144.3.4 MPCPDU structure and encoding

The MPCPDU structure is shown in Figure 144–9, and is further defined as follows:

DestinationAddress:
> In MPCPDUs, the *DestinationAddress* 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..

SourceAddress:
> In MPCPDUs, the *SourceAddress* is the individual MAC address associated with the PLID through which the MPCPDU is transmitted. For MPCPDUs originating at the OLT, this can be the address of any individual MAC. These MACs may all share a single unicast address, as explained in {TBD}.

Length/Type:
> In MPCPDUs this field carries the *MAC_Control_Type* field value as specified in 31.4.1.3.

Opcode:
> This field identifies the specific MPCPDU being encapsulated. *Opcode* field values are defined in Table 31A–1.

OperandList:
> A set of opcode-specific fields as defined in 144.3.4.1 through 144.3.4.7.

Pad:

> This field is present only when the total length of the *OperandList* is below 44 octets. The *Pad* field is added to bring the MPCPDU length up to the minimum frame size (see 4A.2.3.2.4). This field is filled with zeros on transmission, and is ignored on reception.

FCS:
> This is the Frame Check Sequence, typically generated by the MAC.

Octets

	Octets
Destination Address	6
Source Address	6
Length/Type = 0x88-08	2
Opcode	2
Operand List	N
Pad	44 - N
FCS	4

Figure 144-9 – Generic MPCPDU format

Fields within a frame are transmitted from top to bottom. When consecutive octets are used to represent a single numerical value, the most significant octet is transmitted first, followed by successively less significant octets. Bits within each octet are transmitted from LSB to MSB.

1

144.3.4.1 GATE description

The purpose of the 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 *StartTime* value. Up to seven envelope allocations can be carried in a single GATE MPCPDU. Only envelope allocations with non-zero value of 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.
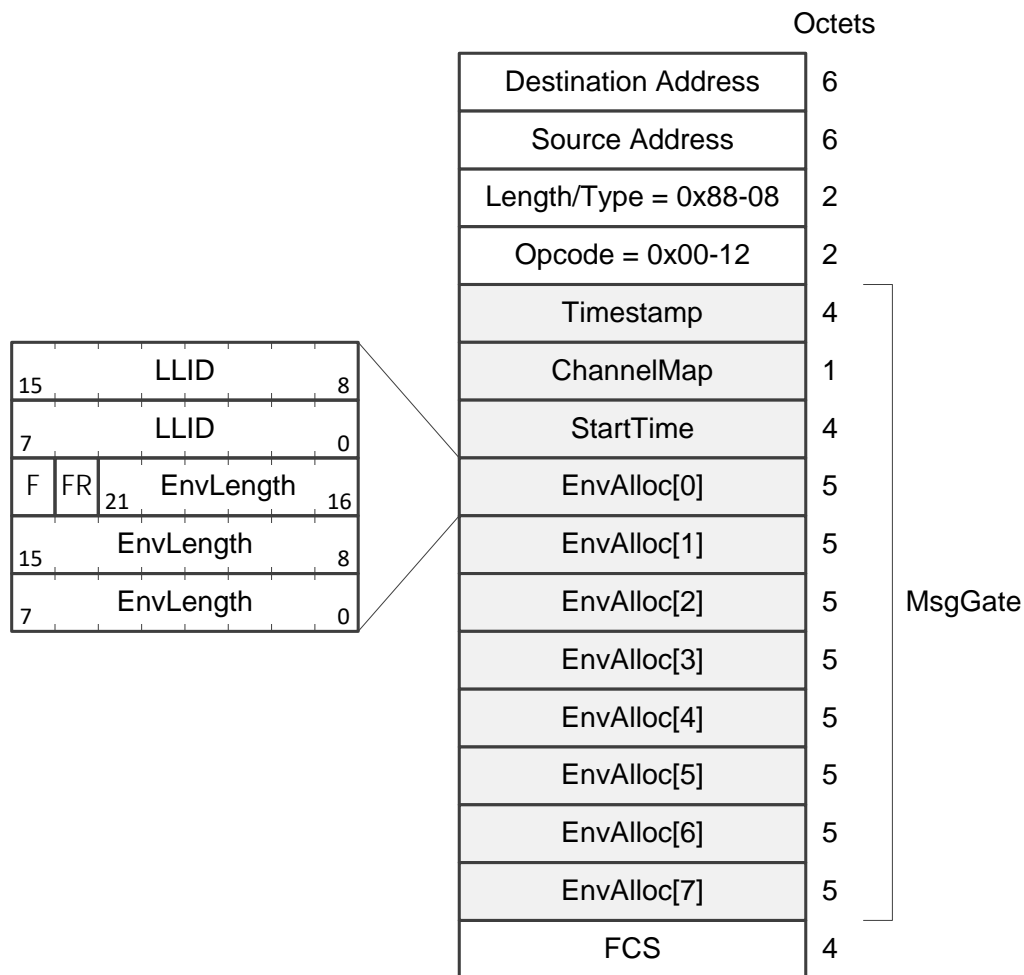

