7 Connectivity configurations

7.1 Introduction

7.2 VLAN configurations

7.3 Tunneling configurations

7.4 Multicast configurations

7.4.1 Introduction

This subclause describes *EPON multicast connectivity*, which refers to EPON's ability to deliver identical copies of a frame from the OLT's input port located at the OLT_CI to a group of ONU's output ports located at ONU_CI.

In general, establishing multicast operation in EPON involves three steps, as shown in Figure 7-20. In the first step, a multicast client issues a request to join a multicast group. In the second step, the EPON multicast transport channel is provisioned by configuring Classifier and Modifier at the OLT and the ONU. The provisioning may involve establishing a new multicast-bearing ESP at the OLT or the ONU, or just adding an additional destination output port to already existing ESP. Finally, in the third step, the multicast data is transported over EPON to the multicast clients.

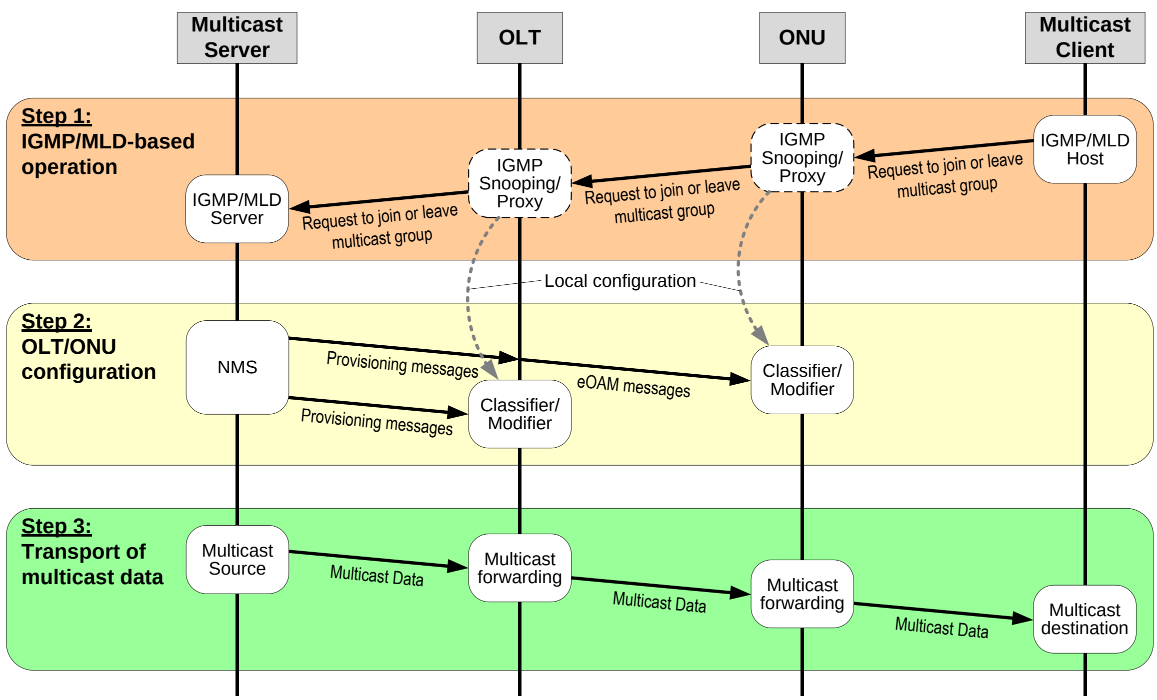

Figure 7-20—Steps establishing multicast operation in EPON

Multicast group control requirements cover methods and protocols used to create and delete multicast groups and to add or remove destination output ports to and from the existing multicast groups (see step 1 in Figure 7-20). The methods to control multicast groups employ IGMP and/or MLD protocols and expect the multicast clients to initiate the process of joining or leaving the multicast groups. The multicast group control requirements are specified in 7.4.3.

Once the new or changed multicast group membership is determined in step 1, the multicast transport mechanisms need to be configured to support this multicast group. Subclause 7.4.4 describes various methods to establish the multicast transport channels and the associated configurations of the ONU and the OLT (see step 2 in Figure 7-20).

It is possible to establish multicast operation solely by the decision of the operator, without involving step 1. In such directly-provisioned multicast configuration, group membership is established by the NMS without any requests from the multicast clients and without employing IGMP/MLD (see 7.4.3.1)..

The multicast transport mechanisms that allow frames to be delivered to all ONUs belonging to a given multicast group (see step 3 in Figure 7-20) are explained in 7.4.2. In this subclause, the term *multicast server* is used to denote collectively a multicast server (source of multicast data frames) and a multicast router (source and destination of multicast control frames), the functionality of which may be geographically or logically distinct. The term *multicast client* is used to denote a recipient of multicast data whose membership in a multicast group can be controlled independently.

The term *group address* represents either the MAC multicast group address or the IPv4/IPv6 multicast group address.

7.4.2 Multicast transport mechanisms

The EPON multicast transport includes *inter-ONU multicast* (i.e., data frame being sent to a subset of ONUs connected to a given OLT) and *intra-ONU multicast* (i.e., data frame being replicated to a subset of service ports within a given ONU).

Intrinsically, in the downstream direction, the P2MP architecture of EPON is a broadcasting medium. As a result, without any additional filtering, a single data frame transmitted by the OLT is received by every ONU. EPON, in most cases, uses the broadcasting properties of its medium to achieve efficient single-copy inter-ONU multicast. Inter-ONU multicast transport typically employs P2MP logical links (i.e., multicast LLIDs) to ensure that a multicast frame is accepted by multiple ONUs (see 7.4.2.1). In addition to the LLID field, the multicast filtering may be based on MAC address, VLAN tags, IP address, or a combination of these fields.

