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144 Multipoint MAC Control for Nx25G-EPON

144.1 Overview

This clause defines the mechanisms and control protocols required in order to reconcile the 25Gb/s or 50Gb/s passive optical network (PON) into the Ethernet framework. A PON is an optical network with no active elements in the signal's path from source to destination. The only interior elements used in a PON are passive optical components, such as optical fiber, splices, and splitters. When combined with the Ethernet protocol, such a network is referred to as Ethernet passive optical network (EPON).

Topics covered in this clause include allocation of transmission resources in EPON, discovery and registration of EPON devices, and reporting of congestion to higher layers to facilitate dynamic bandwidth allocation schemes and statistical multiplexing across the PON.

This clause does address specific bandwidth allocation strategies, authentication of end-devices, quality-of-service definitions, provisioning, or management.

The Multipoint MAC Control (MPMC) sublayer defined in this clause includes two protocols:

- Multipoint control protocol (MPCP) responsible for arbitration of TDM-based access to P2MP medium
- Channel control protocol (CCP) responsible for querying and control of multiple channels within the Nx25G-PON PHY.

The Multipoint MAC Control functionality shall be implemented for subscriber access devices containing point-to-multipoint Physical Layer devices defined in Clause 141.

144.1.1 Principles of point-to-multipoint operation

Point-to multipoint (P2MP) medium is an asymmetric medium based on a tree (or trunk-and-branch) topology. The DTE connected to the trunk of the tree is called optical line terminal (OLT) and the DTEs connected at the branches of the tree are called optical network units (ONU). The OLT typically resides at the service provider's facility, while the ONUs are located at the subscriber premises. A simplified P2MP topology example is depicted in Figure 144-1. Clause 67 provides additional examples of P2MP topologies.

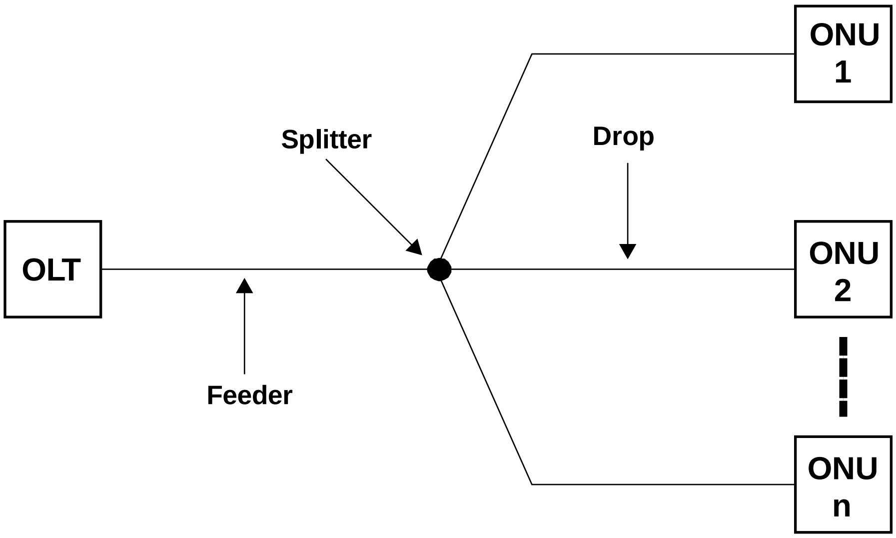

Figure 144–1—PON topology example

144.1.1.1 Transmission arbitration

In the downstream direction (from the OLT to an ONU), signals transmitted by the OLT pass through a 1:N passive splitter (or cascade of splitters) and reach each ONU.

In the upstream direction (from the ONUs to the OLT), the signal transmitted by an ONU would only reach the OLT, but not other ONUs. To avoid upstream data collisions, only a single ONU is allowed to transmit at a time. The Multipoint Control Protocol (MPCP, see 144.4) is responsible for timing and arbitrating the ONU transmissions. This arbitration is achieved by allocating a transmission window (grant) to each ONU. 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 different ONUs assists in optimal allocation of the transmission windows across the PON.

144.1.1.2 The concept of logical links

OLT and ONU devices instantiate multiple MAC elements (see Figure 144-2). P2MP architectures are best viewed as a collection of logical point-to-point and/or point-to-multipoint links. A logical link is created in the MCRS (below the MAC) by tagging each frame (or frame fragment) with a logical link identification (LLID) value and binding each instance of MAC to a specific LLID value. See 143.2.1 for explanation of the mechanism of logical link operation.

A logical connection is formed when a MAC instance at the OLT and a MAC instance at the ONU are bound to the same LLID value. A point-to-point logical link connects a single MAC instance at the OLT to a single MAC instance at the ONU. A point-to-multipoint logical link takes advantage of the broadcasting nature of P2MP topology and connects a single MAC instance at the OLT to multiple MAC instances in different ONUs. In a point-to-multipoint logical link, MAC instances in multiple ONUs are bound to the same LLID value.

By default, the OLT is connected to each ONU via two point-to-point logical links: one link is used for Multipoint MAC Control traffic, such as MPCPDUs (see 144.5) and the other link is used for management traffic, such as OAMPDUs (see Clause 57).

Several single-copy broadcast (SCB) logical links are instantiated automatically. Such links are used to broadcast MPCPDUs, OAMPDUs, or user traffic.

Additional point-to-point and/or point-to-multipoint links between the OLT and ONUs may be provisioned by network management based on specific access network configuration and service requirements. Provisioning of such additional logical links is outside the scope of this standard. Different types of logical links are described in 144.3.2.

144.1.1.3 ONU Discovery and Registration

<subclause text to be supplied later>

144.1.2 Position of Multipoint MAC Control within the IEEE 802.3 hierarchy

<subclause text to be supplied later>

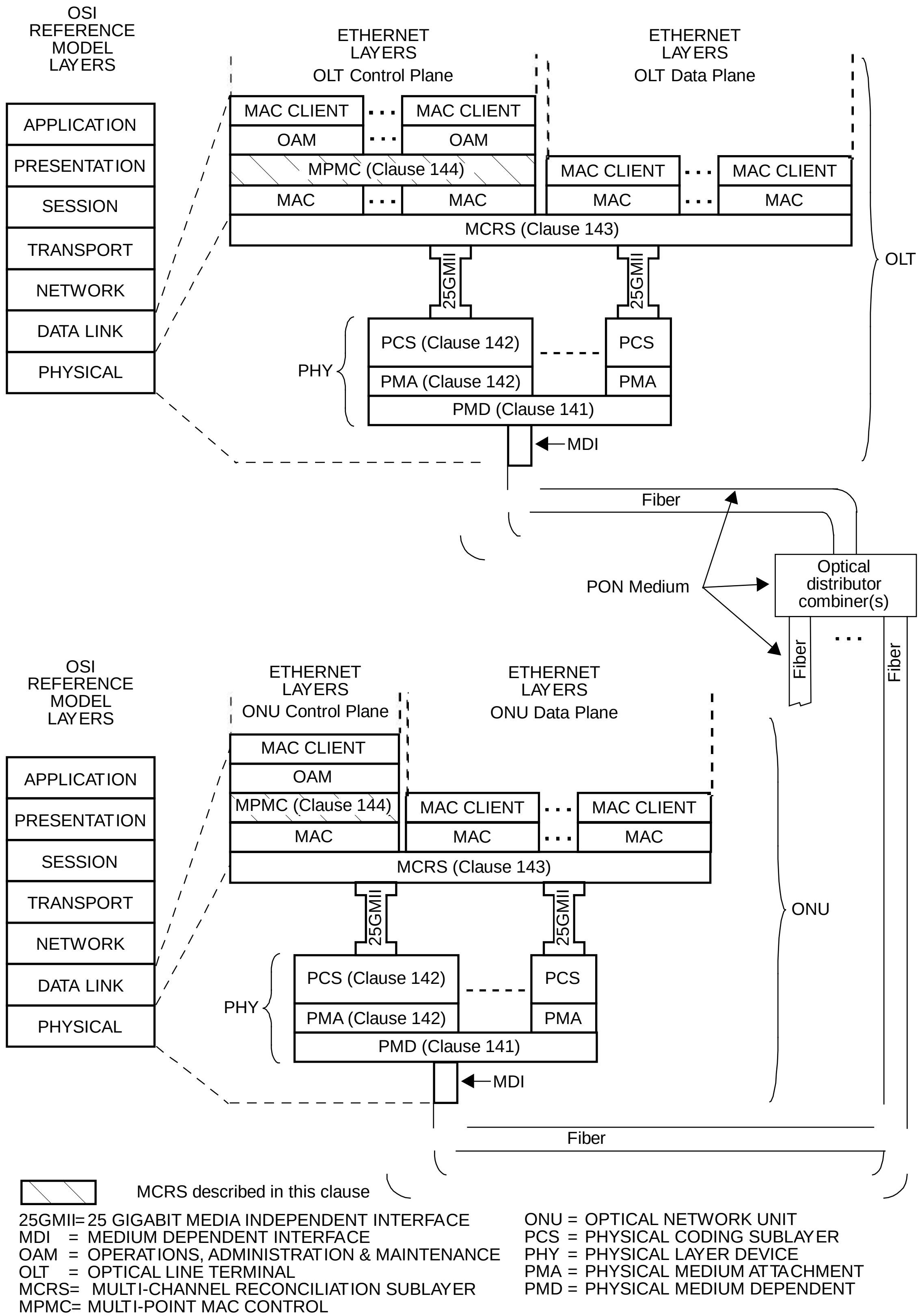

Figure 144–2—Relationship of EPON P2MP PMD to the ISO/IEC OSI reference model and the IEEE 802.3 Ethernet model

144.1.3 Functional block diagram

Figure 144-3 and Figure 144-4 provide a functional block diagram of the Multipoint MAC Control architecture for the OLT and the ONU, respectively.

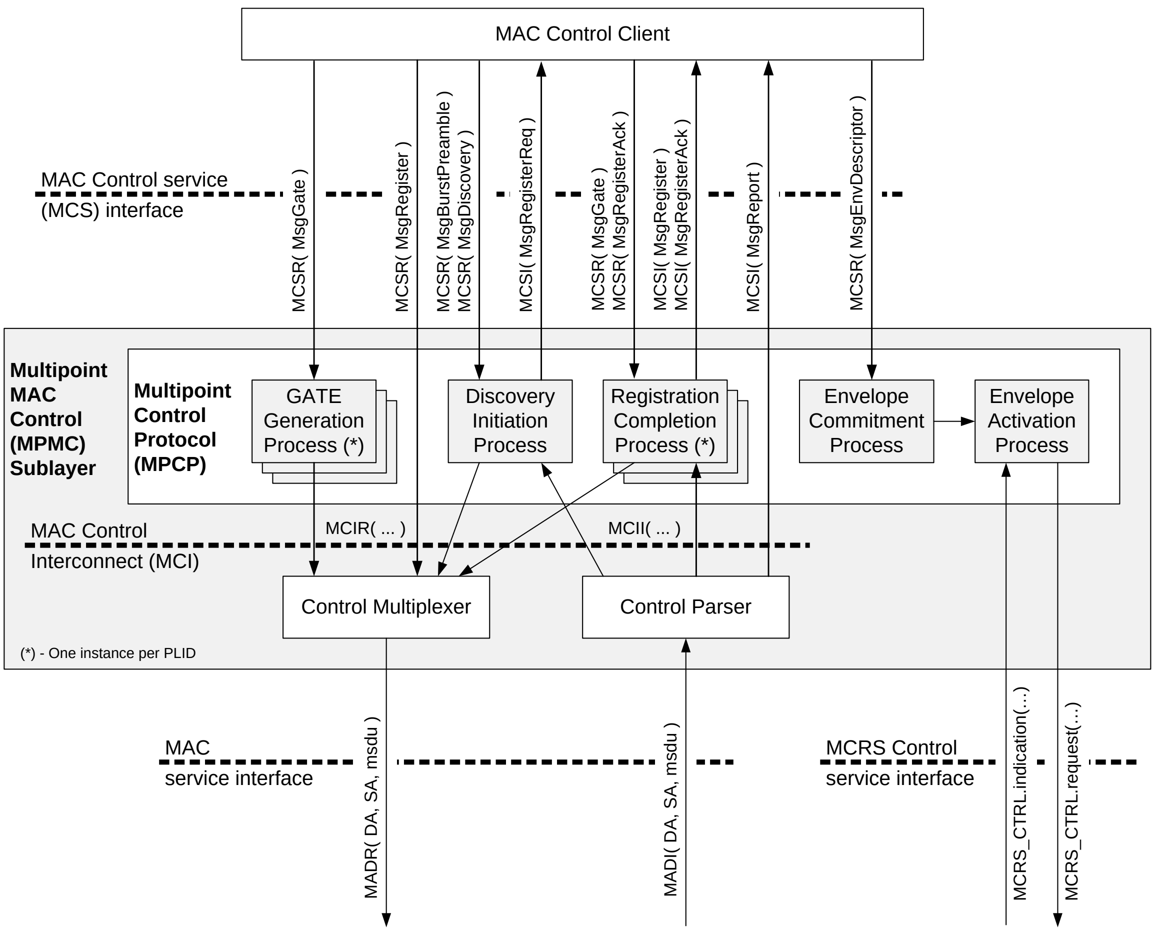

Figure 144-3 – OLT Multipoint MAC Control (MPMC) sublayer functional block diagram.