Figure 144-10 – Format of GATE MPCPDU

The GATE MPCPDU is an instantiation of the Generic MPCPDU and shall be as shown in Figure 144–10. The GATE MPCPDU is identified by the *Opcode* field value of 0x00-12. The *MsgGate* structure represents a set of opcode-specific fields, defined as follows:

    Timestamp:

        This field conveys the content of the MPCP local time counter (see *LocalTime* variable in 144.2.1.2) used for MPCP time synchronization (see 144.3.1.1). This field carries a 32-bit unsigned integer value that represents time in the units of EQT.

    ChannelMap:

        This 8-bit field identifies the upstream channel(s) granted to the ONU in a given GATE MPCPDU..

Table 144–2 shows the mapping between individual bits and upstream channels. When multiple channels are allowed in a single GATE MPCPDU, the transmission on each channel shall start at the ONU's local time equal to the *StartTime* value and have the length as necessary to transmit all allocated envelopes (the sum of all *EnvLength* fields) together with the associated optical and FEC overhead.

Table 144–2—*ChannelMap* bit assignment

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

StartTime:

This 32-bit unsigned integer value represents the start time of the transmission window (burst), expressed in the units of EQT. The start time is compared to the local clock, to correlate the start of the grant.

EnvAlloc:

This is a 40-bit structure that describes the transmission window assigned to a specific LLID. Up to seven *EnvAlloc* elements may be carried by a single GATE MPCPDU. The *EnvAlloc* structure consists of the following sub-fields:

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.

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 (FEC overhead or optical burst-mode overhead).

Fragmentation (F):

When set to 1, this flag informs the ONU that it is allowed to fragment new frames transmitted on the given LLID. When this flag set to 0, the ONU shall not fragment new frames. If a frame fragment remains queued in this LLID since the previous envelope transmission, this old fragment is transmitted first, regardless of the value of the *Fragmentation* flag.

ForceReport (FR):

When this flag 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. When the respective bit is set to 0, the ONU is not required to report the length of the given queue.

144.3.4.2 REPORT description

The purpose of the REPORT message is to report to the OLT the amount of data queued per individual LLID in an ONU. Up to seven LLIDs can be reported by a single REPORT MPCPDU. REPORT MPCPDUs also carry the *Timestamp* value that is used by the OLT to check for the timestamp drift condition (see 144.3.1.1).
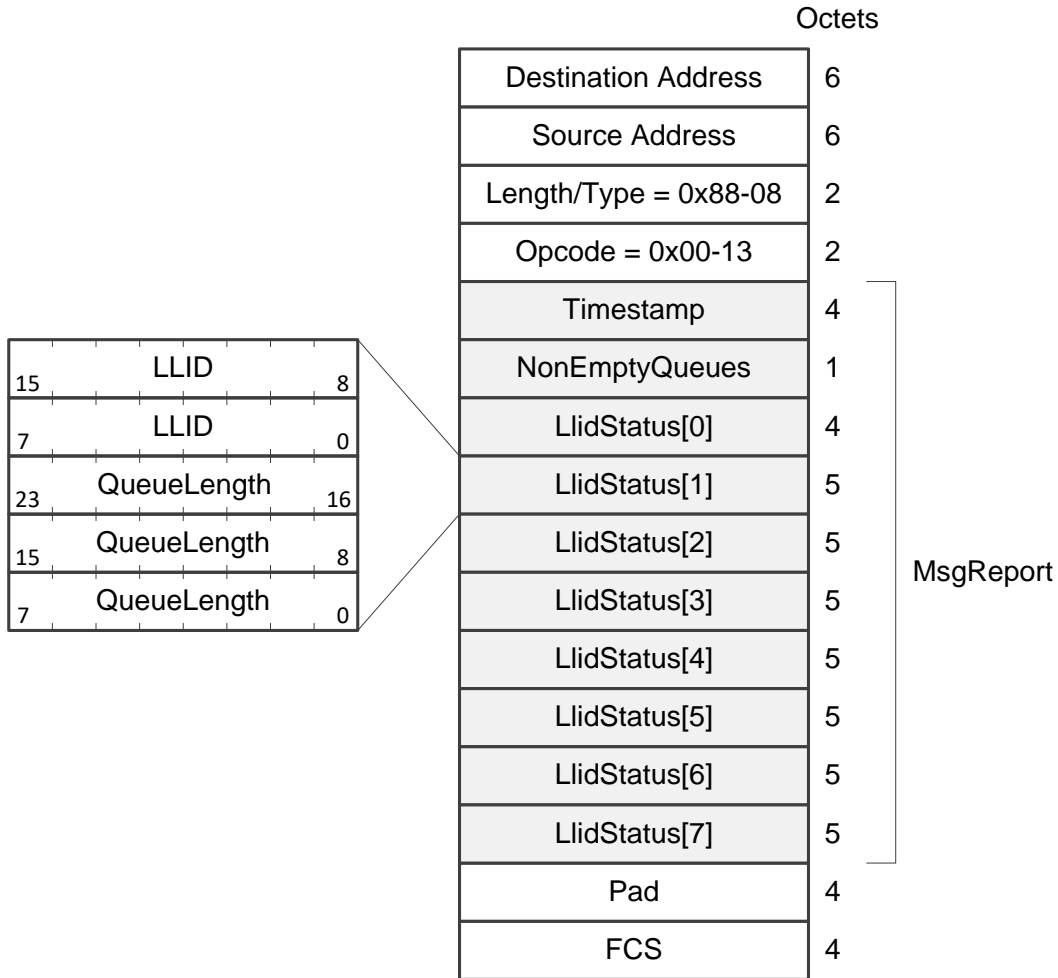
Figure 144-11 – Format of REPORT MPCPDU