Intra-ONU multicast is achieved by configuring a multicast ESP that replicates a received frame into multiple downstream queues, thus delivering a copy of each multicast frame to multiple output ports (see 7.4.2.2).

7.4.2.1 Multicast LLID

A P2MP logical link binds a single MAC instance at the OLT to multiple MAC instances in different ONUs. A dowstream frame transmited by the OLT into a P2MP logical link is delivered to a set of ONUs (see 4.5).

To establish a P2MP logical link, the NMS provisions multiple ONUs to accept the same LLID value, which is refered to as *multicast LLID* (mLLID). A downstream frame sent to such P2MP logical link (i.e., forwarded to the MAC associated with the mLLID) gets delivered to all the ONUs in the given multicast group (i.e., all ONUs that were provisioned to accept this mLLID value).

From the OLT perspective, an mLLID represents a logical channel that delivers frames to a set of ONUs. To serve multicast traffic to a multicast group, the OLT forwards a single copy of each multicast frame to a PON-facing MAC instance associated with the mLLID provisioned for this multicast group.

ONUs are unaware if an LLID is unicast or multicast (i.e., ONUs are unaware whether the same LLID value has been provisioned in other ONUs). At the ONU, there is no distinction in handling the multicast LLID vesus handling the unicast unidirectional LLID.

In some configurations, the logical channel formed by the mLLID is dedicated to a single multicast session. In such configurations, the mLLID value uniquely identifies an individual multicast session and the ONU classification rules may classify multicast frames solely by the mLLID value.

In other configurations, an mLLID logical channel is allocated for a set of multicast sessions. In such configurations, an individual multicast session is identified by a combination of mLLID value and values of some other fields, typically IP Group DA and/or IP SA. Correspondingly, the ONU classification rules may require multiple fields to classify frames as belonging to individual multicast sessions.

Different types of LLIDs (PLID, MLID, and ULID) may be provisioned as multicast LLIDs (see 4.5). Only the multicast ULID is used for delivery of multicast user traffic.

7.4.2.1.1 Multicast PLID

A multicast PLID (mPLID) is used to deliver MPCPDUs to a set of ONUs. Only unidirectional (downstream-only) PLID may be provisioned as mPLID (see 7.4.4.1). At the ONU, the MPCPDUs received in envelopes with mPLID are passed the the same receive queue as MPCPDUs received in envelopes with the primary PLID.

Note that the downstream MPCPDUs sent in envelopes with mPLIDs are typically delivered to multiple ONUs, and therefore the `Timesamp` values in these MPCPDUs are not pre-compensated for the individual ONU’s RTTs. Consequently, an ONU shall not attempt to synchronize its local MPCP clock using the `Timestamp` values from the MPCPDUs received over the unidirectional PLIDs.

7.4.2.1.2 Multicast MLID

A multicast MLID (mMLID) is used to deliver OAMPDUs, CCPDUs, or VLCPDUs (if supported) to a set of ONUs. Only unidirectional (downstream-only) MLID may be provisioned as mMLID (see 7.4.4.1). At the ONU, the management PDUs received in envelopes with mMLID are passed the the same receive queue as the PDUs received in envelopes with the primary MLID. If a management PDU requires a response from an ONU, such response shall be transmitted in an envelope with the primary MLID.

7.4.2.1.3 Multicast ULID

A multicast ULID (mULID) is used to deliver user (data) frames to a set of ONUs. Both bidirectional and unidirectional (downstream-only) ULID may be provisioned as mULID (see 7.4.4.1). At the ONU, the downstream user frames received in envelopes with mULID are passed to the Classifier, just like the data frames received in envelopes with unicast ULIDs. ONUs may transmit upstream data frames in envelopes with mULID, if they were granted to do so, and if the mULID value was provisioned as the bidirectional ULID.

7.4.2.1.4 Broadcast LLID

An LLID that delivers downstream frames to all ONUs connected to a given OLT PON port is called a *broadcast LLID* (bLLID). bLLID is a special case of multicast LLID and it follows the same provisioning principles as described in 7.4.2.1.1–7.4.2.1.3. Additionally, the IEEE Std 802.3 specification defines two bLLID values that are enabled at the ONUs and the OLT without explicit provisioning (see IEEE Std 802.3, 144.3.5):

- `BCAST_PLID` (0x00-02): PLID value reserved for MPCPDU broadcast
- `BCAST_MLID` (0x00-03): MLID value reserved for broadcast of management frames (OAMPDUs, CCPDUs, and optionally, VLCPDUs).

7.4.2.2 Multicast ESP

A multicast EPON Srevice Path (ESP) is a data path that directs each matching frame to a CrossConnect entry for which multiple elements (multiple queues) are provisioned, as illustrated in Figure 7-21.

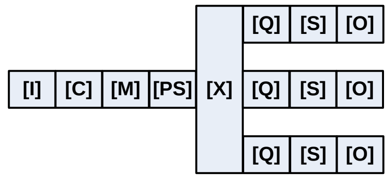

Figure 7-21—Multicast ESP

Generally, to achieve multicast connectivity in EPON, a unicast ESP is provisioned at the OLT, and multicast ESPs are provisioned in target ONUs. The Modifier entry in the unicast ESP at the OLT may be provisioned to insert into each frame traversing that ESP a field (typically a VLAN tag or an IP multicast address) with a specific value, identifying the given multicast group. The Classifiers in the ONUs that belong to this multicast group are provisioned to direct each received frame with the same specific value of the multicast tag to the multicast ESP. The multicast ESP in the ONU forwards the received multicast frame to multiple downstream output ports (i.e., service ports). This is illustrated in Figure 7-22.