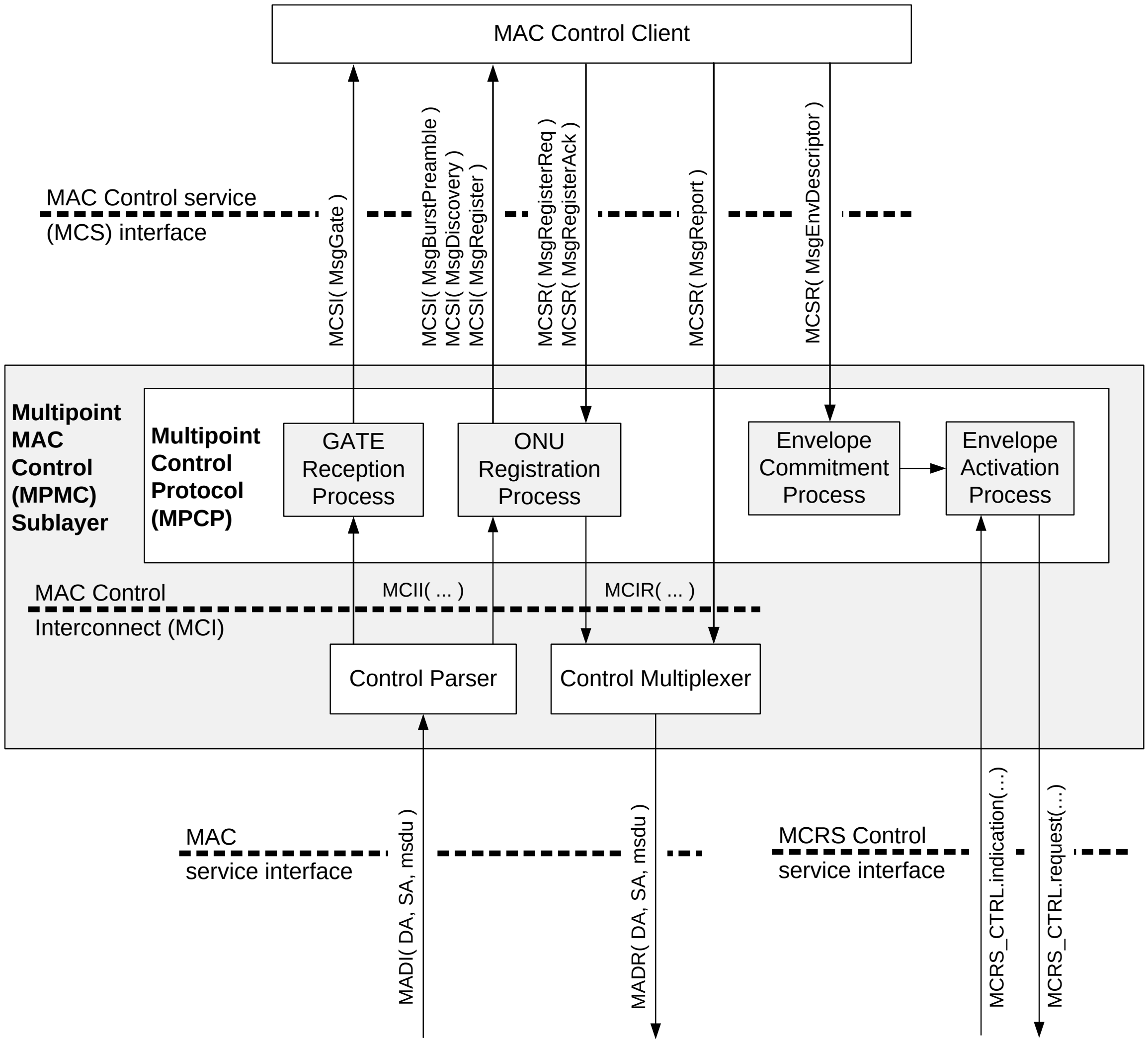

Figure 144-4 – ONU Multipoint MAC Control (MPMC) sublayer functional block diagram.

144.1.4 Service interfaces

The MAC Clients communicate directly with dedicated MAC instances using the standard service interface specified in 2.3. The Multipoint MAC Control does not interface with any MAC Clients.

The MAC Control Clients communicate with Multipoint MAC Control instances using service interface defined in this clause. Each Multipoint MAC Control instance communicates with the underlying MAC sublayer using the standard service interface specified in Annex 4A.3.2. Similarly, Multipoint MAC Control communicates internally using primitives and interfaces consistent with definitions in Clause 31.

144.1.4.1 MAC Control Service (MCS) Interface

MCS interface is an interface between MAC Control sublayer and MAC Control Client above it (see Figure 144-3 and Figure 144-4). The definition and behavior of MAC Control Client is outside the scope of this standard.

The MAC Control sublayer and MAC Control Client communicate via MCS:MA_CONTROL.indication and MCS:MA_CONTROL.request primitives. In the state diagrams used in this clause, the following abbreviations are used:

— MCSI(…) is equivalent to MCS:MA_CONTROL.indication(…);

— MCSR(…) is equivalent to MCS:MA_CONTROL.request(…)

144.1.4.2 MAC Control Interconnect (MCI)

MCI is an internal interface between Control Parser/Multiplexor and other opcode-specific functions of the MAC Control sublayer (see Figure 144-3 and Figure 144-4).

The Control Parser and Control Multiplexor communicate with opcode-specific functions via MCI:MA_CONTROL.indication and MCI:MA_CONTROL.request primitives. In the state diagrams used in this clause, the following abbreviations are used:

— MCII(…) is equivalent to MCI:MA_CONTROL.indication(…);

— MCIR(…) is equivalent to MCI:MA_CONTROL.request(…)

144.1.4.3 MAC Service Interface

MAC Service interface is an interface between MAC sublayer and MAC Control sublayer above it (see Figure 144-3 and Figure 144-4).

The MAC sublayer and MAC Control sublayer communicate via MAC:MA_DATA.indication and MAC:MA_DATA.request primitives. The following abbreviations are used in this clause:

— MADI(…) is equivalent to MAC:MA_DATA.indication(…);

— MADR(…) is equivalent to MAC:MA_DATA.request(…)

144.1.4.4 MCRS Control Interface

MCRS Control interface is an interface between the MAC Control sublayer and Multi-Channel Reconciliation sublayer (MCRS, see Clause 143). MCRS Control interface is used to control timing of envelope transmission over multi-channel P2MP media.

The MAC Control sublayer and the MCRS communicate via MCRS_CTRL.indication and MCRS_CTRL.request primitives.

144.1.5 Compatibility considerations

<subclause text to be supplied later>

144.1.6 State diagram conventions

The body of this standard comprises state diagrams, including the associated definitions of variables, constants, and functions. In case of any discrepancies between a state diagram and descriptive text, the state diagram prevails.

The notation used in the state diagrams follows the conventions of 21.5. State diagram timers follow the conventions of 14.2.3.2 augmented as follows:

a) [start x_timer, y] sets expiration of *y* to timer *x_timer*.
b) [stop x_timer] aborts the timer operation for *x_timer* asserting *x_timer_not_done* indefinitely.

The notation ++ after a variable indicates it is to be incremented by 1. The notation – – after a variable indicates it is to be decremented by 1. The notation –= after a variable indicates that the counter value is to be decremented by the following value. The notation += after a variable indicates that the counter value is to be incremented by the following value. Code examples given in this clause adhere to the style of the "C" programming language.

The vector notations used in the state diagrams for bit vector use 0 to mark the first received bit and so on (for example data<15:0>), following the conventions of 3.1 for bit ordering.

a < *b:* A function that is used to compare two values. Returned value is true when *b* is larger than *a* allowing for wrap around of *a* and *b*. The comparison is made by subtracting *b* from *a* and testing the MSB. When MSB(*a*–*b*) = 1 the value true is returned, else false is returned. In addition, the following functions are defined in terms of *a* < *b*:

$a > b$ is equivalent to $!(a < b \text{ or } a = b)$
$a \geq b$ is equivalent to $!(a < b)$
$a \leq b$ is equivalent to $!(a > b)$

144.2 Protocol-independent operation

As depicted in **Error! Reference source not found.** and **Error! Reference source not found.**, the Multipoint MAC Control comprises the following functional blocks:

a) *Control Parser*. This block is responsible for parsing MAC Control frames, as well as interfacing with Clause 31 entities, and opcode specific blocks.
b) *Control Multiplexer*. This block is responsible for selecting the source of the forwarded frames.
c) *Discovery & Registration Processing*. This block is responsible for handling the MPCP in the context of the MAC.
d) *GATE Generation/Reception Process*. This block is responsible for generating and processing GATE messages.
e) *REPORT Generation/Reception Process*. This block is responsible for generating and processing REPORT messages.
f) *Envelope Commitment and Activation Process*. These blocks are responsible for committing and activating transmission envelopes.

144.2.1 Control Parser and Control Multiplexer

The Control Parser (see Figure 144-6) is responsible for opcode-independent parsing of MAC frames and passing these frames to other processes for opcode-specific operations. Control Parser also extracts the timestamp value from all MPCPDUs that contain Timestamp field and checks whether timestamp drift value is within the acceptable range. There are no interfaces connecting the Control Parser to MAC Clients.

The Control Multiplexer (see Figure 144-7) is responsible for forwarding frames received from multiple opcode-specific processes to the underlying MAC sublayer. Control Multiplexor inserts the timestamp value into all MPCPDUs that carry the Timestamp field. There are no interfaces connecting the Control Multiplexer to MAC Clients.

<Figures 144-7 and 144-7 to be supplied later>

144.2.1.1 Constants

DRIFT_THOLD

TYPE: integer

This constant holds the maximum amount of drift allowed for a timestamp received at the given device. This value is measured in units of EQT.

VALUE: <TBD> (for OLT) or <TBD> (for ONU)

144.2.1.2 Counters

LocalTime

TYPE: 32-bit unsigned

This variable holds the value of the local timer used to control MPCP operation. This variable is advanced by a timer at 390.625 MHz, and is equivalent to one EQT. At the OLT the counter shall track the transmit clock, while at the ONU the counter shall track the receive clock. For accuracy of receive clock, see {TBD reference to Clause 142 needed}. In the ONU, this variable is updated with the received timestamp value by the Control Parser process (see 144.3.2.7.1)..

144.2.1.3 Variables

msdu

See the definition of mac_service_data_unit in 2.3.1.2.

opcode

TYPE: 16-bit unsigned integer

This variable represents the opcode value of the outgoing (in the Control Multiplexor) or incoming (in the Control Parser) MPCPDU.

RTTdelta

TYPE: 16-bit unsigned integer

This variable holds the difference between the previously measured RTT and the new RTT value calculated from the newly-received timestamp. . The RTT value is represented in units of EQT.

RTT

TYPE: 16-bit unsigned integer

This variable holds the measured Round Trip Time to the ONU. The RTT value is represented in units of EQT.

Timestamp

TYPE: 32-bit unsigned integer

In the Control Multiplexor state diagram, this variable holds the PLID-specific value of timestamp to be inserted into an outgoing MPCPDU. In the Control Parser state diagram this variable represents the value of the Timestamp field of the received MPCPDU.

supported_opcode
TYPE: list of 16-bit unsigned integers
A list of all supported opcodes (see Table 31A-1).

timestamp_opcode
TYPE: list of 16-bit unsigned integers
A list of all MPCPDU opcodes that contain the Timestamp field (see Table 31A-1).

timestampDrift
TYPE: Boolean
This variable is used to indicate whether an uncorrectable timestamp drift was detected (when set to True) or not (when set to False). An uncorrectable timestamp drift causes an immediate PLID de-registration (see ONU Registration state diagram in 144.4.3.6.3).

144.2.1.4 Functions

ProcessTimestamp (Timestamp)
This function takes the timestamp value from a received MPCPDU and checks whether the timestamp drift has exceeded the predefined device-specific threshold DRIFT_THOLD. In the OLT, this function also measures and updates the RTT of a given ONU.
In the OLT, the *ProcessTimestamp* function is defined as follows:

```
ProcessTimestamp( Timestamp )
{
   RTTdelta = LocalTime – Timestamp
   timestampDrift = abs(RTTdelta) > DRIFT_THOLD
   RTT = RTT + RTTdelta
}
```

In the ONU, the *ProcessTimestamp* function is defined as follows:

```
ProcessTimestamp( Timestamp )
{
   timestampDrift = abs(LocalTime – Timestamp) > DRIFT_THOLD
}
```

Note: The function abs(n) returns the absolute value of the parameter n.

144.2.1.5 Control Parser state diagram

The OLT and ONU shall implement the Control Parser state diagram shown in Figure 144-8.

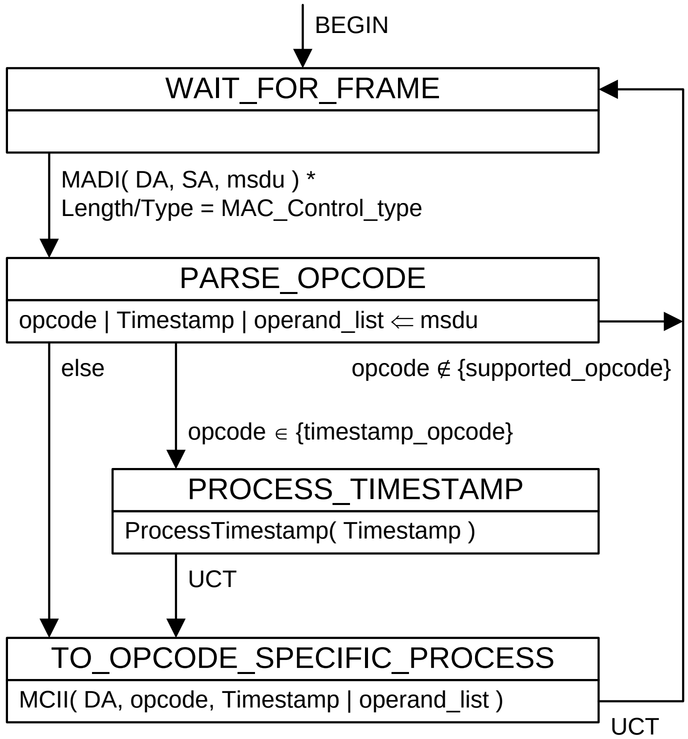

Figure 144-8 – Control Parser state diagram

144.2.1.6 Control Multiplexer state diagram

The OLT and ONU shall implement the Control Multiplexer state diagram shown in Figure 144-9.