The REPORT MPCPDU is an instantiation of the Generic MPCPDU and shall be as shown in Figure 144–11. The REPORT MPCPDU is identified by the *Opcode* field value of 0x00-13. The *MsgReport* structure represents a set of opcode-specific fields, defined as follows:

Timestamp:
> This field conveys the content of the ONU's MPCP local time counter (see *LocalTime* variable in 144.2.1.2) used for MPCP time synchronization (see 144.3.1.1). This field carries a 32-bit unsigned integer value that represents time in the units of EQT.

NonEmptyQueues:
> The number of LLIDs in the ONU with queues that were non-empty at the time of REPORT MPCPDU transmission.

LlidStatus:
> This is a 40-bit structure that describes the occupancy of the queue assigned to a specific LLID. The occupancy reports for up to seven queues may be included into a single REPORT MPCPDU. The *LlidStatus* structure consists of the following sub-fields:
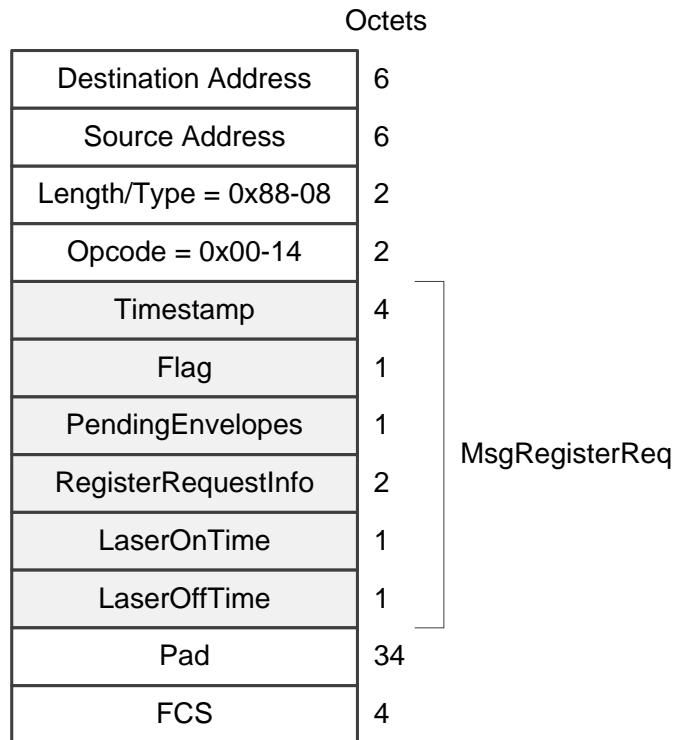
4

LLID:

    This 16-bit unsigned integer value represents the logical link that is being reported. The value of zero in this field signifies an empty *LlidStatus* structure.

QueueLength:

    This 24-bit value represents the length of the queue assigned to the given logical link (as indicated by the value of *LLID* sub-field), including the associated framing overhead (IPG and preamble). The *QueueLength* value is expressed in the units of EQ.