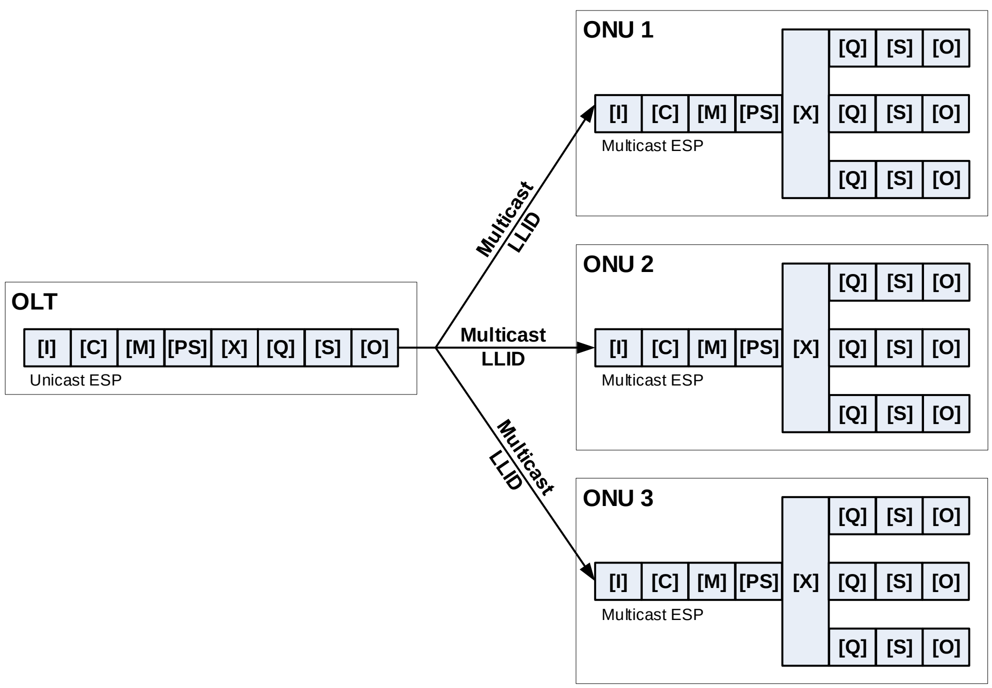

Figure 7-22—Multicast configuration using unicast ESP in the OLT and multicast ESPs in the ONUs

It may be necessary to provision a multicast ESP at the OLT , e.g., in a situation when a multicast group combines 10 Gb/s ONUs with 25 Gb/s and/or 50 Gb/s ONUs. In this case, the CrossConnect at the OLT may be provisioned to duplicate each multicast frame to 10G-EPON and 25G-EPON P2MP logical links (see Figure 7-23). The 50 Gb/s ONUs may receive multicast traffic on a 25 Gb/s P2MP logical link together with 25 Gb/s ONUs, or on a separate 50 Gb/s P2MP logical link (see 7.4.2.3).

It is also possible to use multicast ESP at the OLT in order to eliminate inter-ONU multicast. In this case, EPON multicast connectivity is achieved by duplicating each multicast frame at the OLT into multiple queues and delivering a separate copy of the frame to each ONU using previously established P2P logical links, as shown in Figure 7-24. This method allows independent encyption of each ONU’s traffic (including the multicast traffic), however it consumes more downstream bandwidth than the single-copy multicast method utilizing the mLLD.

