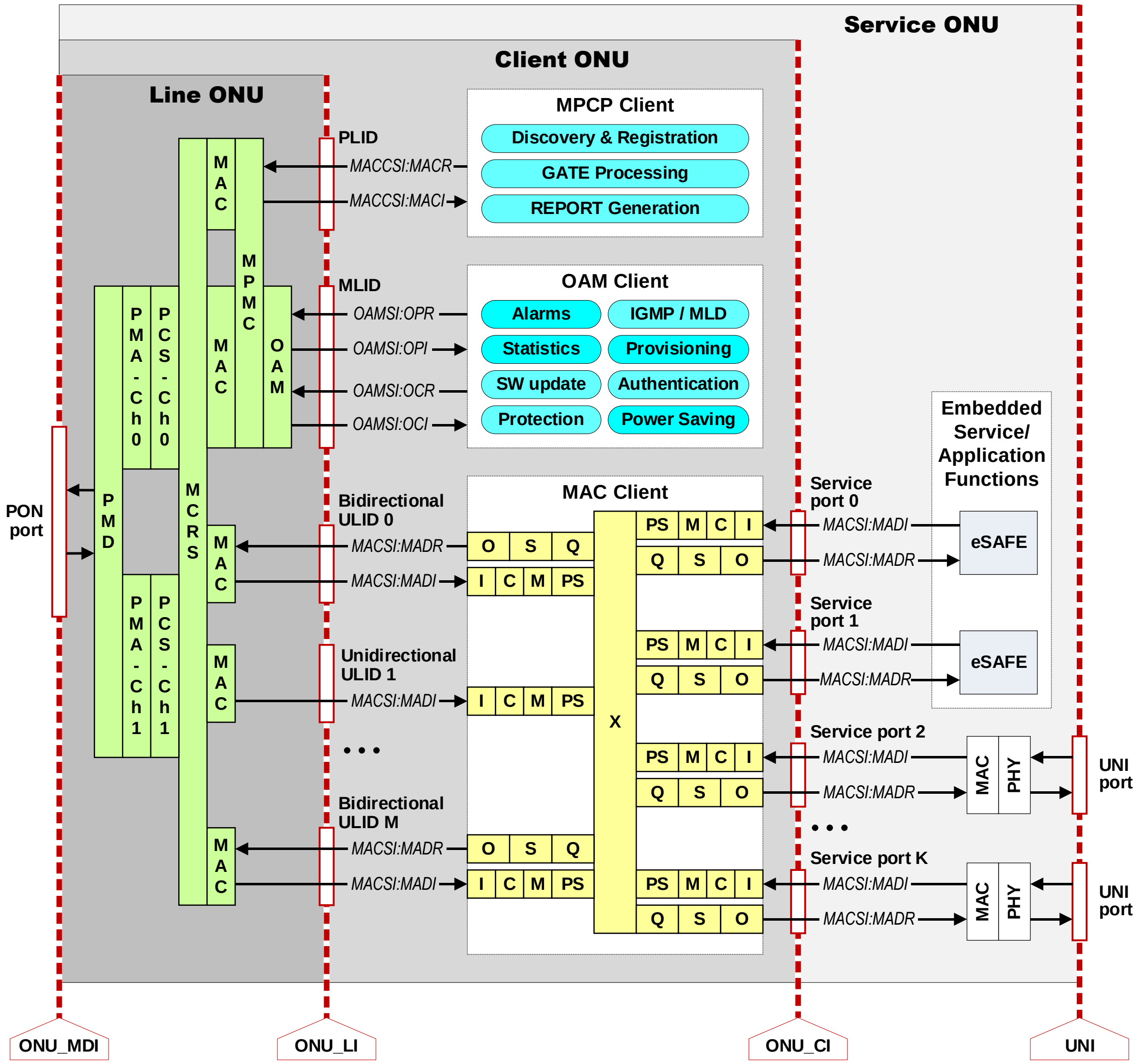

Figure 4-3—ONU architecture

4.8.1 Line ONU

A Line ONU (L-ONU) represents the functionality specified in IEEE Std 802.3 for 25G-EPON or 50G-EPON. This functionality includes the physical layer and portions of data link layer. Figure 4-4 illustrates the ralation of the L-ONU to the reference layering model defined in IEEE Std 802.