144.3.4.3 REGISTER_REQ description

The purpose of the REGISTER_REQ message is to inform the OLT of an ONU's attempt to register or unregister. When multiple ONUs attempt registration, the REGISTER_REQ MPCPDUs are transmitted in the shared discovery window and may collide. The REGISTER_REQ MPCPDUs are transmitted in envelopes with LLID equal to DISC_PLID (see 144.3.3). The REGISTER_REQ MPCPDUs carry the *Timestamp* value that is used by the OLT to measure the round-trip time of that ONU (see 144.3.1.1).

Octets

Destination Address	6
Source Address	6
Length/Type = 0x88-08	2
Opcode = 0x00-14	2
Timestamp	4
Flag	1
PendingEnvelopes	1
RegisterRequestInfo	2
LaserOnTime	1
LaserOffTime	1
Pad	34
FCS	4

MsgRegisterReq (brace spanning Timestamp through LaserOffTime)

Figure 144-12 – Format of REGISTER_REQ MPCPDU

The REGISTER_REQ MPCPDU is an instantiation of the Generic MPCPDU and shall be as shown in Figure 144–12. The REGISTER_REQ MPCPDU is identified by the *Opcode* field value of 0x00-14. The *MsgRegisterReq* structure represents a set of opcode-specific fields, defined as follows:

Timestamp:

    This field conveys the content of the ONU's MPCP local time counter (see *LocalTime* variable in 144.2.1.2) used for MPCP time synchronization (see 144.3.1.1). This field carries a 32-bit unsigned integer value that represents time in the units of EQT.

5

Flag:

This is an 8 bit field that indicates special requirements for the registration, as presented in Table 144–3.

Table 144–3—REGISTER_REQ MPCPDU *Flag* field

Value	Indication	Comment
0	ACK	ONU is requesting registration by the OLT
1	NACK	ONU is requesting deregistration by the OLT
2–255	Reserved	Ignored on reception.

PendingEnvelopes:

This is an unsigned 8-bit value signifying the maximum number of envelope allocations the ONU is capable of buffering. The OLT should not grant the ONU more than this maximum number of envelopes allocations into the future.

RegisterRequestInfo:

This is a 16 bit flag register that informs the OLT about the ONU's supported transmission rate on the channel on which this MPCPDU is transmitted. Table 144–4 presents the structure of the *RegisterRequestInfo* field.

Table 144–4—*RegisterRequestInfo* 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

LaserOnTime:

This field is one octet long and carries the time required to turn the ONU transmitter on. The value of *LaserOffTime* is expressed in the units of EQT.
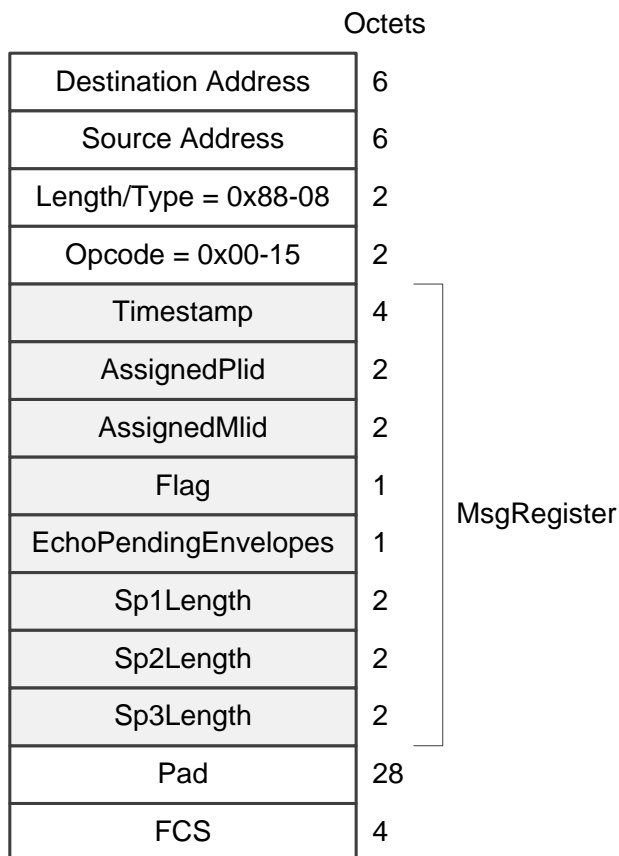
LaserOffTime:

This field is one octet long and carries the time required to turn the ONU transmitter off. The value of *LaserOffTime* is expressed in the units of EQT.