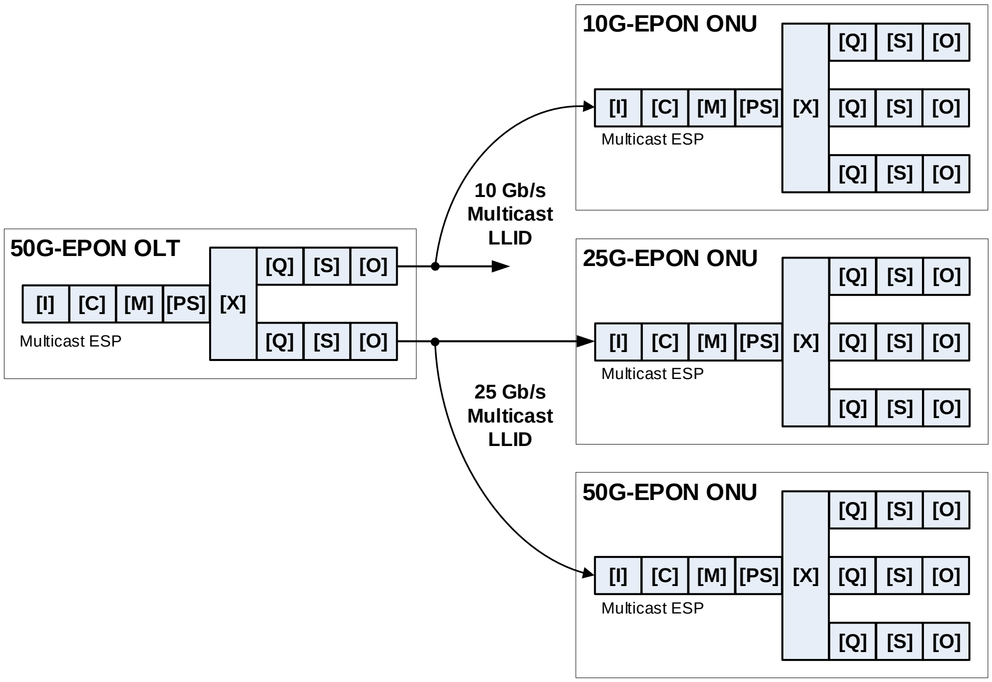

Figure 7-23—Multicast ESP at the OLT to support 10G-EPON and 25/50G-EPON ONUs

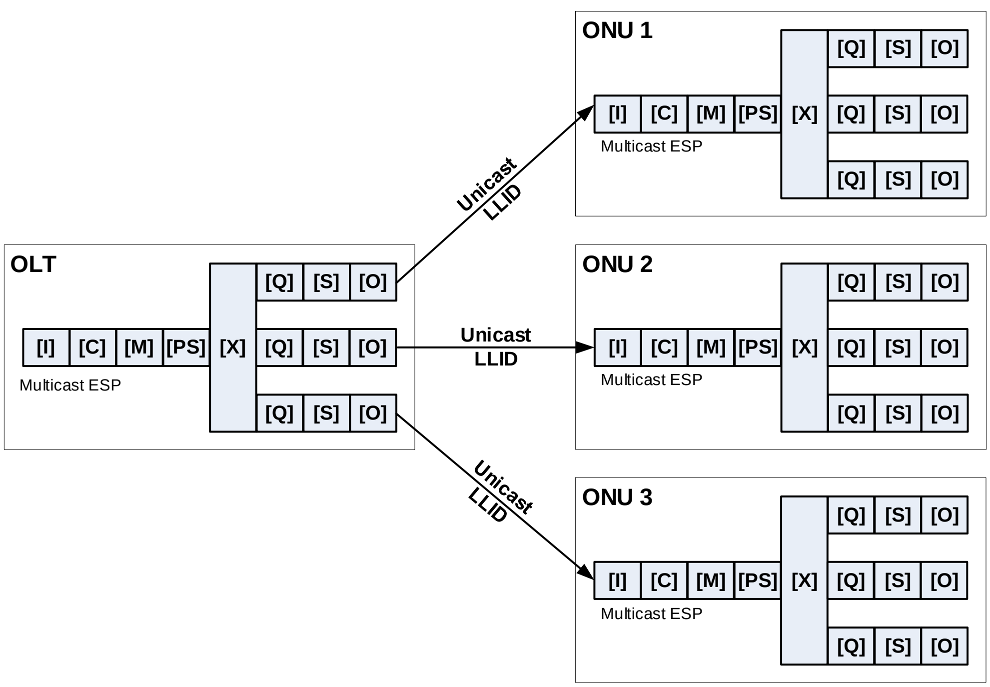

Figure 7-24—Multicast connectivity without inter-ONU multicast

7.4.2.3 25G-EPON and 50G-EPON coexistence

The multicast transport method described in this subclause supports 25G-EPON/50G-EPON coexistence, i.e., an ability to combine 25 Gb/s ONUs and 50 Gb/s ONUs into a single multicast group. Two methods are possible for supporting such multicast group.

One method is to use a single P2MP logical link, i.e., to provision the same mLLID value to be accepted by all ONUs belonging to the given multicast group. Under this method, a unicast ESP is provisioned at the OLT, which transmits a single copy of each multicast frame. However the data rate of the multicast stream is limited to 25 Gb/s, even for the 50G-EPON ONUs that are able to receive at the rate of 50 Gb/s. This method is illustrated in Figure 7-22.

The other method to combine 25 Gb/s ONUs and 50 Gb/s ONUs into a single multicast group is to allocate separate P2MP logical links for the 25 Gb/s ONUs and 50 Gb/s ONUs. In this method, a multicast ESP at the OLT duplicates multicast frames into two separate logical links: one transmitting only to 25 Gb/s ONUs, and the other transmitting only to 50 Gb/s ONUs. This method uses different mLLID values for 25 Gb/s ONUs and 50 Gb/s ONUs. The mLLID that is provisioned for the 50 Gb/s ONUs is able to transmit data at a rate of 50 Gb/s. This method is illustrated in Figure 7-23.

The latter method may also be extended to support multicast groups that combine 1G-EPON and 10G-EPON ONUs (per IEEE Std 1904.1) with 25G-EPON and 50G-EPON ONUs, though such cross-generation multicast support is outside the scope of this standard.

7.4.2.4 ONU-sourced multicast transport

ONU-sourced multicast may be supported by configuring the ONU to transfer any multicast frames to the OLT using an upstream P2P logical link and configuring the OLT to recognize such frames (based on VLAN value or multicast group address, or a combination of both) and to forward such frames into a downstream P2MP logical link. This configuration is illustrated in Figure 6-7.

7.4.3 Multicast group control

7.4.3.1 Client-controlled and server-controlled multicast group membership

A multicast group membership may be *client-controlled* or *server-controlled*. A client-controlled group membership (sometimes refered to as a *dynamic multicast session*) is initiated by multicast clients that independently issue requests to join or leave a multicast group. A server-controlled group membership (sometimes refered to as *static multicast session*) is initiated and configured by a multicast server or NMS without any explicit input from multicast clients. The OLT and ONUs shall support server-controlled multicast and should support client-controlled multicast.