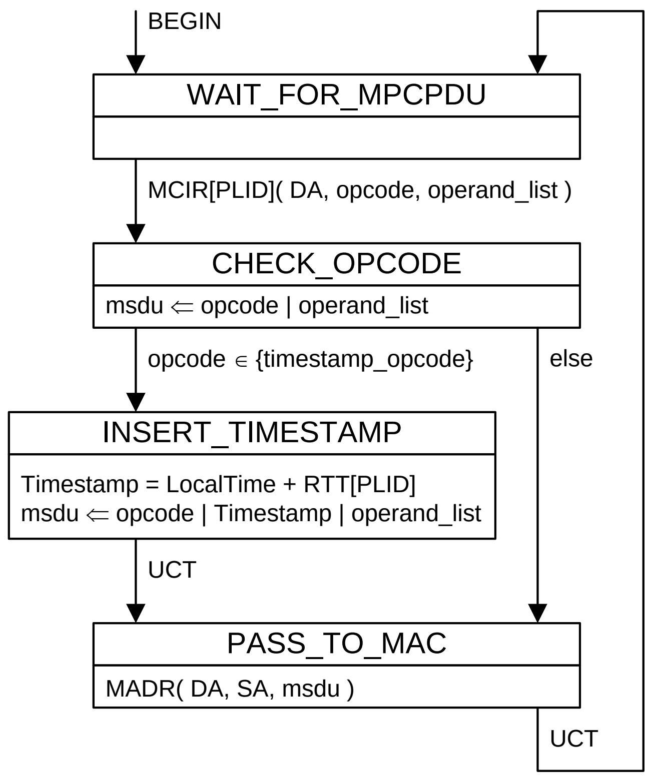

Figure 144-9 – Control Multiplexor state diagram

144.3 Multipoint Control Protocol (MPCP)

144.3.1 Principles of Multipoint Control Protocol

<subclause text to be supplied later>

144.3.1.1 Ranging and timing process

<subclause text to be supplied later>

144.3.1.2 Delay variability requirements

The MPCP protocol relies on strict timing based on distribution of timestamps. A compliant implementation needs to guarantee a constant delay through the MAC and PHY in order to maintain the correctness of the timestamping mechanism. The actual delay is implementation dependent; however, a complying implementation shall maintain a delay variation of no more than <TBD EQs> through the MAC.

144.3.2 Logical Link Identifier (LLID) Types

144.3.2.1 Physical Layer ID (PLID)

The Physical Layer ID (PLID) carries traffic flows critical to Nx25G-EPON operation, such as TDM-based medium access by the ONUs. All multipoint control protocol data units (MPCPDUs) are transported using the PLID. A successful ONU discovery and registration process, described in 144.4.2, results in the assignment of a single unique PLID value to the ONU.

144.3.2.2 Management Link ID (MLID)

Management Link ID (MLID) carries management traffic flows, such as OAMPDUs (see 57.4). Each ONU is assigned a single MLID value as part of the ONU Discovery and Registration process, described in 144.4.2.

144.3.2.3 User Link ID (ULID)

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 ONUs using an appropriate management protocol outside the scope of this standard. ULID values need not have a one-to-one binding of OLT MAC to an ONU MAC. An ULID that binds a single OLT MAC to multiple MACs in different ONUs represents a multicast ULID.

144.3.2.4 Group Link ID (GLID)

Group Link ID (GLID) is a special class of LLIDs that enable consolidation of multiple LLIDs into arbitrary groups. For example, all LLIDs for a specific subscriber hosted on an ONU servicing numerous subscribers could be grouped together into a single GLID. In another example, all LLIDs supporting a specific traffic class (e.g., best-effort traffic) on a multi-subscriber ONU could be grouped together. GLID values are used only for bandwidth granting and reporting purposes. The actual transmission is identified by either a PLID, an MLID, or a ULID value.

144.3.3 Allocation of LLID values

Table 144-x shows the allocation of LLID values.

Table 144-x – Allocation of LLID values

LLID Value	Designation	Description
0x00-00	ESC_PLID	A reserved PLID value indicating an empty EnvAlloc[n] field in a GATE MPPDU. ESC_PLID is also used in MCRS_CTRL.request primitive to mark the end of upstream burst.
0x00-01	DISC_PLID	PLID value used for discovery of unregistered ONUs. An unregistered ONU shall accept only the envelopes with DISC_PLID value in the LLID field. Registered ONUs shall ignore the envelopes with DISC_PLID value in the LLID field.
0x00-02	BCAST_PLID	PLID value reserved for MPCPDU broadcast. Every registered ONU shall accept envelopes with BCAST_PLID value in the LLID field. Unregistered ONUs shall ignore the envelopes with BCAST_PLID value in the LLID field.
0x00-03	BCAST_MLID	MLID value reserved for broadcast of management frames (OAMPDUs). Every registered ONU shall accept envelopes with BCAST_MLID value in the LLID field. Unregistered ONUs shall ignore the envelopes with BCAST_MLID value in the LLID field.

0x00-04 to 0x0F-FF	Reserved	Reserved values shall not be allocated.
0x10-00 to 0xFF-FE	Available	The range of LLID values available for allocation to PLID, MLID, ULID, or GLID. The values may be allocated to form unicast, multicast, or broadcast connections. LLID allocation policy is outside the scope of this standard.
0xFF-FF	BCAST_ULID	ULID value reserved for broadcast of user data to all ONUs connected to the given OLT port. Every registered ONU shall accept envelopes with BCAST_ULID value in the LLID field.

All unregistered ONUs shall only accept envelopes with DISC_PLID values. Upon successful registration, an ONU shall no longer accept envelopes with DISC_PLID. Instead, a registered ONU shall accept all envelopes that contain any of the following LLID values:

- The specific PLID value assigned to this ONU during registration;
- The specific MLID value assigned to this ONU during registration
- Broadcast PLID (BCAST_PLID)
- Broadcast MLID (BCAST_MLID)
- Broadcast ULID (BCAST_ULID)

After registration, an ONU may also be configured to use multiple ULID values via management. The method of provisioning these additional ULID values is outside the scope of this standard.

144.3.4 MPCPDU structure and encoding

The MPCPDU structure is shown in Figure 144-30, and is further defined as follows:

a) Destination Address (DA): The DA in MPCPDU is the MAC Control Multicast address as specified in the annexes to Clause 31, or the individual MAC address associated with the PLID to which the MPCPDU is destined.

b) Source Address (SA): The SA in MPCPDU is the individual MAC address associated with the PLID through which the MPCPDU is transmitted. For MPCPDUs originating at the OLT end, this can be the address any of the individual MACs. These MACs may all share a single unicast address, as explained in 144.6.2.

c) Length/Type: The Length/Type in MPCPDUs carries the MAC_Control_Type field value as specified in 31.4.1.3.

d) Opcode: The opcode identifies the specific MPCPDU being encapsulated. Values are defined in Table 31A–1.

e) Timestamp: The timestamp field conveys the content of the MPCP time counter (see *LocalTime* variable in 144.3.2.2) at the time of transmission of the MPCPDUs. This field is 32 bits long and counts time in the units of EQT.

f) Data/Reserved/PAD: These 40 octets are used for the payload of the MPCPDUs. When not used they are filled with zeros on transmission, and ignored on reception.

g) FCS. This field is the Frame Check Sequence, typically generated by the MAC.

Field	Octets
Destination Address	6
Source Address	6
Length/Type = 0x88-08	2
Opcode	2
Timestamp	4
Data/Reserved/Pad	40
FCS	4

Figure 144–30—Generic MPCPDU

Fields within a frame are transmitted from top to bottom. Octets within each field are transmitted from least significant to most significant. Bits within each octet are transmitted from LSB to MSB.

144.3.4.1 SYNC_PATTERN description

The SYNC_PATTERN MPCPDU is an instantiation of the Generic MPCPDU, and is further defined as follows:

a) Opcode. The opcode for the SYNC_PATTERN MPCPDU is 0x00-18.
b) PatternInfo: This is a 16-bit field, with individual bits defined per SpInfo field value.

Table 144–7—PatternInfo field value

Bit(s)	Field Name	Meaning
0-1	Index	Indicates the index of the Sync Pattern element being configured by the OLT. Valid range for the Index is 0 to *Count-1*.
2	Reserved	Ignored on reception
3-4	Count	Indicates the number of Sync Pattern elements in a burst. The valid values are 2 or 3.
5-6	Reserved	Ignored on reception
7	Balanced	Indicates whether the given Sync Pattern element is to be balanced or not: 0 – Sync Patterns is to remain unbalanced, i.e., Sync Pattern value is repeated unchanged 1 – Sync Patterns is to be balanced, i.e., each 257-bit block of Sync Pattern element (starting with the second block) is an inversion of its preceding block.
8-14	Reserved	Ignored on reception

15	Value, bit 0	Carries the 1st (index 0) bit of the Sync Pattern value.

c) Value: This is a 32-octet field, containing right-justified bits 1 through 256 of the Sync Pattern element (SP_1, SP_2, or (if present) SP_3), where bit 0 of the Sync Pattern is carried in the *PatternInfo* field. The allocation of remaining 256 bits in the *Value* field is shown in Sync Pattern placement in .

Table 144–8—Sync Pattern placement in *Value* field

Octet	Value (binary)
0	SP<8:1>
...	...
30	SP<248:241>
31	SP<256:249>

d) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored at reception. The size of this field is fixed and equal to 6 octets.

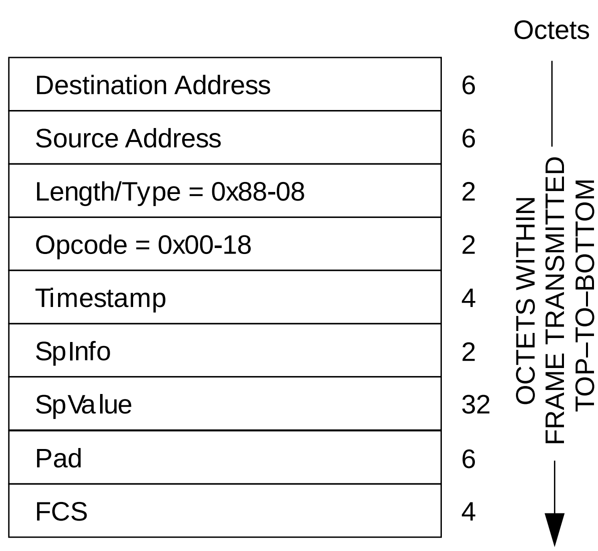

Figure 144–37—SYNC_PATTERN MPCPDU

144.3.4.2 DISCOVERY description

The DISCOVERY MPCPDU is an instantiation of the Generic MPCPDU and shall be as shown in Figure 144-36 with details defined as follows:

a) Opcode. The opcode for the DISCOVERY MPCPDU is 0x00-17.

b) Channel Assignment: This 8-bit flag register, where bits 0 and 1 contain a bitmap representing the wavelength channel(s) on which to transmit on during the assigned transmission slot. Bits 2-7 are reserved.

c) Start Time: This 32-bit unsigned integer value represents the start time of the transmission grant, expressed in the units of EQT. The start time is compared to the local clock, to correlate the start of the discovery grant.

d) Discovery Grant Length: This 22-bit unsigned field represents the length of the discovery grant, expressed in the units of EQ. 2 bits in the 24-bit field are reserved

e) ONU RSSI Min. This is 16-bit unsigned integer field, representing the minimum RSSI threshold value for ONUs, with the LSB equal to 0.1 uW, covering the range of 0 to 6.5535 mW (~ -40 to +8.2 dBm).

f) ONU RSSI Max. This is 16-bit unsigned integer field, representing the maximum RSSI threshold value for ONUs, with the LSB equal to 0.1 uW, covering the range of 0 to 6.5535 mW (~ -40 to +8.2 dBm).

g) Discovery Information. This is a 16-bit flag register. Discovery Information Fields presents the internal structure of the Discovery Information flag field.

h) SP1Length: This is an 16-bit field, value-encoded to indicate the number of times SP_1 is repeated when used during the Discovery Window.

i) SP2Length: This is an 16-bit field, value-encoded to indicate the number of times SP_2 is repeated when used during the Discovery Window.

j) SP3Length: This is an 16-bit field, value-encoded to indicate the number of times SP_3 is repeated when used during the Discovery Window.

k) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored at reception. The size of this field is fixed and equal to 20.

Table 144–6—Discovery Information Field

Bit	Flag field	Values
0	Reserved	Ignored on Reception
1	OLT is 10G upstream capable	0 – OLT does not support 10 Gb/s reception 1 – OLT supports 10 Gb/s reception
2	OLT is 25G upstream capable	0 – OLT does not support 25 Gb/s reception 1 – OLT supports 25 Gb/s reception
3-4	Reserved	Ignored on Reception
5	OLT is opening 10G Discovery Window	0 – OLT cannot receive 10 Gb/s data in this window 1 – OLT can receive 10 Gb/s data in this window
6	OLT is opening 25G Discovery Window	0 – OLT cannot receive 25 Gb/s data in this window 1 – OLT can receive 25 Gb/s data in this window
7-15	Reserved	Ignored on Reception

k)

Editor's Note (to be removed prior to publication): Motion #9 from 2019/03 meeting states: "In order to extend OLT burst receiver dynamic range, move to extend the discovery message shown in umeda_3ca_1b_0318.pdf pages 7 and 8 to support ONUs with different RX_RSSI to be registered in different time slots. Align the table with new bit positions in draft as amended in this meeting". However, both slides 7 and 8 from the referenced deck show different changes to Discovery Information field with no way to reconcile both changes in a single message format. Clarification via comment is needed.