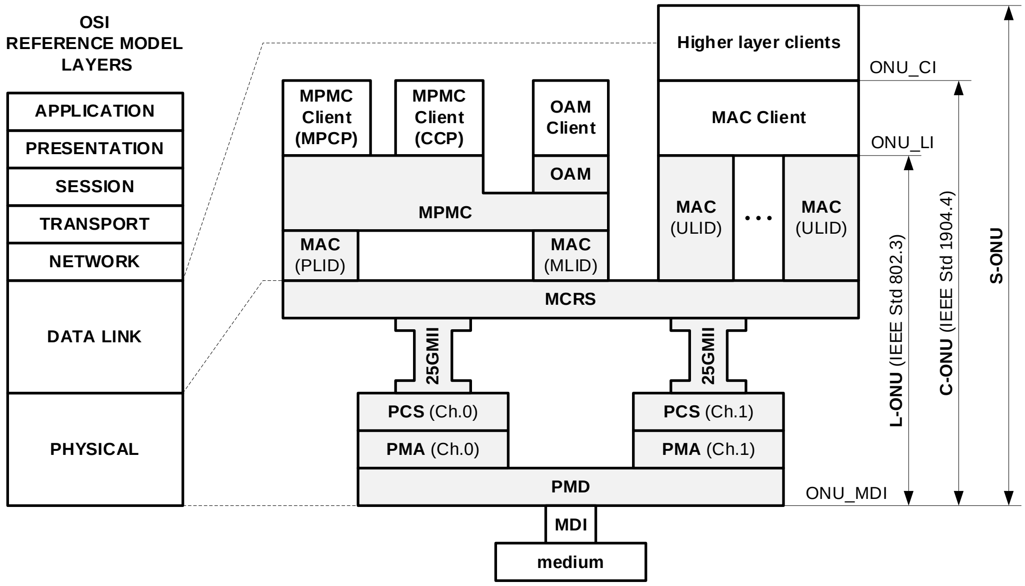

Figure 4-4—Relationship of L-ONU interfaces to the ONU layering model defined in IEEE Std 802.3

The location of the L-ONU in the ONU architecture is presented in Figure 4-3.

An L-ONU represents the basic logical entity that is responsible for the Physical Layer connectivity in EPON. As such, the L-ONU is capable of sending and receiving various types of Ethernet frames: data frames, OAM frames, or MPCP frames, where the payload is provided via the C-ONU. The L-ONU does not initiate the MPCP discovery and registration processes. It does not have frame buffers to store frames received across the subscriber interfaces.

As shown in Figure 4-3, the L-ONU interfaces with the PON media at the ONU_MDI (see4.9.2) and it interfaces with the higher-layer clients at the ONU_LI (see4.9.4). The ONU_LI instantiates a number of logical ports, where each such port represents a single logical link (LLID).

By itself, the L-ONU is not capable of establishing bidirectional connectivity with the OLT and requires the support of the C-ONU functions defined in this standard.

4.8.2 Client ONU

A Client ONU (C-ONU) combines a single L-ONU instance with higher-layer *client* functions, such as the following:

— *OAM Client* functions: Provisioning, Statistics, Alarms, and Power Saving agents, Internet Group Management Protocol/Multicast Listener Discovery (IGMP/MLD), Authentication agents, etc.

— *MAC Control Client* functions: discovery and registration, *GATE* MPCPDU processing and *REPORT* MPCPDU generation agents

— *MAC Client* functions: see Clause 6 for details on these data path functions

These functions reside above the ONU_LI (see 4.9.4) but below the ONU_CI (see4.9.6). The C-ONU is capable of establishing bidirectional connectivity with the OLT, sending and receiving subscriber frames (and providing all the necessary processing), and participating in the MPCP and OAM frame exchanges and related processes (e.g., discovery and registration, OAM discovery).

The C-ONU interfaces with the Service ONU at the ONU_CI. The ONU-CI instantiates a number of service ports (see Figure 4-1).