7.4.3.2 IGMP-based and MLD-based multicast group control

If the client-controlled multicast group membership method is utilized, it relies on either IGMP or MLD protocols. The ONU does not proxy or snoop IGMP/MLD messages to track IP multicast group membership and has no IP multicast control protocol awareness. In the upstream direction, the ONU forwards IGMP/MLD control messages received from the multicast clients to the OLT after adding appropriate encapsulation parameters as configured by the OLT. All processing of IGMP/MLD control messages and tracking of IP multicast group membership are centralized and performed by a multicast control agent, that may reside in the OLT or elsewhere.

7.4.3.2.1 ONU requirements

In the upstream direction, the ONU shall forward all IGMP/MLD control messages received at the service to the ONU_MDI using a provisioned unicast ESP. The Modifier block of the ESP may be configured to add a VLAN Tag to the multicast control frame prior to forwarding the multicast control frame to the ONU_MDI.

In the downstream direction, multicast-group-specific IGMP/MLD control frames are forwarded according to the forwarding rules configured on the ONU.

7.4.3.2.2 OLT requirements

The following requirements apply to the OLT if the optional client-controlled multicast membership method is supported and the multicast control agent resides in the OLT.

When the OLT receives a *JOIN* request for a specific IP multicast session from a multicast client connected to a specific service port, it performs the following actions:

a) If OLT does not know the instance of the service port to which the multicast client is connected, it shall query the ONU to determine an instance of a service port on which the given client's MAC address has been learned.

b) If the ONU is not already configured to receive the mLLID carrying the requested IP multicast session, the OLT shall provision the mLLID (see 7.4.2.3.1).

c) If the ONU is not already configured to receive the requested IP multicast session, the OLT shall add a new classification and forwarding rule to forward the requested multicast session to the specific service port (see 7.4.2.3.2).

d) If the ONU is already receiving the requested multicast session, but the given service port is not configured to receive the multicast session, the OLT shall modify the existing classification and forwarding rule to include the additional service port into the existing multicast group. The rule modification involves provisioning of a new rule and then deleting the old rule (see 7.4.2.3.2).

e) If the given service port is already configured to receive the requested IP multicast session, the OLT takes no action.

In some implementations, when the OLT receives the first *JOIN* request for a specific IP multicast session from a multicast client connected to a specific service port, the OLT verifies whether this service port is authorized to receive the requested IP multicast session. In such scenario, the OLT provisions the mLLID and the necessary classification and forwarding rules in the ONU only if the service port is authorized to receive the multicast session. The method used to authorize the service ports is outside of scope of this standard.

If the IP multicast session requested by a client does not exist in the OLT (i.e., the requested multicast stream is not being currently forwarded to any multicast clients on the given EPON), the OLT shall provision a local multicast-bearing ESP that forwards multicast traffic identified by the requested IP multicast address to the same mLLID that is provisioned on the ONUs to receive this multicast stream.

When the OLT determines that there are no multicast clients for an IP multicast session connected to an ONU service port, the OLT shall modify the associated classification and forwarding rules at the ONU to stop forwarding the indicated multicast session to the service port (see 7.4.2.3.3).

When the OLT determines that there are no multicast clients for an IP multicast session connected to any of the service ports on an ONU, the OLT shall configure the ONU to delete the associated classification and forwarding rule (see 7.4.2.3.3).

When the OLT determines that there are no multicast clients connected to any of the service ports on an ONU for any of IP multicast sessions being delivered on a specific mLLID, in addition to deleting the classification and forwarding rules associated with these IP multicast sessions, the OLT shall configure the ONU to delete the mLLID used to deliver these IP multicast sessions (see 7.4.2.3.1).

7.4.4 Provisioning of multicast transport

The OLT provisions multicast forwarding either in response to multicast clients' requests to join a specific multicast group, in case of client-controlled multicast group membership, or in response to a NMS request, in case of server-controlled multicast group membership. In either case, provisioning of LLID-based multicast forwarding involves the following two steps:

- Configuring inter-ONU multicast per (see 7.4.4.1), and
- Configuring intra-ONU multicast

The OLT controls the intra-ONU forwarding through provisioning of classification/forwarding rules that forward the multicast frames to a set of destination service ports for the given multicast sesssion. In scenarios where service ports belonging to a given multicast session are known to the OLT, the OLT provisions the intra-ONU multicast using the method defined in 7.4.4.2. However, in some scenarios (e.g., when using the client-controlled multicast), the OLT is only aware of the MAC addresses of the multicast clients. In this case, the OLT provisions the intra-ONU multicast as specified in 7.4.4.3.

7.4.4.1 Provisioning of inter-ONU multicast based on mLLID

The inter-ONU multicast is provisioned using the *acConfigLlid* (0xDD/0x01-20) action (see 14.6.2.8). Using this action, the OLT may add a new mLLID to an ONU, delete a specific mLLID from the ONU, or delete all mLLIDs from the ONU.

Deleting one or all mLLIDs from the ONU shall not modify or delete any of the rules provisioned into Classifier/Modifier using the *aRuleSetConfig* (0xDB/0x05-01) attribute.

The OLT may retrieve a list of all registered mLLIDs in the ONU using the attribute *aLlidType* (0xDB/0x01-20) (see 14.4.2.16).

7.4.4.2 Provisioning of intra-ONU multicast using service ports

A multicast group at an ONU denotes a set of service ports configured to forward frames belonging to a given multicast session. A multicast group is created at an ONU when the first service port is configured to forward frames belonging to a given multicast session. A multicast group is considered deleted when the last port is configured to not forward frames belonging to a given multicast session.