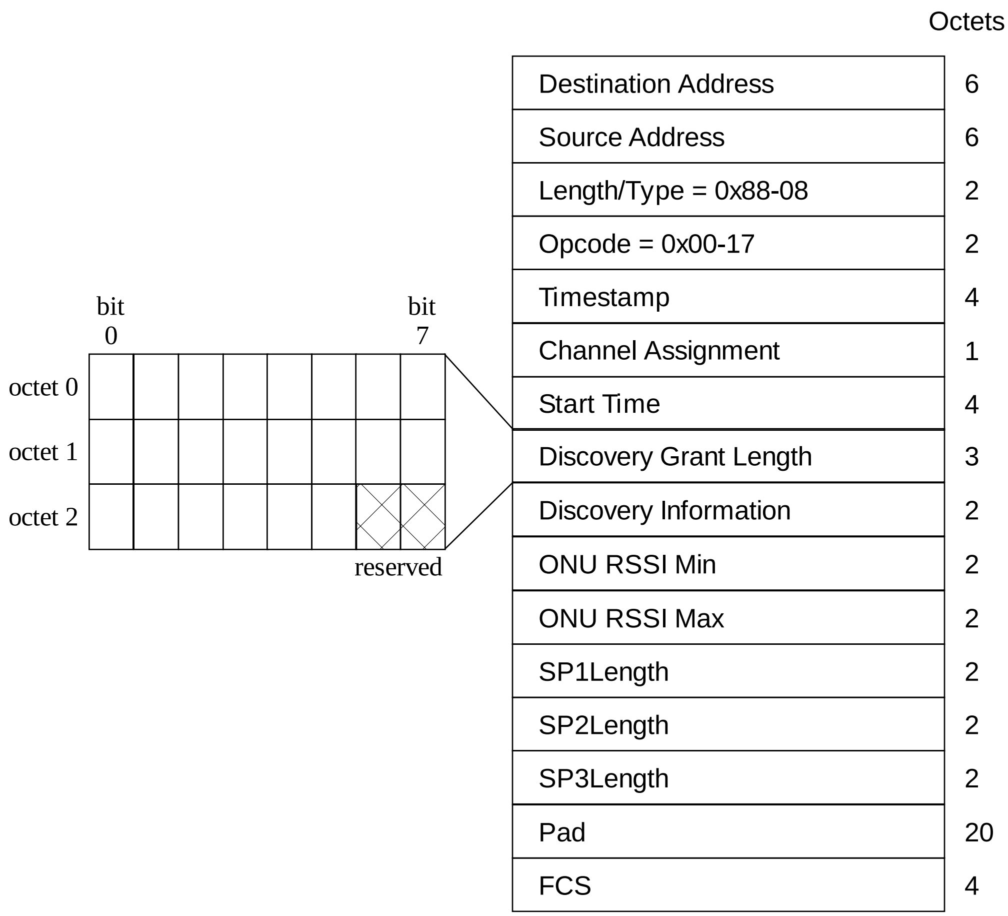

Figure 144–36—DISCOVERY MPCPDU

144.3.4.3 REGISTER_REQ description

The REGISTER_REQ MPCPDU is an instantiation of the Generic MPCPDU and shall be as shown in **Error! Reference source not found.** with details defined as follows:

a) Opcode. The opcode for the REGISTER_REQ MPCPDU is 0x00-14.
b) Flags. This is an 8 bit flag register that indicates special requirements for the registration, as presented in REGISTER_REQ MPCPDU Flags field.

Table 144–2—REGISTER_REQ MPCPDU Flags field

Value	Indication	Comment
0	Reserved	Ignored on reception.
1	Register	Registration attempt for ONU.
2	Reserved	Ignored on reception.

3	Deregister	This is a request to deregister the ONU. Subsequently, the MAC is deallocated and the LLID may be reused.
4–255	Reserved	Ignored on reception.

b)

c) Pending Envelopes. This is an unsigned 8 bit value signifying the maximum number of future grants the ONU is capable of buffering. The OLT should not grant the ONU more than this maximum number of *Pending Envelopes* vectors comprised of {llid, envlength, force_report, fragmentation} into the future.

d) Discovery Information. This is a 16 bit flag register. Discovery Information field presents the structure of the Discovery Information flag.

Table 144–3—Discovery Information field

Bit	Flag field	Values
0	Reserved	Ignored on Reception
1	ONU is 10G upstream capable	0 – ONU transmitter is not capable of 10 Gb/s 1 – ONU transmitter is capable of 10 Gb/s
2	ONU is 25G upstream capable	0 – ONU transmitter is not capable of 25 Gb/s 1 – ONU transmitter is capable of 25 Gb/s
3-4	Reserved	Ignored on Reception
5	10G registration attempt	0 - 10 Gb/s registration is not attempted 1 - 10 Gb/s registration is attempted
6	25G registration attempt	0 - 25 Gb/s registration is not attempted 1 - 25 Gb/s registration is attempted
7-15	Reserved	Ignored on Reception

d)

e) Laser On Time. This field is 1 octet long and carries the Laser On Time characteristic for the given ONU transmitter. The value is expressed in the units of EQ.

f) Laser Off Time. This field is 1 octet long and carries the Laser Off Time characteristic for the given ONU transmitter. The value is expressed in the units of EQ.

g) Pad/Reserved. This field is transmitted as zeroes. The size of this field is fixed and equal to 34 octets.

The REGISTER_REQ MPCPDU is generated by a MAC Control instance mapped to an undiscovered ONU, and as such shall be marked with a broadcast type of LLID (see TBD).

	Octets
Destination Address	6
Source Address	6
Length/Type = 0x88-08	2
Opcode = 0x00-14	2
Timestamp	4
Flags	1
Pending Envelopes	1
Discovery Information	2
Laser On Time	1
Laser Off Time	1
Pad	34
FCS	4

Figure 144–33—REGISTER_REQ MPCPDU

144.3.4.4 REGISTER description

The REGISTER MPCPDU is an instantiation of the Generic MPCPDU and shall be as shown in **Error! Reference source not found.** with details defined as follows:

a) DA. The destination address used shall be an individual MAC address.
b) Opcode. The opcode for the REGISTER MPCPDU is 0x00-15.
c) Assigned Port (PLID). This field holds a 16 bit unsigned value reflecting the Physical LLID (see 143.2.1.1) of the port assigned following registration.
d) Assigned Port (MLID). This field holds a 16 bit unsigned value reflecting the Management LLID (see 143.2.1.2) of the port assigned following registration.
e) Flags. this is an 8 bit flag register that indicates special requirements for the registration, as presented in REGISTER MPCPDU Flags field.

Table 144–4—REGISTER MPCPDU Flags field

Value	Indication	Comment
0	Reserved	Ignored on reception.
1	Reregister	The ONU is explicitly asked to re-register.
2	Deregister	This is a request to deallocate the port and free the LLID. Subsequently, the MAC is deallocated.

3	Ack	The requested registration is successful.
4	Nack	The requested registration attempt is denied by the MAC Control Client.
5–255	Reserved	Ignored on reception.

e)

f) Echoed Pending Envelopes. This is an unsigned 8-bit value signifying the number of future grants the ONU may buffer before activating. The OLT should not grant the ONU more than this number of grants into the future.

g) SP1Length: This is an 16-bit field, value-encoded to indicate the number of times SP_1 is repeated when used outside the Discovery Window, i.e., during the normal granting operation.

h) SP2Length: This is an 16-bit field, value-encoded to indicate the number of times SP_2 is repeated when used outside the Discovery Window, i.e., during the normal granting operation.

i) SP3Length: This is an 16-bit field, value-encoded to indicate the number of times SP_3 is repeated when used outside the Discovery Window, i.e., during the normal granting operation.

j) Pad/Reserved. This field is transmitted as zeroes. The size of this field is fixed and equal to 28.

The REGISTER MPCPDU is generated by a MAC Control instance mapped to all ONUs and such frame is marked by the broadcast LLID (see TBD).

	Octets
Destination Address	6
Source Address	6
Length/Type = 0x88-08	2
Opcode = 0x00-15	2
Timestamp	4
Assigned Port (PLID)	2
Assigned Port (MLID)	2
Flags	1
Echo Pending Envelopes	1
SP1Length	2
SP2Length	2
SP3Length	2
Pad	28
FCS	4

Figure 144–34—REGISTER MPCPDU

144.3.4.5 REGISTER_ACK description

The REGISTER_ACK MPCPDU is an instantiation of the Generic MPCPDU and shall be as shown in **Error! Reference source not found.** with details defined as follows:

a) Opcode. The opcode for the REGISTER_ACK MPCPDU is 0x00-16.

b) Flags. This is an 8-bit flag register that indicates special requirements for the registration, as presented in REGISTER_ACK MPCPDU Flags fields.

Table 144–5—REGISTER_ACK MPCPDU Flags fields

Value	Indication	Comment
0	Nack	The requested registration attempt is denied by the MAC Control Client.
1	Ack	The registration process is successfully acknowledged.
2–255	Reserved	Ignored on reception.

b)

c) Echoed Assigned Port (PLID). This field holds a 16-bit unsigned value reflecting the Physical LLID (see 143.2.1.1) for the port assigned following registration.

d) Echoed Assigned Port (MLID). This field holds a 16-bit unsigned value reflecting the Management LLID (see 143.2.1.2) for the port assigned following registration.

e) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored at reception. The size of this field is fixed and equal to 35.

The REGISTER_ACK MPCPDU is generated by a MAC Control instance mapped to an ONU, and as such is marked with the PLID of the originating ONU.

	Octets
Destination Address	6
Source Address	6
Length/Type = 0x88-08	2
Opcode = 0x00-16	2
Timestamp	4
Flags	1
Echo Assigned Port (PLID)	2
Echo Assigned Port (MLID)	2
Pad	35
FCS	4

Figure 144–35—REGISTER_ACK MPCPDU

144.3.4.6 GATE description

The purpose of GATE message is to grant transmission windows to ONUs for upstream transmission on the shared medium. A single grant to an ONU may consist of multiple GATE MPCPDUs, all having the same *Grant Start Time* value. Up to seven envelope allocations can be included in a single GATE MPCPDU (see **Error! Reference source not found.**). Only envelope allocations with non-zero value within the LLID field are processed by the ONU. A GATE MPCPDU with no *EnvAlloc* (i.e., all LLID fields equal to zero) is valid and may be used as an MPCP keep alive from the OLT to the ONU.

The GATE MPCPDU is an instantiation of the Generic MPCPDU and shall be as shown in **Error! Reference source not found.** with details defined as follows:

a) Opcode. The opcode for the GATE MPCPDU is 0x00-12.
b) Channel Assignment: This 8-bit flag register, where bits 0-1 contain a bitmap representing the upstream channel(s) granted to the ONU. Bits 2-7 are reserved. Channel Assignment flags shows the mapping between individual bits and upstream channels. When multiple channels are assigned, a transmission on each channel shall start at Grant Start Time and shall have the length as necessary to transmit all allocated envelopes together with the associated optical and FEC overhead.

Table 144–1—Channel Assignment flags

Bit	Channel field	Values
0	Upstream channel 0	0 – do not use upstream channel 0 for transmission 1 – use upstream channel 0 for transmission
1	Upstream channel 1	0 – do not use upstream channel 1 for transmission 1 – use upstream channel 1 for transmission
2-7	Reserved	set to 0

b)
c) Grant Start Time: This 32-bit unsigned integer value represents the start time of the transmission window (burst), expressed in the units of EQ. The start time is compared to the local clock, to correlate the start of the grant.
d) EnvAlloc is a 40-bit structure that describes the transmission window assigned to a specific LLID. Up to 7 envelope allocations may be included into a single GATE MPCPDU. The EnvAlloc structure consists of the following sub-fields:
   1) LLID: This 16-bit unsigned integer value represents the logical link that is being allocated a transmission slot. The value of 0 in this field signifies an empty *EnvAlloc* structure that shall be skipped over by the parser.
   2) EnvLength: This 22-bit unsigned value represents the length of the envelope assigned to this specific LLID. The length of the envelope is expressed in the units of EQ. The *EnvLength* represents the number of EQs to be sourced from a corresponding (virtual) MAC, less one EQ reserved for the Envelope Header. The *EnvLength* does not include any transmission overhead components.
   3) Fragmentation (F): This flag informs the ONU whether it is allowed to fragment new frames transmitted on the given LLID. If a frame fragment remains queued in this LLID since previous envelope transmission, this fragment is transmitted first, regardless of the value of the *Fragmentation* flag.
   4) Forced Report (FR): When the respective bit is set to 0, no action is required from the ONU. When the respective bit is set to 1, the ONU shall report the total length of the frames (including IPG and preamble), queued for transmission on this specific LLID.

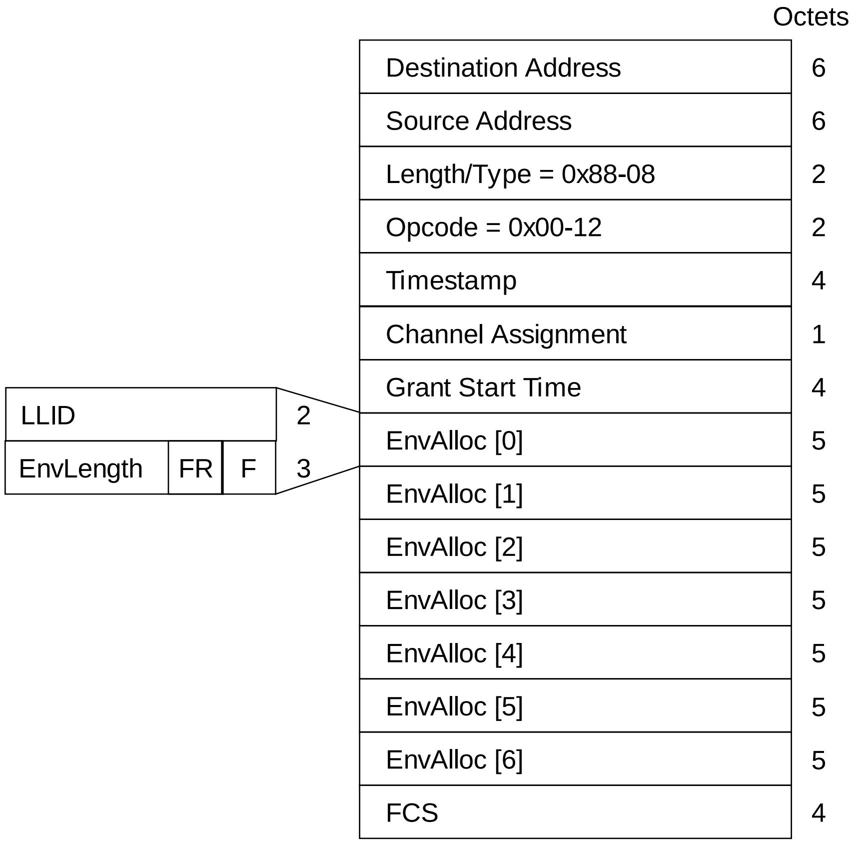

Figure 144–31—GATE MPCPDU

144.3.4.7 REPORT description

REPORT MPCPDU has several functionalities, i.e.:

— The time stamp carried in the *Timestamp* field in each REPORT MPCPDU is used for round trip time (RTT) calculation,

— ONUs use the REPORT MPCPDUs to indicate the amount of data queued in individual LLIDs, and

— REPORT MPCPDUs are also used as keep–alives from ONU to the OLT.