4.8.3 Service ONU

A Service ONU (S-ONU) combines one C-ONU together with various embedded service/application entities (eSAFEs) residing above the ONU_CI (see 4.9.6) interface. The C-ONU typically includes one or more subscriber UNI ports.

Each of the service ports instantiated by the C-ONU at the ONU_CI interface is either connected to an eSAFE device within an S-ONU or is exposed as a physical UNI port for connecting subscriber CPE.

Examples of eSAFE devices/sub-sustems residing above the ONU_CI include embedded Router (eRouter), embedded Set-Top Box (eSTB), embedded Digital Voice Adapter (eDVA) and many others, for example as described in [eDOCSIS] **(Ed. Note: add bib entry to Annex Bib)**. These elements are typically subject to separate specifications and remain outside the scope of this standard.

Note that some of the eSAFE devices may have their own physical ports exposed as Ethernet or non-Ethernet UNI ports at the S-ONU. Those ports are expected to be managed as part of the eSAFE device management and are outside the scope of this standard.

4.9 Interfaces

This subclause provides definitions of functional interfaces specified for the ONU and OLT devices. These interfaces do not require any specific implementation; however, they may have corresponding primitives defined in IEEE Std 802.3, as indicated below. The positions of these interfaces and the primitives supported by each interface are illustrated in Figure 4-5. The internal sublayer interfaces `MACSI`, `MACCSI`, and `OAMSI` are defined in 3.5.