To add a port to a specific multicast group, the OLT uses the attribute *aRuleSetConfig* (0xDB/0x05-01) (see 14.4.6.1). To replicate a multicast frame to multiple service ports, the *aRuleSetConfig* attribute includes multiple *sResult* sub-attributes with the *sFrameAction* set to *QUEUE* (see 14.4.6.1.2).

To add the *first* service port to a multicast group, the OLT shall generate the *aRuleSetConfig* attribute that includes:

- One or more *sClause* sub-attributes necessary to match frames belonging to specific multicast flow
- A single *sResult* sub-attribute with the action set to *QUEUE*, directing traffic to a specific queue associated with a specific service port instance.

To add an additional service port to a multicast group already existing in the ONU, the OLT shall generate a new *aRuleSetConfig* attribute that contains an additional *sResult* sub-attribute with the action set to *QUEUE*, but is otherwise identical to the existing rule for the given multicast group.

The OLT shall not generate a rule with multiple *sResult* sub-attributes pointing to the same instance of a service port. The ONU shall reject a rule with multiple *sResult* sub-attributes pointing to the same instance of a service port.

To delete a service port from an existing multicast group in the given ONU, the OLT shall generate a new *aRuleSetConfig* attribute, that does not contain the *sResult* sub-attribute forwarding traffic to the port being deleted, but is otherwise identical to the existing rule for the given multicast group.

To ensure that the multicast sessions currently being forwarded to the existing multicast clients are not interrupted when the multicast group is modified (i.e., a new service port is added to the group or one of existing service ports is deleted from the group), the OLT shall generate the new *aRuleSetConfig* attribute before deleting the old *aRuleSetConfig* attribute. The OLT shall not configure the ONU to delete the old *aRuleSetConfig* attribute before it receives a confirmation from the ONU that the new attribute was configured successfully.

When a new rule is added at the ONU and the old rule is deleted after that, and if the new rule contains the same *sClause* sub-attributes and some of the *sResult* clauses forwarding traffic to the same queues as the old rule, the Classifier at the ONU shall not discard any frames destined to these queues, i.e., the multicast flows to the existing and remaining multicast clients are not interrupted when other clients are added or deleted.

To delete all service ports from an existing multicast group in the given ONU, the OLT shall delete the associated *aRuleSetConfig* attribute entirely. This effectively deletes the entire multicast group in the given ONU.

7.4.4.3 Provisioning of intra-ONU multicast using MAC addresses

The MAC-based multicast group control is used in situations where only the MAC addresses of multicast clients are known to the OLT. The MAC-based multicast group control is a two-step process:

1) The OLT queries the ONU to find out an instance of a service port on which the given MAC address has been learned.
2) The OLT adds this instance of service port to the given multicast group using the method described in 7.4.4.2.

To retrieve the instance of the service port on which the given MAC address has been learned, the OLT shall use the *acGetUniMacLearned* (0xDD/0x01-08) action (see 14.6.2.7). If the sub-attribute *sUniPort* contains the value 0xFF, indicating that the given MAC address has not been learned on any of service ports, the OLT shall not perform step 2).

To delete a multicast client from a given multicast group under the MAC-based multicast group control method, the OLT may query the ONU again to find out the instance of the service port of a given multicast client. Alternatively, the OLT may retain the association of MAC clients and service ports when each new multicast client is added, and the OLT may proceed to modify forwarding rules (i.e., add a new rule and/or delete an old rule) without additional querying of the ONU.

7.4.4.4 Provisioning examples of multicast forwarding based on mULID and IP group address

This subclause illustrates OLT and ONU multicast forwarding process based on mULID and IP group address. Other configurations, while not explicitly described here, are also possible. For example, multicast forwarding can be based on mULID only, on mULID and L2 DA and/or SA, etc.

7.4.4.4.1 OLT forwarding behavior

Multicast frames arriving to the NNI are classified using either IP destination address or a combination of IP destination address and IP source address and are then associated with an mULID for forwarding across the PON. This is achieved by provisioning an ESP Classifier rule that includes minimally the destination IP multicast address, and may additionally include the source IP address, to determine the appropriate mULID on which to transport the frames.

In the simplest case, there is a one-to-one association between an IP multicast group and an mULID. A more complex case exists wherein an mULID carries frames from more than one multicast group. The set of multicast groups that may be aggregated to use the same mULID for transport across the PON is determined by operator provisioning.

In the multicast mode based on combined ULID and IP group address, in the downstream direction, the OLT applies rules and actions as illustrated in Table 7-32. Each rule (row) in the given table represents a separate multicast group.

Table 7-32—Classifier rules and Modifier actions for downstream ESP in the OLT multicast filtering mode based on mULID and IP group address[a–f]

Classifier rules	Modifier actions	Description
IF (EXISTS(IPv4_HEADER) AND IPv4_DA == IP4GA$_1$) THEN <m$_0$,…,x$_1$>	[m$_0$]: none	These rules are provisioned when multicast filtering is performed based on IPv4 multicast destination address. If a frame's IPv4_DA field matches the provisioned IPv4 group address IP4GA$_n$, the frame is forwarded to the CrossConnect entry (x$_n$) that forwards the frame further to an output port associated with the proper mULID.
…		
IF (EXISTS(IPv4_HEADER) AND IPv4_DA == IP4GA$_n$) THEN <m$_0$,…,x$_n$>		
IF (EXISTS(IPv4_HEADER) AND IPv4_DA == IP4GA$_1$ AND IPv4_SA == IP4SA$_1$) THEN <m$_0$,…,x$_1$>	[m$_0$]: none	These rules are provisioned when multicast filtering is performed based on IPv4 destination and source addresses. If a frame's IPv4_DA field matches the provisioned IPv4 group address IP4GA$_n$ and IPv4_SA field matches the provisioned IPv4 source address IP4SA$_n$, the frame is forwarded to the CrossConnect entry (x$_n$) that forwards the frame further to an output port associated with the proper mULID.
…		
IF (EXISTS(IPv4_HEADER) AND IPv4_DA == IP4GA$_n$ AND IPv4_SA == IP4SA$_n$) THEN <m$_0$,…,x$_n$>		