The REPORT MPCPDU is an instantiation of the Generic MPCPDU and shall be as shown in **Error! Reference source not found.** with details defined as follows:

a) Opcode. The opcode for the REPORT MPCPDU is 0x00-13.
b) NonEmptyQueues: The number of LLIDs in the ONU with non-empty queues.
c) LLIDstatus is a 40-bit structure that describes the occupancy of the queue assigned to a specific LLID. The occupancy of 7 queues may be included into a single REPORT MPCPDU. The LLIDstatus structure consists of the following sub-fields:
   1) LLID: This 16-bit unsigned integer value represents the logical link that is reporting the queue occupancy.
   2) QueueLength: This 24-bit unsigned value represents the occupancy of the queue associated with the given logical link (as indicated by the value of *LLID* sub-field).
d) Pad/Reserved. This field is transmitted as zeroes. The size of this field is fixed and equal to 4 octets.

The REPORT MPCPDU is generated by a MAC Control instance mapped to an ONU, and as such is marked with the PLID of the originating ONU.

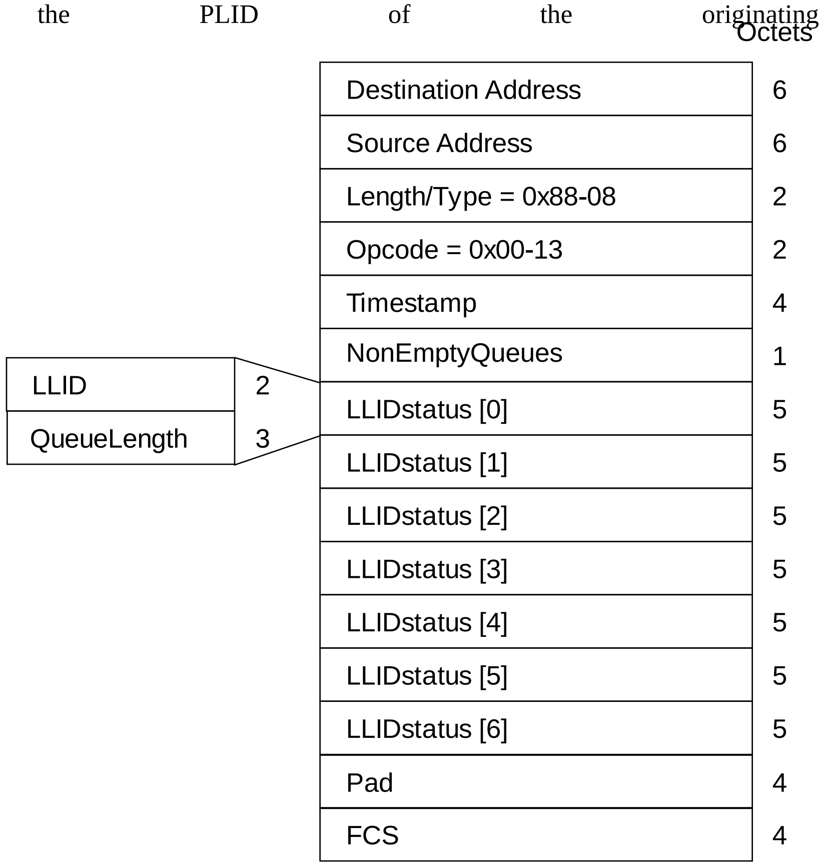

Figure 144–32—REPORT MPCPDU

144.3.5 Discovery process

Discovery is the process whereby newly connected or off-line ONUs are provided access to the PON. The process is driven by the OLT, which periodically makes available Discovery Windows during which off-line ONUs are given the opportunity to make themselves known to the OLT. The periodicity of these windows is unspecified. The OLT signifies that a discovery period is occurring by broadcasting a DISCOVERY MPCPDU, which includes the starting time and length of the Discovery Window, along with the *Discovery Information* field, as defined in 77.3.6.1. With the appropriate settings of individual flags contained in this 16 bit wide field, the OLT notifies all the ONUs about its upstream and downstream channel transmission capabilities. Note that the OLT may simultaneously support more than one data rate in the given transmission direction.

Off-line ONUs, upon receiving a DISCOVERY MPCPDU, wait for the period to begin and then transmit a REGISTER_REQ MPCPDU to the OLT. Discovery Windows are unique in that they are the only times when multiple ONUs can access the PON simultaneously, and transmission overlap can occur. In order to reduce transmission overlaps, a contention algorithm is used by all ONUs. Measures are taken to reduce the probability for overlaps by artificially simulating a random distribution of distances from the OLT. Each ONU waits a random amount of time before transmitting the REGISTER_REQ MPCPDU that is shorter than the length of the Discovery Window. Note that multiple valid REGISTER_REQ MPCPDUs can be received by the OLT during a single Discovery Window. Included in the REGISTER_REQ MPCPDU is the ONU's

MAC address and number of maximum pending envelopes. Additionally, a registering ONU notifies the OLT of its transmission capabilities in the upstream and downstream channels by setting appropriately the flags in the Discovery Information field, as specified in 77.3.6.3.

Note that even though a compliant ONU is not prohibited from supporting more than one data rate in any transmission channel, it is expected that a single supported data rate for upstream and downstream channel is indicated in the Discovery Information field. Moreover, in order to assure maximum utilization of the upstream channel and to decrease the required size of the guard band between individual data bursts, the registering ONU notifies the OLT of the laser on/off times, by setting appropriate values in the Laser On Time and Laser Off Time fields, where both values are expressed in the units of EQ.

Editor's Note (to be removed prior to publication): need to review the use of EQ as the unit of time / size, and decide whether it is EQ, TQ, blocks, etc. in each and single case.

Upon receipt of a valid REGISTER_REQ MPCPDU, the OLT registers the ONU, allocating and assigning two new port identities (PLID and MLID), and bonding them to corresponding MACs in the OLT.

The next step in the process is for the OLT to transmit a REGISTER MPCPDU containing the PLID and MLID to the newly discovered ONU. The REGISTER MPCPDU also contains the OLT's required synchronization time. Moreover, the OLT echoes the maximum number of pending envelopes. The OLT also sends the target value of laser on time and laser off time, which may be different than laser on time and laser off time delivered by the ONU in the REGISTER_REQ MPCPDU.

The OLT at that time has enough information to schedule the ONU for access to the PON and transmits a standard GATE MPCPDU allowing the ONU to transmit a REGISTER_ACK MPCPDU. Upon receipt of the REGISTER_ACK MPCPDU, the discovery process for that ONU is complete, the ONU is registered and normal message traffic can begin. It is the responsibility of Layer Management to perform the MAC bonding, and start transmission from/to the newly registered ONU. The discovery message exchange is illustrated in **Error! Reference source not found.**.

There may exist situations when the OLT requires that an ONU go through the discovery sequence again and reregister. Similarly, there may be situations where an ONU needs to inform the OLT of its desire to deregister. The ONU can then reregister by going through the discovery sequence. For the OLT, the REGISTER MPCPDU may indicate a value, Reregister or Deregister, that if either is specified forces the receiving ONU into reregistering. For the ONU, the REGISTER_REQ MPCPDU contains the Deregister bit that signifies to the OLT that this ONU needs to be deregistered.

The Discovery process also includes announcement of the *SpValue* structure using the SYNC_PATTERN MPCPDU exchange between the OLT and the ONU. Two or three separate SYNC_PATTERN MPCPDUs are sent by the OLT, announcing the value of SP_1, SP_2, and optionally SP_3 portions of the FEC unprotected area in the head of the upstream burst (see <TBD reference to clause 143>). Repeat counts for SP_1, SP_2, and optionally SP_3 during the Discovery Window are announced within the DISCOVERY MPCPDU. Repeat counts for SP_1, SP_2, and optionally SP_3 outside of the Discovery Window (normal granting operation) are announced within the REGISTER MPCPDU. Combined, this allows the OLT to effectively configure the Sync Pattern structure and optimize it for the specific OLT receiver implementation.

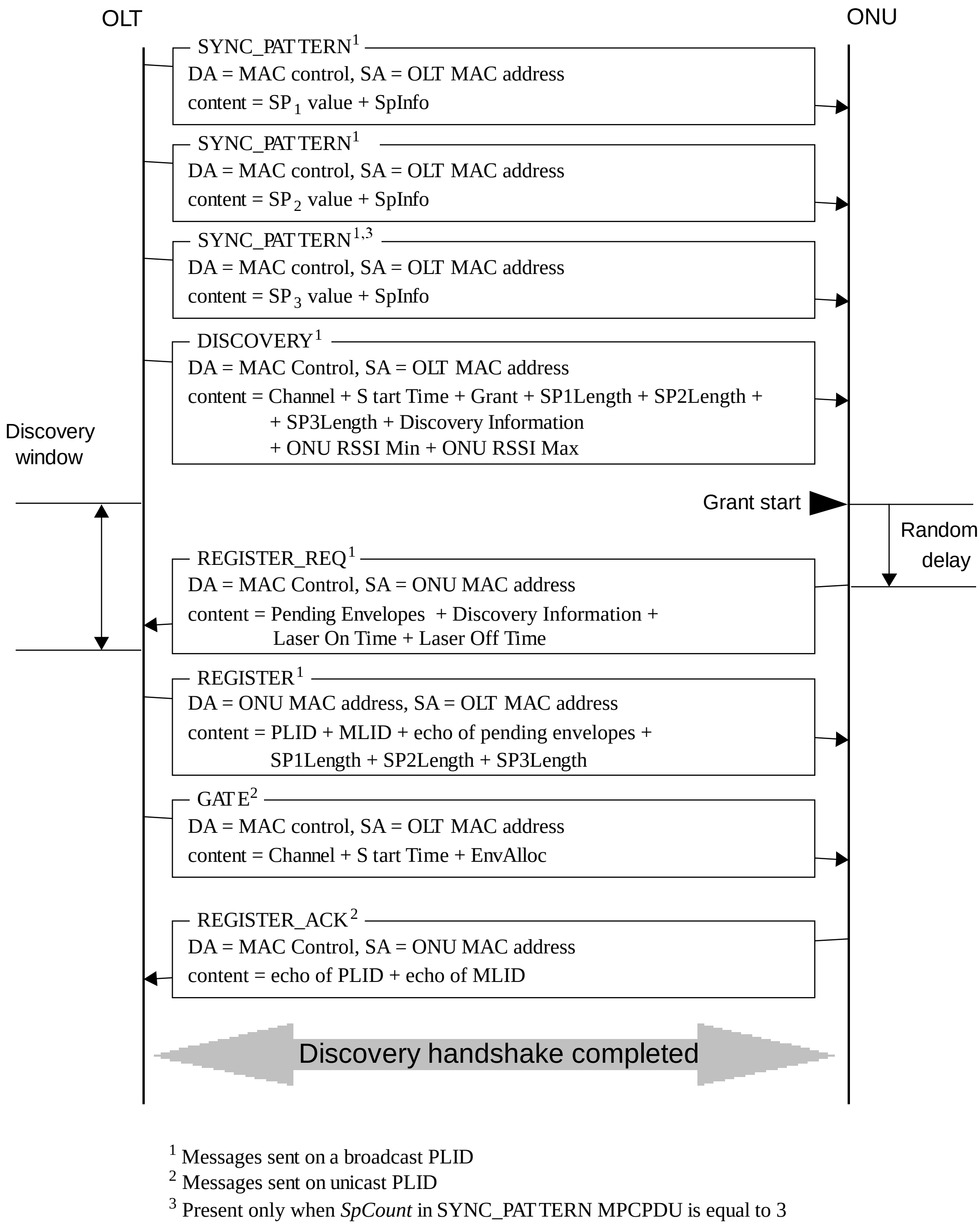

Figure 144–10—Discovery handshake message exchange

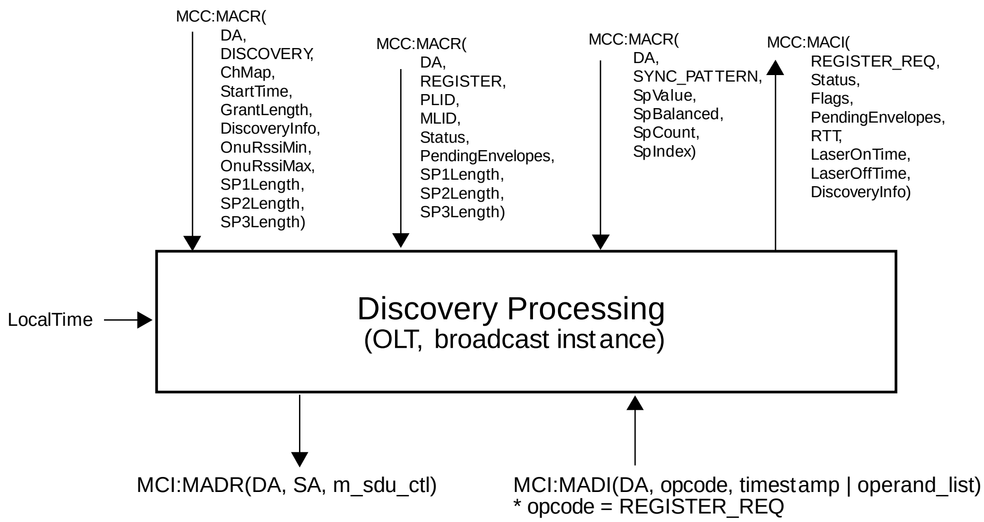

Figure 144–11—Discovery Processing service interfaces (OLT, broadcast instance)