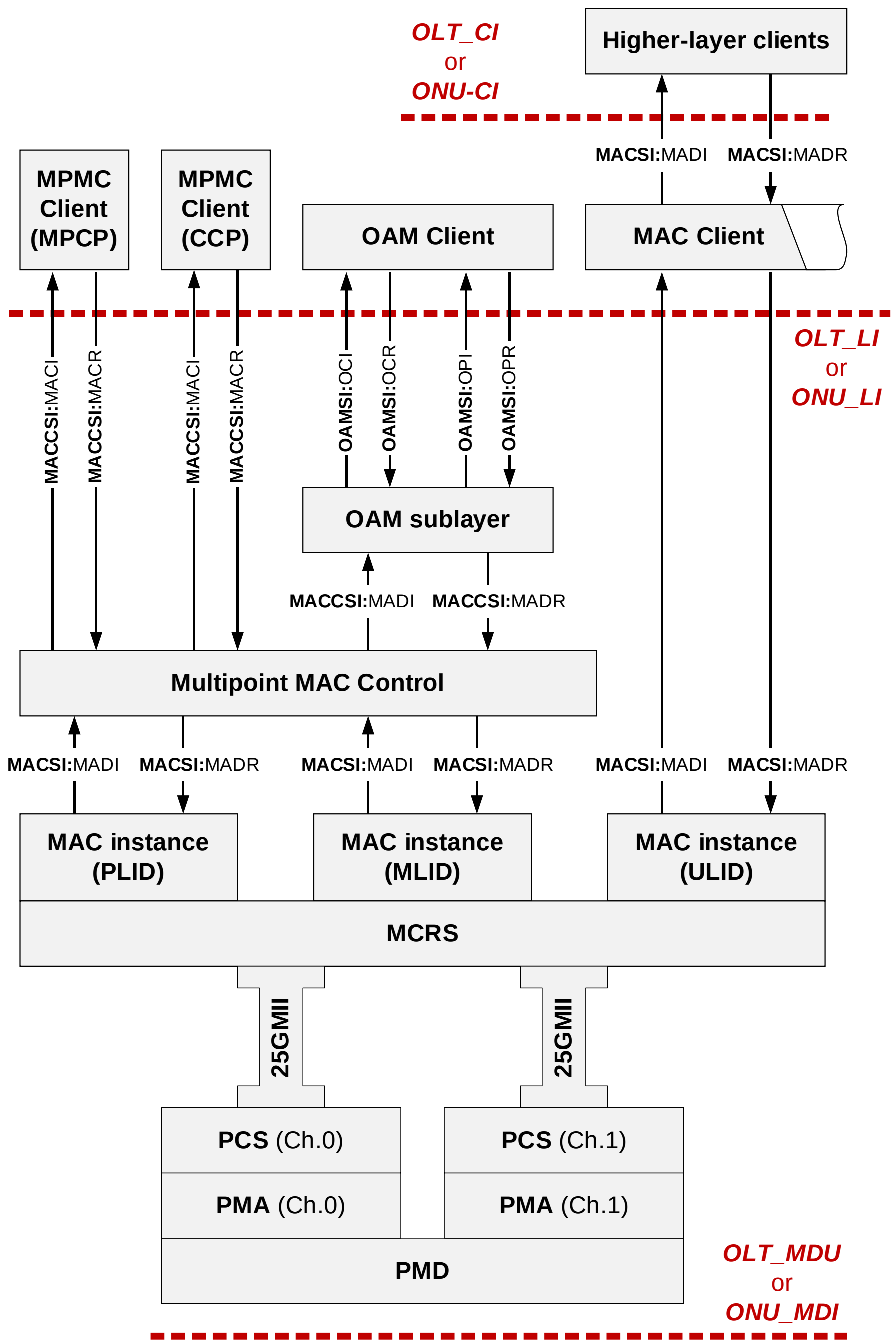

Figure 4-5: Position of functional interfaces in the OLT and ONU devices

4.9.1 OLT_MDI

The OLT_MDI represents an interface between the L-OLT and the physical PON medium. This interface corresponds to the MDI specified in IEEE Std 802.3, Clause 141.

4.9.2 ONU_MDI

The ONU_MDI represents an interface between the L-ONU and the physical PON medium. This interface corresponds to the Medium Dependent Interface (MDI) specified in IEEE Std 802.3, Clause 141.

4.9.3 OLT_LI

The OLT_LI represents the interface between the L-OLT and C-OLT functionalities. From a practical point of view, the OLT_LI represents the boundary of IEEE 802.3 specifications for EPON, covering the PMD, PMA, PCS, MCRS, MAC, MPMC, and OAM sublayers.

This interface corresponds to the following IEEE 802.3 interfaces:

— MAC data service interface (using `MADI` and `MADR` primitives, as described in 3.4) for subscriber data frames exchanged between the MAC Client and L-OLT

— MAC Control service interface (using `MACI` and `MACR` primitives, as described in 3.4) for MAC Control frames exchanged between the MAC Control Client and L-OLT

— OAM service interface (using `OCI`, `OCR`, `OPI`, and `OPR` primitives, as described in 3.4) for OAM frames exchanged between the OAM Client and L-OLT

4.9.4 ONU_LI

The ONU_LI represents the interface between the L-ONU and C-ONU functionalities. From a practical point of view, the ONU_LI represents the boundary of IEEE 802.3 specifications for EPON, covering the PMD, PMA, PCS, MCRS, MAC, MPMP, and OAM sublayers, residing below the ONU_LI.

This interface corresponds to the following IEEE 802.3 interfaces:

— MAC data service interface (using `MADI` and `MADR` primitives, as described in 3.4) for subscriber data frames exchanged between the MAC Client and L-ONU

— MAC Control service interface (using `MACI` and `MACR` primitives, as described in 3.4) for MAC Control frames exchanged between the MAC Control Client and L-ONU

— OAM service interface (using `OCI`, `OCR`, `OPI`, and `OPR` primitives, as described in 3.4) for OAM frames exchanged between the OAM Client and L-ONU

4.9.5 OLT_CI

The OLT_CI represents the interface between the C-OLT and the S-OLT functionalities. The OLT_CI instantiates a number of service ports, which may be internal ports connected to embedded service-specific functions or external ports (i.e., NNI ports) exposed in the S-OLT for connection to the backbone network. The OLT_CI corresponds to D/MN_E interface defined in DPoE-SP-ARCH.

4.9.6 ONU_CI

The ONU_CI represents the interface between the C-ONU and the S-ONU functionalities. The ONU_CI instantiates a number of service ports, which may be internal ports connected to embedded service/application functions (sSAFEs) or external ports (i.e., UNI ports) exposed in the S-ONU for connection to physical CPE devices. The ONU_CI corresponds to S-interface defined in DPoE-SP-ARCH.