Classifier rules	Modifier actions	Description
IF (EXISTS(IPv6_HEADER) AND IPv6_DA == $IP6GA_1$) THEN $<m_0,\ldots,x_1>$	$[m_0]$: none	These rules are provisioned when multicast filtering is performed based on IPv6 multicast destination address. If a frame's IPv6_DA field matches the provisioned IPv6 group address $IP6GA_n$, the frame is forwarded to the CrossConnect entry (x_n) that forwards the frame further to an output port associated with the proper mULID.
…		
IF (EXISTS(IPv6_HEADER) AND IPv6_DA == $IP6GA_n$) THEN $<m_0,\ldots,x_n>$		
IF (EXISTS(IPv6_HEADER) AND IPv6_DA == $IP6GA_1$ AND IPv6_SA == $IP6SA_1$) THEN $<m_0,\ldots,x_1>$	$[m_0]$: none	These rules are provisioned when multicast filtering is performed based on IPv6 destination and source addresses. If a frame's IPv6_DA field matches the provisioned IPv6 group address $IP6GA_n$ and IPv6_SA field matches the provisioned IPv6 source address $IP6SA_n$, the frame is forwarded to the CrossConnect entry (x_n) that forwards the frame further to an output port associated with the proper mULID.
…		
IF (EXISTS(IPv6_HEADER) AND IPv6_DA == $IP6GA_n$ AND IPv6_SA == $IP6SA_n$) THEN $<m_0,\ldots,x_n>$		

[a] $IP4GA_1$–$IP4GA_n$ represent provisioned IPv4 destination group addresses.

[b] $IP4SA_1$–$IP4SA_n$ represent provisioned IPv4 source addresses.

[c] $IP6GA_1$–$IP6GA_n$ represent provisioned IPv6 destination group addresses.

[d] $IP6SA_1$–$IP6SA_n$ represent provisioned IPv6 source addresses.

[e] When both source and destination addresses are used for matching multicast frames, the same values of destination group addresses may be combined with different values of the source addresses, and the same value of the source address may be combined with different values of the destination addresses. A unique combination of source and destination addresses identifies a unique multicast group.

[f] x_1–x_n represent the CrossConnect entry that forwards the frame to an output port associated with the proper mULID. When the OLT supports 10 Gb/s and 25/50 Gb/s downstream channels, the x_i entry is provisioned to duplicate frames to two downstream queues: one associated with 10 Gb/s mLLID and the other associated with 25 Gb/s mULID. Both multicast LLIDs may have the same or different numerical values.

7.4.4.4.2 ONU forwarding behavior

At the ONU, multicast sessions may be identified by any of the following combinations of fields:

- IP DA
- IP DA and IP SA
- mULID value and IP DA
- mULID value, IP DA, and IP SA

In the multicast mode based on combined ULID and IP group address, in the downstream direction, the ONU shall apply rules and actions as illustrated in Table 7-33. Each rule (row) in the given table represents a separate multicast session.

Table 7-33—Classifier rules and Modifier actions for downstream ESP in the ONU multicast filtering mode based on mULID and IP group address[a–g]

<table>
<tr><th>Classifier rules</th><th>Modifier actions</th><th>Description</th></tr>
<tr><td>IF (EXISTS(IPv4_HEADER) AND IPv4_DA == IP4GA$_1$)
THEN <m_0,…,x_1></td><td rowspan="3">[m_0]: none</td><td rowspan="3">These rules are provisioned when multicast filtering is performed based on IPv4 multicast destination address.
If a frame's IPv4_DA field matches the provisioned IPv4 group address IP4GA$_n$, the frame is forwarded to the CrossConnect entry (x_n) that forwards the frame further to a set of output ports associated with the given IP multicast session.</td></tr>
<tr><td>…</td></tr>
<tr><td>IF (EXISTS(IPv4_HEADER) AND IPv4_DA == IP4GA$_n$)
THEN <m_0,…,x_n></td></tr>
<tr><td>IF (EXISTS(IPv4_HEADER) AND IPv4_DA == IP4GA$_1$ AND IPv4_SA == IP4SA$_1$)
THEN <m_0,…,x_1></td><td rowspan="3">[m_0]: none</td><td rowspan="3">These rules are provisioned when multicast filtering is performed based on IPv4 destination and source addresses.
If a frame's IPv4_DA field matches the provisioned IPv4 group address IP4GA$_n$ and IPv4_SA field matches the provisioned IPv4 source address IP4SA$_n$, the frame is forwarded to the CrossConnect entry (x_n) that forwards the frame further to a set of output ports associated with the given IP multicast session.</td></tr>
<tr><td>…</td></tr>
<tr><td>IF (EXISTS(IPv4_HEADER) AND IPv4_DA == IP4GA$_n$ AND IPv4_SA == IP4SA$_n$)
THEN <m_0,…,x_n></td></tr>
<tr><td>IF (EXISTS(IPv6_HEADER) AND IPv6_DA == IP6GA$_1$)
THEN <m_0,…,x_1></td><td rowspan="3">[m_0]: none</td><td rowspan="3">These rules are provisioned when multicast filtering is performed based on IPv6 multicast destination address.
If a frame's IPv6_DA field matches the provisioned IPv6 group address IP6GA$_n$, the frame is forwarded to the CrossConnect entry (x_n) that forwards the frame further to a set of output ports associated with the given IP multicast session.</td></tr>
<tr><td>…</td></tr>
<tr><td>IF (EXISTS(IPv6_HEADER) AND IPv6_DA == IP6GA$_n$)
THEN <m_0,…,x_n></td></tr>
</table>