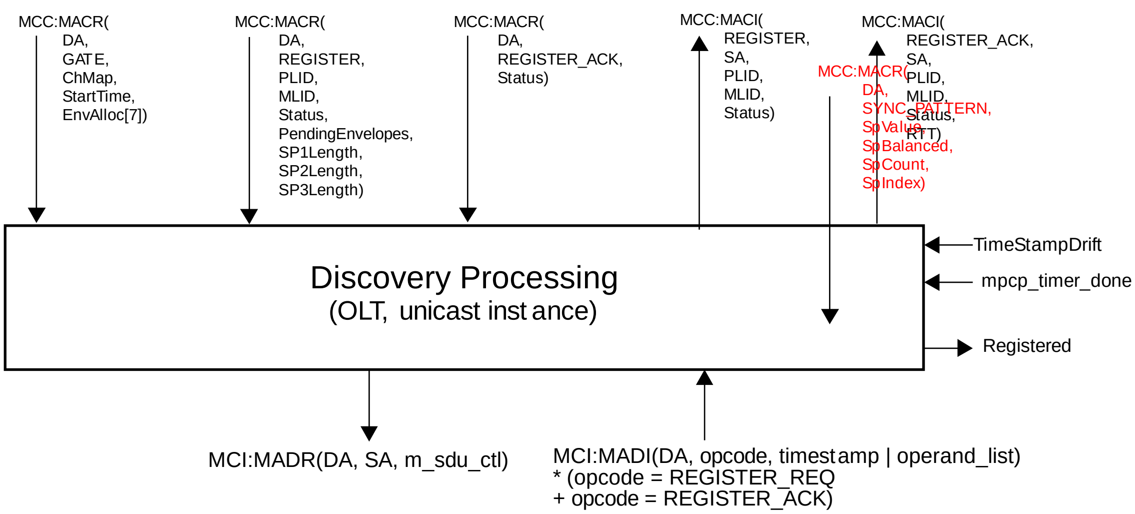

Figure 144–12—Discovery Processing service interfaces (OLT, unicast instance)

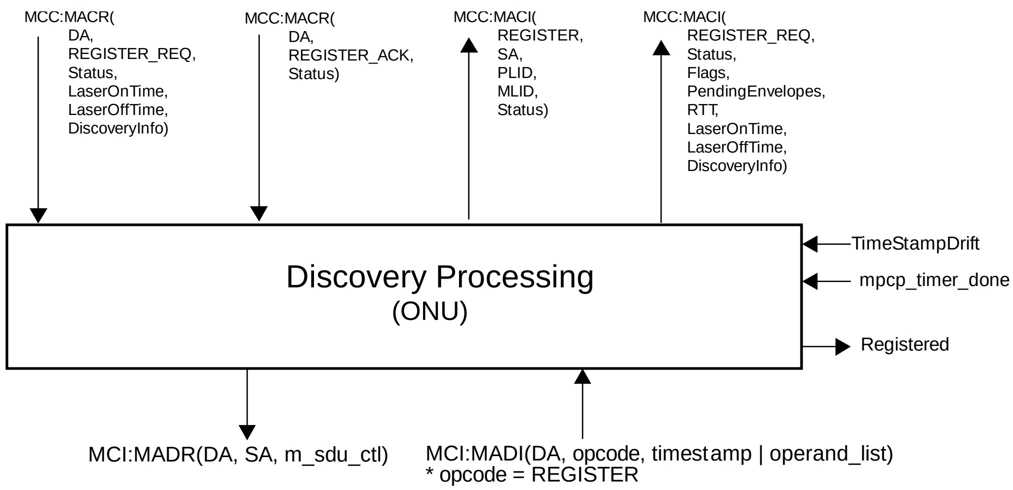

Figure 144–13—Discovery Processing service interfaces (ONU)

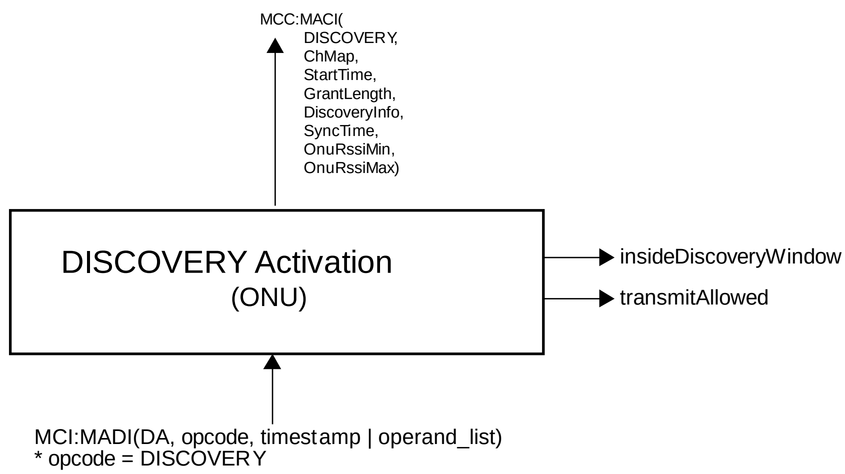

Figure 144–14—DISCOVERY Activation service interfaces (ONU)

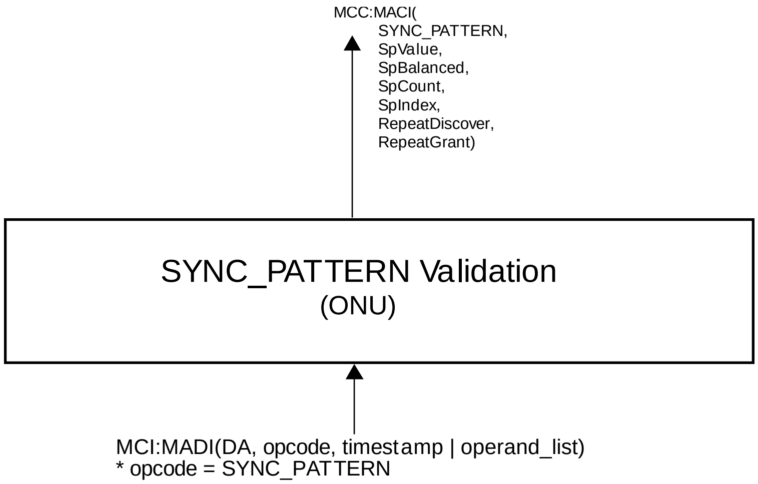

Figure 144–15—SYNC_PATTERN Validation service interfaces (ONU)

144.3.5.1 Constants

ACK_GATE_LIMIT

The maximum number of GATE MPCPDUs that the OLT issues to a registering ONU to provide an opportunity for REGISTER_ACK MPCPDU transmission.
TYPE: integer
VALUE: 8

DISCOVERY_MARGIN

This constant holds the extra margin that should be reserved at the end of a discovery grant to accommodate the largest possible round-trip time on a given ODN. The round-trip time also includes any internal delays in the OLT and ONU, such as FEC encoding and decoding delays. DISCOVERY_MARGIN is expressed in units of EQT.
TYPE: integer
VALUE: 80,078 (205 us default value)

REQ_LENGTH

This constant holds the envelope length sufficient to carry a single REGISTER_REQ MPCPDU. It is expressed in units of EQ.
TYPE: integer
VALUE: 10

144.3.5.2 Counters

GateCount

This counter counts the number of remaining GATE MPCPDUs to be issued to a registering ONU before the registration attempt deemed failed due to lack of acknowledgement (i.e., missing REGISTER_ACK MPCPDU).

LocalTime

This counter is defined in 144.3.2.2.

144.3.5.3 Variables

DeregistrationTrigger

TYPE: Boolean

This variable is set to true when at least one of multiple conditions for ONU deregistration becomes true. Otherwise, the variable is set to false. The DeregistrationTrigger is an alias for the following code:

```
DeregistrationTrigger =
   // 1) ONU MPCP is unresponsive
   MissedReportCount == MISSED_REPORT_LIMIT OR

   // 2) Timestamp drift exceeded the safe margin
   TimestampDrift == true OR

   // 3) ONU requested deregistration
   ( MCII(MsgRegisterAck) AND MsgRegisterAck.Flag = Deregister ) OR

   // 4) OLT MAC Control Client initiated ONU deregistration
   ( MCSR(MsgRegisterAck) AND MsgRegisterAck.Flag = Deregister )
```

GrantEndTime

TYPE: 32-bit unsigned

This variable holds the time at which the ONU grant ends. Failure of a REGISTER_ACK message from an ONU to arrive at the OLT before GrantEndTime for more than ACK_GATE_LIMIT times is a fatal error in the discovery process, and causes registration to fail for the specified ONU. The value of GrantEndTime is expressed in the units of EQT.

MaxDelay

TYPE: 32-bit unsigned

This variable indicates maximum delay the ONU can apply to REGISTER_REQ MPCPDU transmission while remaining within the allocated discovery grant. MaxDelay is expressed in units of EQT.

Registered

TYPE: Boolean

This variable holds the current registration status of a PLIDIt is set to true once the discovery process is complete and registration is acknowledged.

RegStart

TYPE: 32-bit unsigned

This variable indicates the ONU local time at which it REGISTER_REQ MPCPDU is to be transmitted. The RegStart is delayed from the discovery grant start time by a random amount to prevent persistent collisions of REGISTER_REQ MPCPDUs from multiple registering ONUs. RegStart is expressed in units of EQT.

SpIndex

TYPE: 2-bit unsigned

This variable indicates the index of the synchronization pattern announced by the OLT in the SYNC_PATTERN MPCPDU. The *SpIndex* variable takes values 0 or 1 in case when two synchronization patterns are used, or 0, 1, and 2, in case when three synchronization patterns are used. Details about individual synchronization pattern elements, their number, and meaning are covered in 142.2.2.2.

144.3.5.4 Functions

BurstLength(env_length)

This function takes the envelope length (or a total of multiple envelope lengths) and calculates the total length of the upstream burst, including the following overhead components:

a) The length of SP1 synchronization pattern (SP1Length)
b) The length of SP2 synchronization pattern (SP2Length)
c) The length of SP3 synchronization pattern (SP3Length), if it is used.
d) Rounding overhead due to 256b/257b line coding
e) The FEC Parity overhead
f) The length of burst terminating sequence, including the EBD and laser-off time

The result is converted into EQT and is rounded up to the next integer value.

Random(min_value, max_value)

This function returns a random value uniformly distributed in the range from min_value to the max_value, inclusive.

144.3.5.5 Messages

MsgBurstSync

A set of parameters (operand_list) carried in multiple SYNC_PATTERN MPCPDUs. Within the OLT Discovery Initiation process (see 144.4.3.6.1), the MsgBurstSync set is received from the MAC Control Client and is transmitted in 2 or 3 SYNC_PATTERN MPCPDUs, as determined by the MsgBurstSync.Count parameter. Within the ONU Registration process (see 144.4.3.6.4), the parameters received in multiple SYNC_PATTERN MPCPDUs are combined and passed to the MAC Control Client as a single MsgBurstSync set. The MsgBurstSync set includes the following parameters:

Count:	The number of synchronization patterns that ONU is instructed to generate during the discovery attempt. The allowed values are 2 or 3.
Balanced[Count]:	An array of Boolean values, where n^{th} element of the array indicates whether the n^{th} synchronization pattern should be balanced or not.
Value[Count]:	An array of 257-bit values, where n^{th} element of the array represents the n^{th} synchronization pattern.

MsgDiscovery

A set of parameters (operand_list) carried in DISCOVERY MPCPDU, as defined in 144.4.2.2.

MsgGate

A set of parameters (operand_list) carried in GATE MPCPDU, as defined in 144.4.2.6.

MsgRegsiter

A set of parameters (operand_list) carried in REGISTER MPCPDU, as defined in 144.4.2.4.

MsgRegisterAck
A set of parameters (operand_list) carried in REGISTER_ACK MPCPDU, as defined in 144.4.2.5.

MsgRegisterReq
A set of parameters (operand_list) carried in REGISTER_REQ MPCPDU, as defined in 144.4.2.3.

MsgSyncPattern
A set of parameters (operand_list) carried in SYNC_PATTERN MPCPDU, as defined in 144.4.2.1.

144.3.5.6 Discovery Initiation state diagram

The Discovery Process in the OLT shall implement a single instance the Discovery Initiation state diagram shown in Figure 144-6. This instance shall be associated with the DISC_PLID value, i.e., it only receives and generates MPCPDUs that are carries in envelopes with DISC_PLID value.