144.3.4.4 REGISTER description

The REGISTER message is used to convey to the registering ONU the assigned PLID and MLID values. As the ONU is not yet aware of its assigned PLID value, the REGISTER MPCPDUs are transmitted in envelopes with LLID equal to DISC_PLID (see 144.3.3), however they use the ONU's MAC address as the REGISTER MPCPDU destination address.

The OLT also may send the REGISTER MPCPDU to an already-registered ONU to request it to de-register or re-register. Such REQUEST MPCPDUs are sent in the envelopes with the unicast PLID assigned to the given ONU.

Octets

Field	Octets
Destination Address	6
Source Address	6
Length/Type = 0x88-08	2
Opcode = 0x00-15	2
Timestamp	4
AssignedPlid	2
AssignedMlid	2
Flag	1
EchoPendingEnvelopes	1
Sp1Length	2
Sp2Length	2
Sp3Length	2
Pad	28
FCS	4

Fields Timestamp through Sp3Length constitute MsgRegister.

Figure 144-13 – Format of REGISTER MPCPDU

The REGISTER MPCPDU is an instantiation of the Generic MPCPDU and shall be as shown in Figure 144–13. The REGISTER MPCPDU is identified by the *Opcode* field value of 0x00-15. The *MsgRegister* structure represents a set of opcode-specific fields, defined as follows:

Timestamp:
This field conveys the content of the OLT's MPCP local time counter (see *LocalTime* variable in 144.2.1.2) used for MPCP time synchronization (see 144.3.1.1). This field carries a 32-bit unsigned integer value that represents time in the units of EQT.

AssignedPlid:
This field holds a 16-bit unsigned value reflecting the physical layer identifier (PLID, see 144.3.2.1) assigned to the ONU during the registration.

AssignedMlid:

>This field holds a 16-bit unsigned value reflecting the management link identifier (MLID, see 144.3.2.2) assigned to the ONU during the registration.

Flag:

>This is an 8 bit flag register that indicates special requirements for the registration, as presented in Table 144–5.

Table 144–5—REGISTER MPCPDU *Flag* field

Value	Indication	Comment
0	ACK	The ONU's requested registration is successful or a registered ONU is asked to re-register
1	NACK	The registration request is denied or a registered ONU is asked to deregister.
2–255	Reserved	Ignored on reception.

EchoPendingEnvelopes:

>This is an unsigned 8-bit value holding the number of envelope descriptors the ONU is able to buffer for a future activation. This is a confirmation of the *PendingEnvelopes* value received in REGISTER_REQ MPCPDU.

SP1Length:

>This is a 16-bit field indicating the number of times SP1 is to be repeated at the beginning of a burst (see 142.1.3).

SP2Length:

>This is a 16-bit field indicating the number of times SP2 is to be repeated at the beginning of a burst (see 142.1.3).
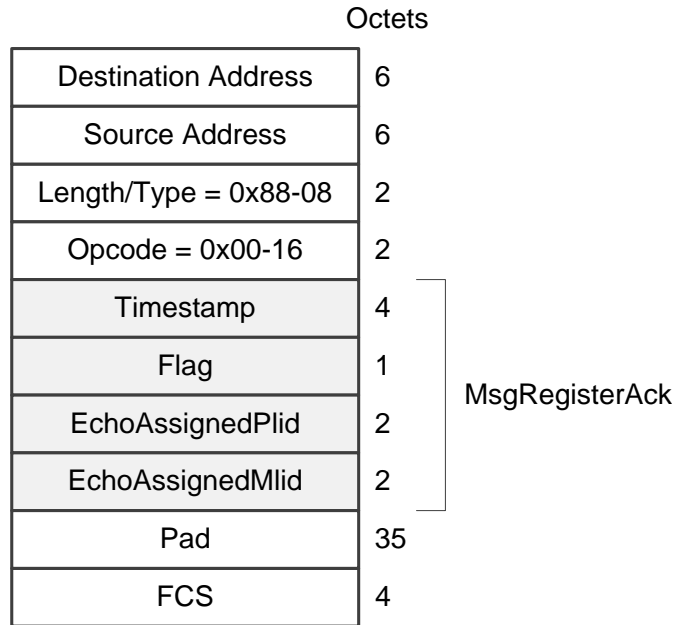
SP3Length:

>This is a 16-bit field indicating the number of times SP3 is to be repeated at the beginning of a burst (see 142.1.3).

144.3.4.5 REGISTER_ACK description

The REGISTER_ACK message is transmitted by the ONU to acknowledge the completion of the registration process. This is the first MPCPDU that the ONU transmits on its unique assigned PLID.