Classifier rules	Modifier actions	Description
IF (EXISTS(IPv6_HEADER) AND IPv6_DA == IP6GA$_1$ AND IPv6_SA == IP6SA$_1$) THEN <m_0,…,x_1>	[m_0]: none	These rules are provisioned when multicast filtering is performed based on IPv6 destination and source addresses. If a frame's IPv6_DA field matches the provisioned IPv6 group address IP6GA$_n$ and IPv6_SA field matches the provisioned IPv6 source address IP6SA$_n$, the frame is forwarded to the CrossConnect entry (x_n) that forwards the frame further to a set of output ports associated with the given IP multicast session.
…		
IF (EXISTS(IPv6_HEADER) AND IPv6_DA == IP6GA$_n$ AND IPv6_SA == IP6SA$_n$) THEN <m_0,…,x_n>		
IF (ULID_VALUE == MULID AND EXISTS(IPv4_HEADER) AND IPv4_DA == IP4GA$_1$) THEN <m_0,…,x_1>	[m_0]: none	These rules are provisioned when multicast filtering is performed based on mULID value and IPv4 multicast destination address. If a frame's ULID_VALUE field matches the provisioned MULID value and IPv4_DA field matches the provisioned IPv4 group address IP4GA$_n$, the frame is forwarded to the CrossConnect entry (x_n) that forwards the frame further to a set of output ports associated with the given IP multicast session.
…		
IF (ULID_VALUE == MULID AND EXISTS(IPv4_HEADER) AND IPv4_DA == IP4GA$_n$) THEN <m_0,…,x_n>		
IF (ULID_VALUE == MULID AND EXISTS(IPv4_HEADER) AND IPv4_DA == IP4GA$_1$ AND IPv4_SA == IP4SA$_1$) THEN <m_0,…,x_1>	[m_0]: none	These rules are provisioned when multicast filtering is performed based on mULID value and IPv4 destination and source addresses. If a frame's ULID_VALUE field matches the provisioned MULID value and IPv4_DA field matches the provisioned IPv4 group address IP4GA$_n$ and IPv4_SA field matches the provisioned IPv4 source address IP4SA$_n$, the frame is forwarded to the CrossConnect entry (x_n) that forwards the frame further to a set of output ports associated with the given IP multicast session.
…		
IF (ULID_VALUE == MULID AND EXISTS(IPv4_HEADER) AND IPv4_DA == IP4GA$_n$ AND IPv4_SA == IP4SA$_n$) THEN <m_0,…,x_n>		

Classifier rules	Modifier actions	Description
IF (ULID_VALUE == MULID AND EXISTS(IPv6_HEADER) AND IPv6_DA == IP6GA$_1$) THEN <m_0,…,x_1>	[m_0]: none	These rules are provisioned when multicast filtering is performed based on mULID value and IPv6 multicast destination address. If a frame's ULID_VALUE field matches the provisioned MULID value and IPv6_DA field matches the provisioned IPv6 group address IP6GA$_n$, the frame is forwarded to the CrossConnect entry (x_n) that forwards the frame further to a set of output ports associated with the given IP multicast session.
…		
IF (ULID_VALUE == MULID AND EXISTS(IPv6_HEADER) AND IPv6_DA == IP6GA$_n$) THEN <m_0,…,x_n>		
IF (ULID_VALUE == MULID AND EXISTS(IPv6_HEADER) AND IPv6_DA == IP6GA$_1$ AND IPv6_SA == IP6SA$_1$) THEN <m_0,…,x_1>	[m_0]: none	These rules are provisioned when multicast filtering is performed based on mULID value and IPv6 destination and source addresses. If a frame's ULID_VALUE field matches the provisioned MULID value and IPv6_DA field matches the provisioned IPv6 group address IP6GA$_n$ and IPv6_SA field matches the provisioned IPv6 source address IP6SA$_n$, the frame is forwarded to the CrossConnect entry (x_n) that forwards the frame further to a set of output ports associated with the given IP multicast session.
…		
IF (ULID_VALUE == MULID AND EXISTS(IPv6_HEADER) AND IPv6_DA == IP6GA$_n$ AND IPv6_SA == IP6SA$_n$) THEN <m_0,…,x_n>		

[a] IP4GA$_1$−IP4GA$_n$ represent provisioned IPv4 destination group addresses.

[b] IP4SA$_1$−IP4SA$_n$ represent provisioned IPv4 source addresses.

[c] IP6GA$_1$−IP6GA$_n$ represent provisioned IPv6 destination group addresses.

[d] IP6SA$_1$−IP6SA$_n$ represent provisioned IPv6 source addresses.

[e] MULID represents provisioned mULID value.

[f] When both source and destination addresses are used for matching multicast frames, the same values of destination group addresses may be combined with different values of the source addresses, and the same value of the source address may be combined with different values of the destination addresses. A unique combination of source and destination addresses identifies a unique multicast group.

[g] x_1−x_n represent the CrossConnect entry that forwards the frame to a set of downstream queues associated with the the given IP multicast session.