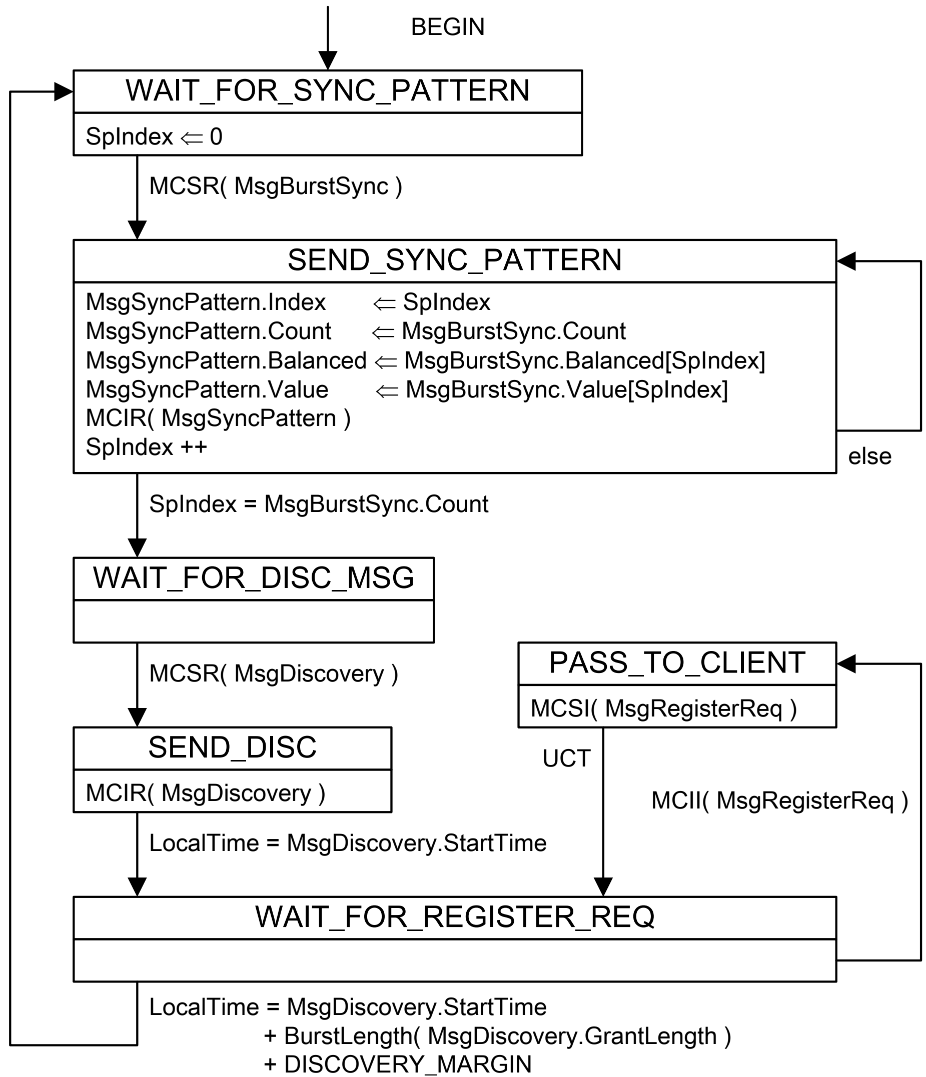

Figure 144-6 – OLT Discovery Initiation state diagram

144.3.5.7 Registration Completion state diagram

The Discovery Process in the OLT shall implement multiple instances of the Registration Completion state diagram shown in Figure 144-7. Each instance of the Registration Completion state diagram shall be associated with the unicast PLID being registered.

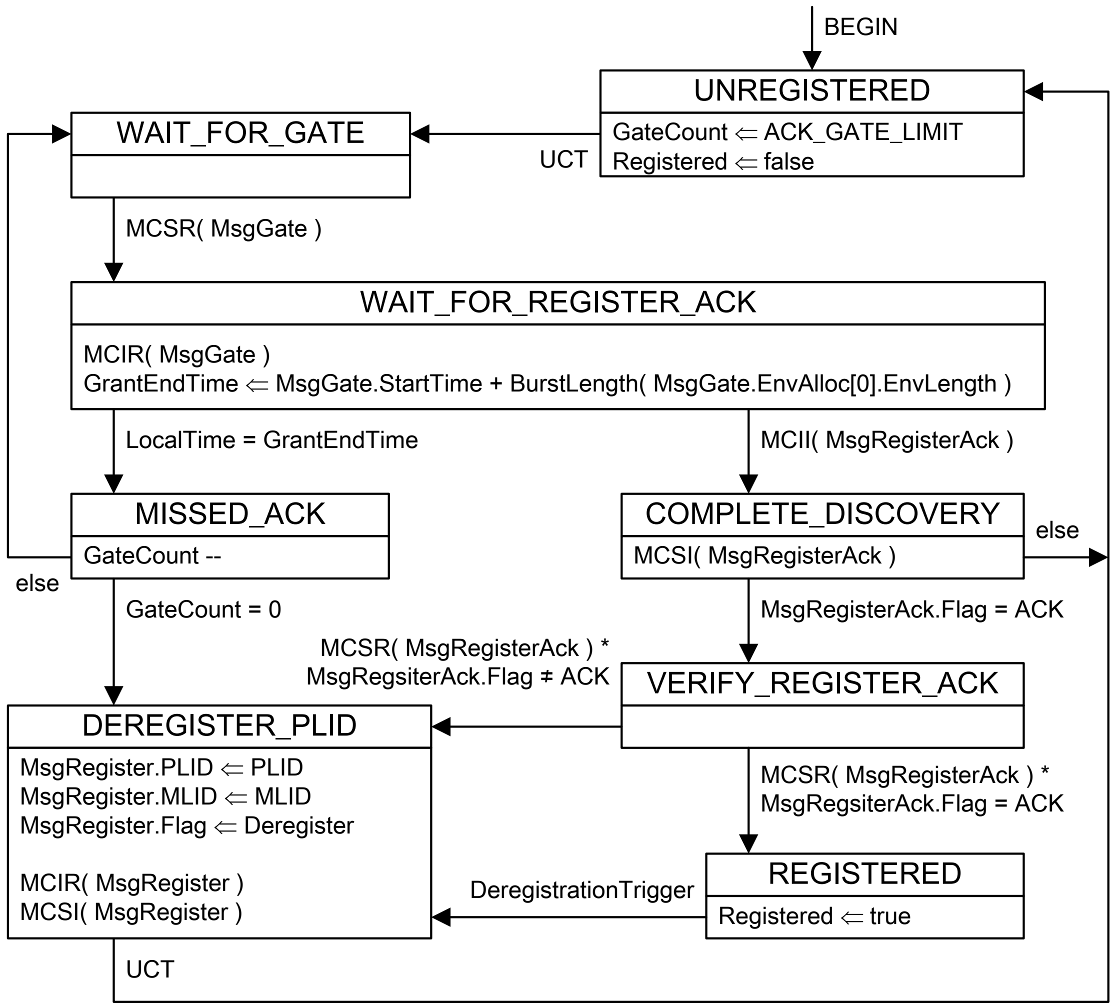

Figure 144-8 – OLT Registration Completion state diagram

144.3.5.8 ONU Registration state diagram

The Discovery Process in the ONU shall implement a single instance of the ONU Registration state diagram shown in Figure 144-x. This instance is associated with the DISC_PLID value when the Registered variable is equal to false, and it is associated with unicast PLID and BCAST_PLID values, when the Registered variable is equal to true.

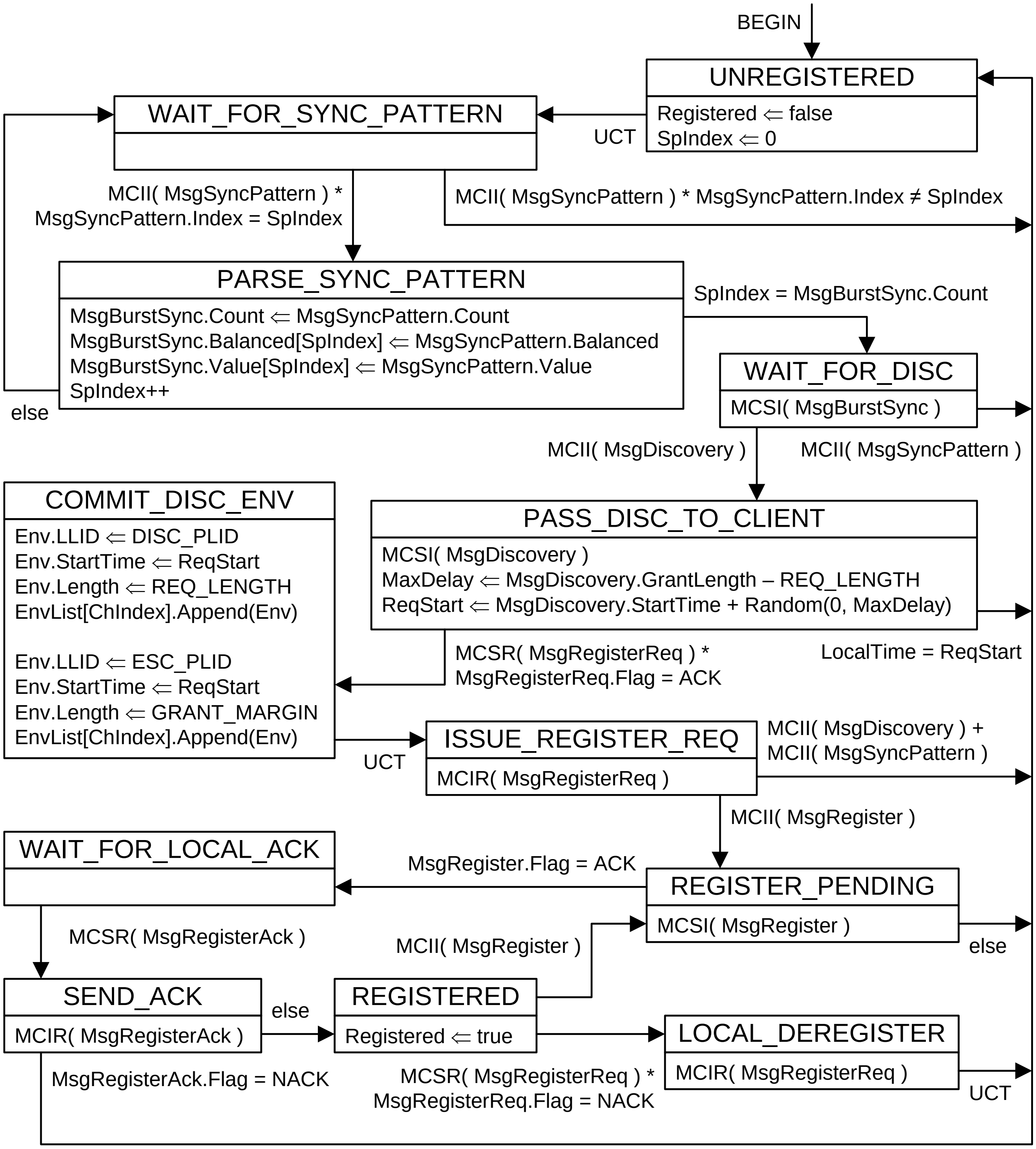

Figure 144-x – ONU Registration state diagram

144.3.6 Granting Process

<subclause introduction text to be supplied later>

144.3.6.1 Constants

MPCP_PROCESS_DLY

This constant represents the maximum time allowed for the ONU to complete MPCPDU processing. The value is expressed in the units of EQT.
Type: 32-bit unsigned
Value: 6,400 (16.384 µs)

GRANT_MARGIN

This constant represents the total time required for an ONU to terminate one burst and immediately initiate another burst. The constant includes the following burst overhead components:

a) The length of end-of-burst delimiter (EBD)
b) The length of SP1 synchronization pattern (SP1Length)
c) The length of SP2 synchronization pattern (SP2Length)
d) The length of SP3 synchronization pattern (SP3Length), if it is configured.
e) The FEC Parity overhead (see

All the above overhead components are represented in terms of 257-bit line coding blocks. The sum of these values S is converted into units of EQ as S×4.
Type: 22-bit unsigned integer
Value: Determined at the time of ONU discovery
NOTE: if ONU is scheduled separate grants whose start times are less than GRANT_MARGIN apart, the latter grant is discarded.

GATE_TIMEOUT

This constant represents the maximum allowed interval of time between two GATE messages generated by the OLT to the same ONU, expressed in units of EQT.
Type: 32 bit unsigned
Value: 19,531,250 (50 ms, default value)

144.3.6.2 Counters

LocalTime

This counter is defined in 144.3.2.2.

144.3.6.3 Variables

Back2BackEnv[]

TYPE: 2-element array of boolean values
A boolean that represents whether the next envelope is to be transmitted immediately upon completion of the previous envelope (if both envelopes belong to the same grant). The value is set to true upon activation of the first envelope in a grant and it is reset to false upon activation of the grant-terminating envelope (i.e., an envelope with LLID = ESC_PLID). Each element of the array is associated with the respective MCRS channel.

ChIndex

TYPE: 1-bit unsigned integer
The value of this variable indicates the channel the Envelope Descriptor is intended for, where the value of 0 corresponds to channel 0, value of 1 - channel 1, etc.

ChStatus

TYPE: 8-bit unsigned integer
The value of this variable represents a binary-encoded status of upstream channels at the ONU. Bit 0 corresponds to channel 0 and bit 1 corresponds to channel 1. Bits 2 through 7 are set to 0. The value of each bit has the following meaning:
1 = channel is enabled
0 = channel is disabled

Env
TYPE: structure
Env is a structure representing a single envelope descriptor. It includes the following fields:
LLID: LLID value of a an envelope descriptor
StartTime: Start time of given envelope. Within a single burst, all envelope descriptions have the same EnvStartTime value. The StartTime is expressed in units of EQT.
Length: The length of the envelope, including the envelope header. The Length value is expressed in units of EQ.

EnvIndex
TYPE: 16-bit unsigned integer
The value of this variable indicates the index of the Envelope Descriptor in the MsgEnvDescriptor message.

EnvList[]
TYPE: an array of lists (FIFO) containing envelope descriptors (see 144.x.x.x). Each element of the array is associated with the respective MCRS channel. Each EnvList[ch] list has several associated functions:
`EnvList[ch].Append( env )`: this function appends a new envelope description *env* to the end of the list;
`EnvList[ch].Clear()`: this function deletes all envelope descriptors from the list;
`EnvList[ch].IsEmpty()`: this function returns true if EnvList[ch] list has any envelopes descriptors, otherwise, false is returned;
`EnvList[ch].PeekHead()`: this function returns the first (the oldest) envelope descriptor without removing it from the list;
`EnvList[ch].RemoveHead()`: this function returns the first (the oldest) envelope descriptor and removes it from the list;

NextEnv
See the definition of Env variable above.