Octets

Destination Address	6
Source Address	6
Length/Type = 0x88-08	2
Opcode = 0x00-16	2
Timestamp	4
Flag	1
EchoAssignedPlid	2
EchoAssignedMlid	2
Pad	35
FCS	4

MsgRegisterAck

Figure 144-14 – Format of REGISTER_ACK MPCPDU

The REGISTER_ACK MPCPDU is an instantiation of the Generic MPCPDU and shall be as shown in Figure 144–14. The REGISTER_ACK MPCPDU is identified by the *Opcode* field value of 0x00-16. The *MsgRegisterAck* structure represents a set of opcode-specific fields, defined as follows:

Timestamp:

 This field conveys the content of the OLT's MPCP local time counter (see *LocalTime* variable in 144.2.1.2) used for MPCP time synchronization (see 144.3.1.1). This field carries a 32-bit unsigned integer value that represents time in the units of EQT.

Flag:

 This is an 8-bit flag register that indicates special requirements for the registration, as presented in Table 144–6.

Table 144–6—REGISTER_ACK MPCPDU Flag field

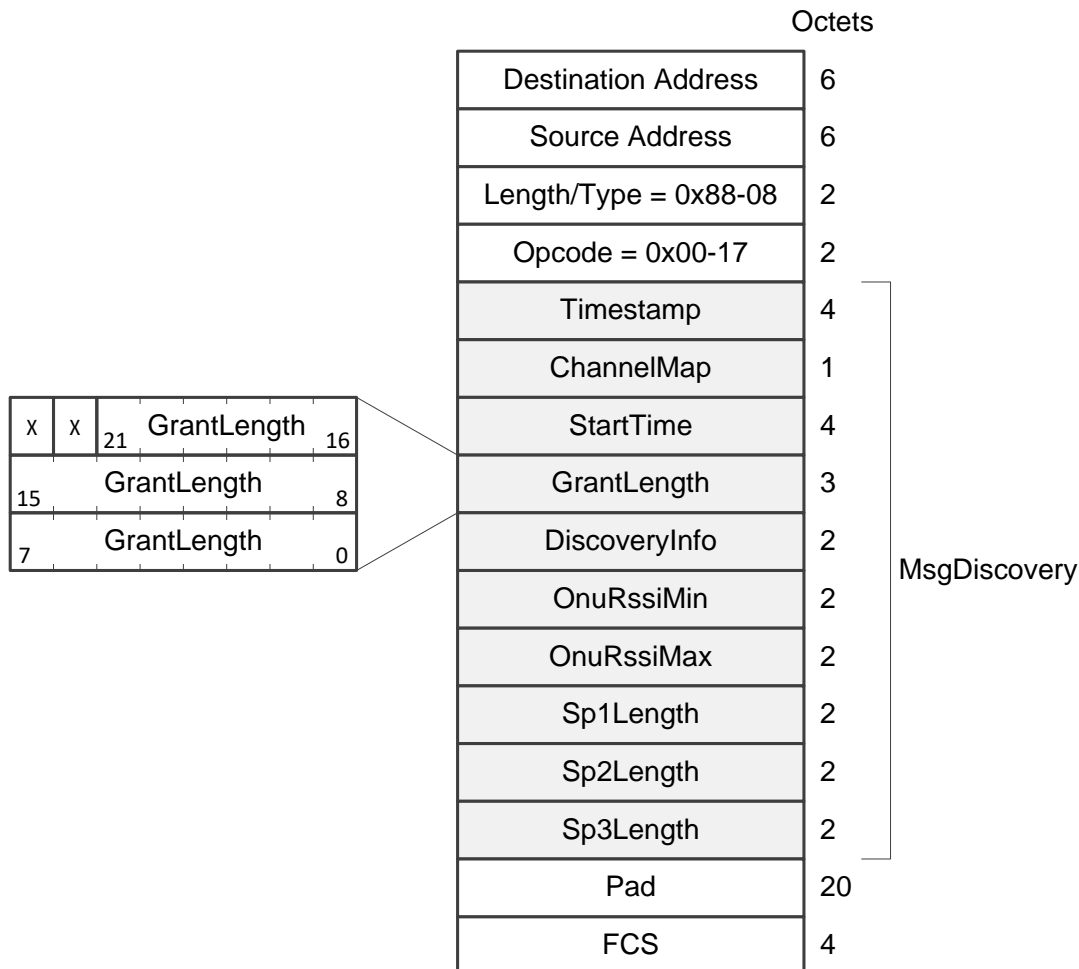| Value	Indication	Comment
0	ACK	The Registration Process is successfully acknowledged.
1	NACK	The requested registration attempt is denied by the MAC Control Client.
2–255	Reserved	Ignored on reception.