Registered
This variable is defined in 144.4.3.3

144.3.6.4 Functions

IsValid(llid)
This function returns true if the LLID value *llid* is active (i.e., is registered and is eligible to transmit data). Otherwise, false is returned.

144.3.6.5 Timers

GateTxTimer
The OLT is required to generate GATE MPCPDUs with a periodicity of less than

GATE_TIMEOUT. This timer counts down time remaining before a forced generation of a GATE message in the OLT.

144.3.6.6 Messages

MsgEnvDescriptor

A set of parameters (operand_list) representing multiple envelope descriptors for a given channel. In the OLT, MsgEnvDescriptor is generated by the MAC Control Client based on local traffic queue status and downstream frame scheduling policies. In the ONU, MsgEnvDescriptor is generated by the MAC Control Client based on envelope allocations (EnvAlloc[n]) received in GATE MPCPDUs. The MsgEnvDescriptor set includes the following parameters:

ChIndex:	a 1-bit integer indicating whether the following envelope descriptors are intended for channel 0 or channel 1.
EnvStartTime:	32-bit unsigned integer representing the start time of an envelope. This value is expressed in units of EQT.
EnvCount:	16-bit unsigned integer representing the number of envelope descriptors carried in the message.
EnvLLID[EnvCount]:	An array 16-bit elements, where n^{th} element of the array represents the LLID value for the n^{th} envelope descriptor.
EnvLength[EnvCount]:	An array of 22-bit elements, where n^{th} element of the array represents the envelope length for the n^{th} envelope descriptor.

MsgGate

This message is defined in 144.4.3.5.

144.3.6.7 Gate Generation state diagram

The OLT shall implement the Gate Generation state diagram as shown in Figure 144-24. A separate instance of the state diagram shall be implemented per each registered ONU (PLID).

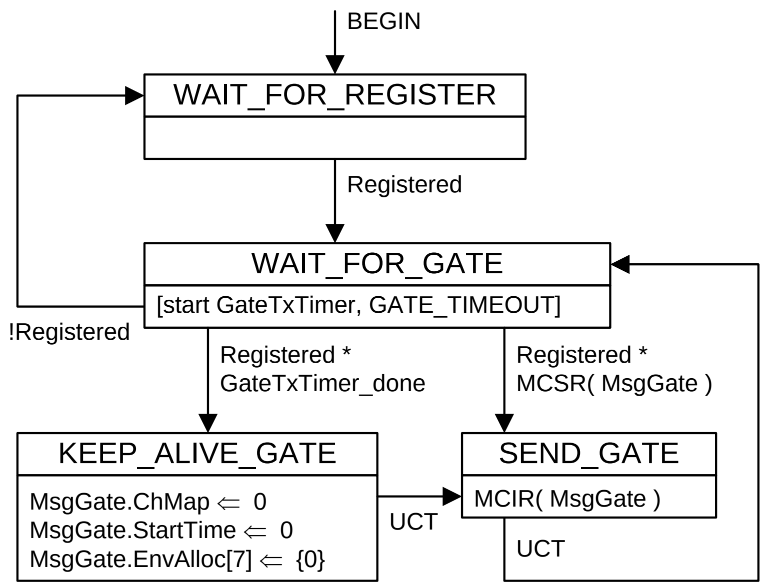

Figure 144-24 – Gate Generation state diagram

144.3.6.8 Gate Reception state diagram

The ONU shall implement a single instance of the Gate Reception state diagram as shown in Figure 144-25.

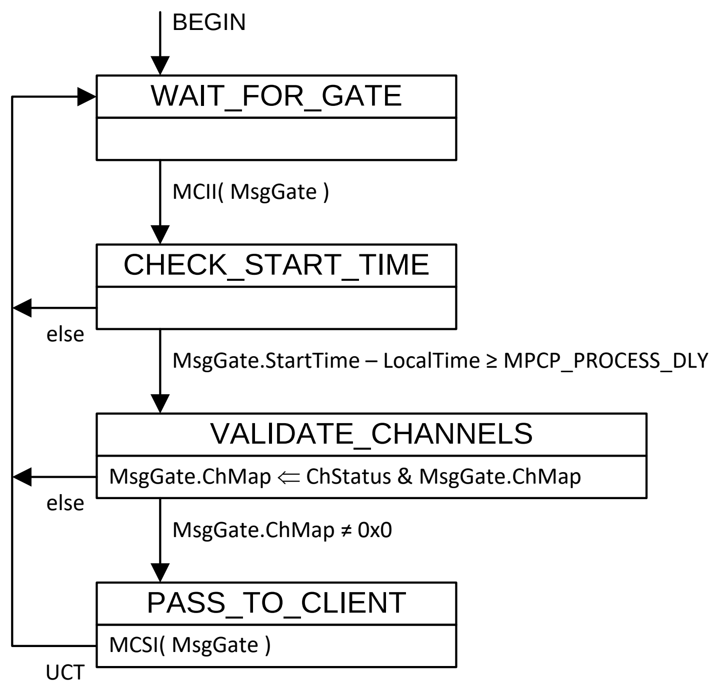

Figure 144-25 – Gate Reception state diagram

Editor's Note (to be removed prior to publication): AI for Glen to add text for subtraction operation for rollover variables. Add text into 144.1.6 State diagram conventions

144.3.6.9 OLT Envelope Commitment state diagram

The OLT shall implement a single instance of the Envelope Commitment state diagram as shown in Figure 144-xx.

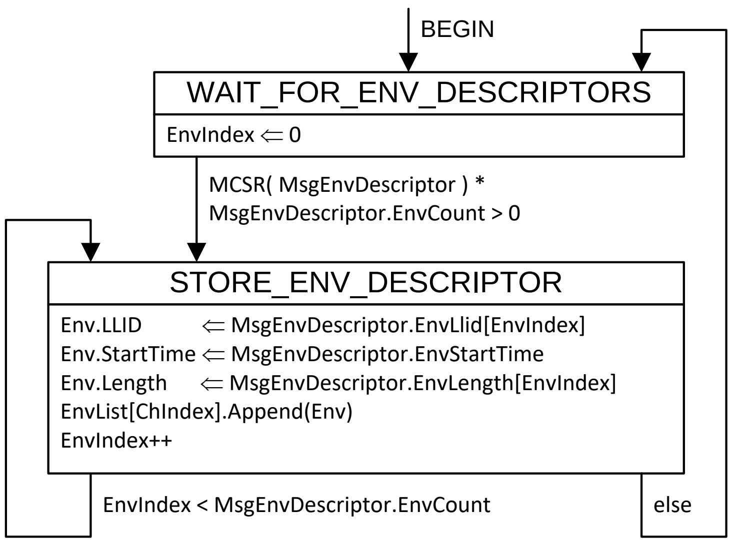

Figure 144-xx – OLT Envelope Commitment state diagram

144.3.6.10 ONU Envelope Commitment state diagram

The ONU shall implement a single instance of the Envelope Commitment state diagram as shown in Figure 144-26.

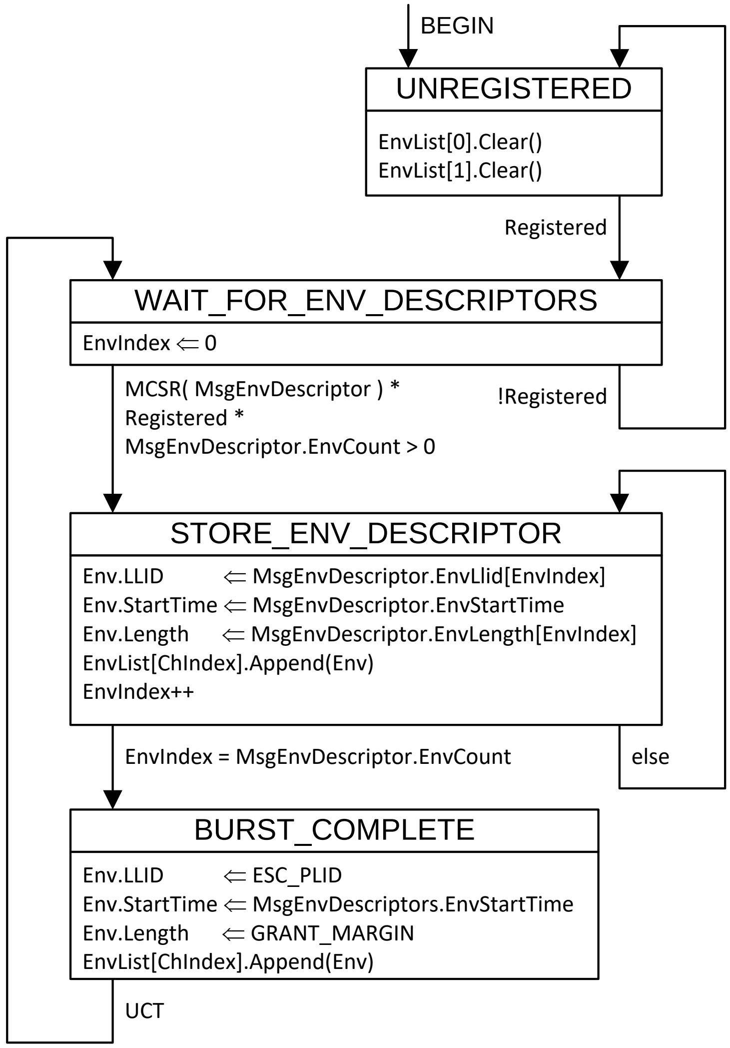

Figure 144-26 – ONU Envelope Commitment state diagram

144.3.6.11 Envelope Activation state diagram

The OLT and the ONU shall implement a single instance of the Envelope Activation state diagram, as depicted inFigure 144-27.

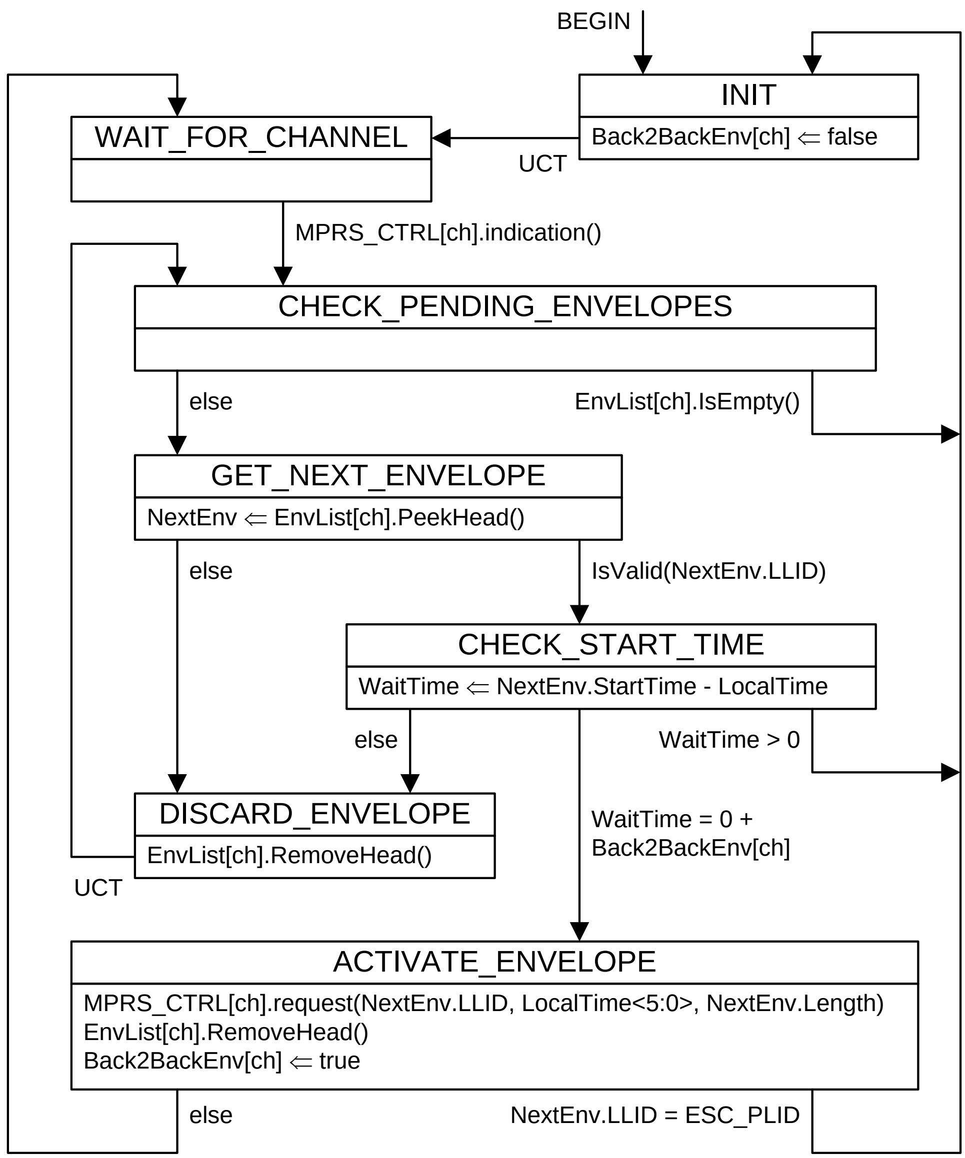

Figure 144-27 – Envelope Activation state diagram

144.3.7 Discovery Process in dual-rate systems

<subclause text to be supplied later>

144.3.7.1 OLT speed-specific discovery

<subclause text to be supplied later>

144.3.7.2 ONU speed-specific registration

<subclause text to be supplied later>

144.4 Channel Control Protocol (CCP)

<subclause text to be supplied later>

144.4.1 Principles of Channel Control Protocol

<subclause text to be supplied later>

144.4.2 CCPDU structure and encoding

<subclause text to be supplied later>

144.4.2.1 CC_REQUEST description

<subclause text to be supplied later>

144.4.2.2 CC_RESPONSE description

<subclause text to be supplied later>

144.5 Protocol implementation conformance statement (PICS) proforma for Multipoint MAC Control for Nx25G-EPON

<subclause text to be supplied later>