EchoAssignedPlid:

 This field holds a 16-bit unsigned value of the PLID (see 144.3.2.1) assigned to the ONU in the process of registration (see 144.3.2.1).

EchoAssignedMlid:

 This field holds a 16-bit unsigned value of the MLID (see 144.3.2.1) assigned to the ONU in the process of registration (see 144.3.2.1).

144.3.4.6 DISCOVERY description

The DISCOVERY message is used by the OLT to announce a discovery grant to all unregistered ONUs. The DISCOVERY MPCPDUs are transmitted in envelopes with LLID equal to DISC_PLID (see 144.3.3). All registered ONUs ignore the DISC_PLID, and therefore do not respond to the DISCOVERY MPCPDUs.

Octets

Field	Octets
Destination Address	6
Source Address	6
Length/Type = 0x88-08	2
Opcode = 0x00-17	2
Timestamp	4
ChannelMap	1
StartTime	4
GrantLength	3
DiscoveryInfo	2
OnuRssiMin	2
OnuRssiMax	2
Sp1Length	2
Sp2Length	2
Sp3Length	2
Pad	20
FCS	4

The Timestamp through Sp3Length fields form MsgDiscovery.

GrantLength detail: bits 21–16 (with two X bits), bits 15–8, bits 7–0.

Figure 144-15 – Format of DISCOVERY MPCPDU

The DISCOVERY MPCPDU is an instantiation of the Generic MPCPDU and shall be as shown in Figure 144–15. The DISCOVERY MPCPDU is identified by the *Opcode* field value of 0x00-17. The *MsgDiscovery* structure represents a set of opcode-specific fields, defined as follows:

Timestamp:

This field conveys the content of the OLT's MPCP local time counter (see *LocalTime* variable in 144.2.1.2) used for MPCP time synchronization (see 144.3.1.1). This field carries a 32-bit unsigned integer value that represents time in the units of EQT.

ChannelMap:

This 8-bit field identifies the upstream channel(s) granted to the ONU in a given DISCOVERY MPCPDU. Table 144–2 shows the mapping between individual bits and upstream channels. When multiple channels are allowed in a single DISCOVERY MPCPDU, an unregistered ONU shall attempt to register on a single channel only. The choice of the channel is implementation-specific.

StartTime:

This 32-bit unsigned integer value represents the start time of the discovery window (burst), expressed in the units of EQT. The start time is compared to the local clock, to correlate the start of the grant. The ONU's burst typically does not start at the advertised discovery grant *StartTime*, but is delayed by a random time interval to avoid persistent collisions of REGISTER_REQ messages from multiple unregistered ONUs (see 144.3.5).

GrantLength:

This 22-bit unsigned value represents the length of the discovery grant expressed in the units of EQ. The *GrantLength* does not include any transmission overhead components (FEC overhead or optical burst-mode overhead).

DiscoveryInfo:

This is a 16-bit flag register. Table 144–7 presents the internal structure of the *DiscoveryInfo* field.

Table 144–7—*DiscoveryInfo* 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

OnuRssiMin:

This is a 16-bit unsigned integer field, representing the minimum RSSI threshold for the given discovery attempt. Only the ONUs with measured RSSI greater or equal to *OnuRssiMin* shall generate a REGISTER_REQ message in the given discovery window. The unit of *OnuRssiMin* value is 0.1 μW, allowing the entire field to cover the range of 0 to 6.5535 mW (~ -40 to +8.2 dBm).

OnuRssiMax:

This is a 16-bit unsigned integer field, representing the maximum RSSI threshold for the given discovery attempt. Only the ONUs with measured RSSI lower or equal to *OnuRssiMax* shall generate a REGISTER_REQ message in the given discovery window. The unit of *OnuRssiMax* value is 0.1 μW, allowing the entire field to cover the range of 0 to 6.5535 mW (~ -40 to +8.2 dBm).

SP1Length:

This is a 16-bit unsigned integer field indicating the number of times SP1 is to be repeated at the beginning of a burst carrying the REGISTER_REQ MPCPDU (see 142.1.3).

SP2Length:

This is a 16-bit unsigned integer field indicating the number of times SP2 is to be repeated at the beginning of a burst carrying the REGISTER_REQ MPCPDU (see 142.1.3)..
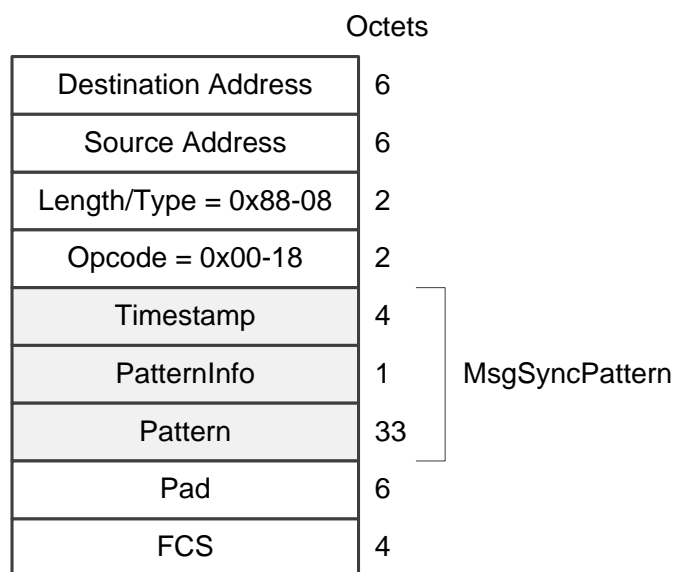
SP3Length:

This is a 16-bit unsigned integer field indicating the number of times SP3 is to be repeated at the beginning of a burst carrying the REGISTER_REQ MPCPDU (see 142.1.3)..

144.3.4.7 SYNC_PATTERN description

The SYNC_PATTERN message is transmitted by the OLT to announce a synchronization pattern (257-bit sequence) to be used by ONUs at the beginning of each upstream burst (i.e., as a burst preamble). The OLT may announce two or three distinct patterns to be used at the beginning of every burst (see 142.1.3). An unregistered ONU does not respond to a DISCOVERY message if it did not receive all the required SYNC_PATTERN MPCPDUs before it received the DISCOVERY MPCPDU. Generally, the SYNC_PATTERN MPCPDUs are transmitted in envelopes with LLID equal to DISC_PLID (see 144.3.3). An ONU that received all the required synchronization patterns and subsequently registered with the OLT, continues to use the same synchronization patterns after the registration.

The OLT is able to change the synchronization patterns of a registered ONU by transmitting the SYNC_PATTERN MPCPDUs to any registered ONU or to a group of registered ONUs using unicast or multicast PLID. The SYNC_PATTERN MPCPDUs are not explicitly acknowledged by the ONUs.

Octets

Destination Address	6
Source Address	6
Length/Type = 0x88-08	2
Opcode = 0x00-18	2
Timestamp	4
PatternInfo	1
Pattern	33
Pad	6
FCS	4

MsgSyncPattern (brackets Timestamp, PatternInfo, Pattern)

Figure 144-16 – Format of SYNC_PATTERN MPCPDU

The SYNC_PATTERN MPCPDU is an instantiation of the Generic MPCPDU and shall be as shown in Figure 144–16. The SYNC_PATTERN MPCPDU is identified by the *Opcode* field value of 0x00-18. The *MsgSyncPattern* structure represents a set of opcode-specific fields, defined as follows:

Timestamp:
This field conveys the content of the OLT's MPCP local time counter (see *LocalTime* variable in 144.2.1.2) used for MPCP time synchronization (see 144.3.1.1). This field carries a 32-bit unsigned integer value that represents time in the units of EQT.

PatternInfo:
This is a 16-bit field, with individual bits defined per Table 144–8.

Table 144–8—*PatternInfo* field

Bit(s)	Field Name	Meaning
0-1	*Index*	Indicates the index of the synchronization 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 synchronization pattern elements in a burst. The valid values are 2 or 3.
5-6	Reserved	Ignored on reception
7	*Balanced*	Indicates whether the given synchronization pattern element is to be balanced or not: 0 – synchronization sequence is to remain unbalanced, i.e., the *Pattern* value is repeated unchanged 1 – synchronization sequence is to be balanced, i.e., each 257-bit *Pattern* block (starting with the second block) is an inversion of its preceding block
8-14	Reserved	Ignored on reception
15	*Pattern*, bit 0	Carries the 1st bit (index 0) of the synchronization pattern value.

Pattern:

This is a 32-octet field, containing bits 1 through 256 of the synchronization pattern element. The bit 1 is transmitted first, immediately following the *PatternInfo* field. The bit 256 is transmitted last. Taking the last bit of the *PatternInfo* field together with the 256-bit *Pattern* field yields the full 257-bit synchronization pattern sequence as it is expected to be transmitted by the ONU.