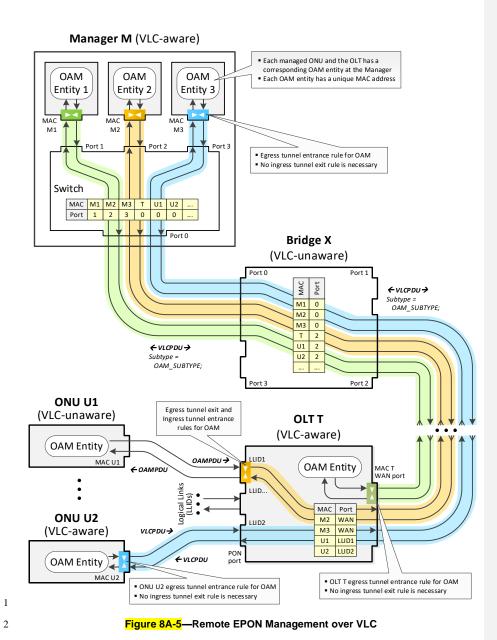1 **Annex 8A**

2 **(informative)**

3 **VLC configuration examples**

4 **8A.1 OAM over VLC use case, VLC-unaware end points**

5 **8A.2 OAM over VLC use case, VLC-aware end points**

6 **8A.3 OAM over VLC use case, VLC-aware end point and VLC-unaware end point**

7 **8A.4 Remote ITU-T PON Management over VLC use case**

8 **8A.5 Remote IEEE EPON Management over VLC use case**

9 **8A.5.1 Introduction**

10 This example illustrates a use case in which an EPON OLT and mulitple EPON ONUs are managed by a
11 remote management station (referred to as "Manager") using the OAM protocol defined in IEEE Std 802.3
12 and extended in IEEE Std 1904.1.

13 In the most general case, the Manager is separated from the OLT by one or more MAC bridge entities (see
14 Figure 8A-5). This use case assumes that the Manager and the OLT are VLC-aware, but the intermediate
15 network bridges are VLC-unaware. To illistrate the diverse deployment scenarios, this use case considers a
16 mixture of VLC-aware and VLC-unaware ONUs connected to the same OLT. For simplicity, it is assumed
17 that the Manager and OLT are single Ethernet port devices, but this is not a requirement.

18 The OAM protocol defined in IEEE Std 802.3 is a peer-to-peer (link-based) protocol. Therefore, each
19 OAM entity in a manged device has a corresponding peer OAM entity in the Manager. As illustrated in
20 Figure 8A-5, each OAM entity within the Manager is assigned an individual MAC address (addresses M1,
21 M2, and M3). The OLT has the MAC address T.

22 As in previous examples, it is assumed that all the frame relay entities (in the Manager, in the OLT, in
23 Bridge X, as well as in any intermediate bridges) have already populated their forwarding tables with
24 entries for MAC addresses on the Manager, the OLT and the ONUs. These entries may be created
25 dynamically by a MAC learning function or be provisioned statically by the NMS.

Deleted: sense

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Manager M (VLC-aware)

OAM Entity 1 · OAM Entity 2 · OAM Entity 3

- Each managed ONU and the OLT has a corresponding OAM entity at the Manager
- Each OAM entity has a unique MAC address

MAC M1 · MAC M2 · MAC M3

Port 1 · Port 2 · Port 3

- Egress tunnel entrance rule for OAM
- No ingress tunnel exit rule is necessary

Switch

MAC	M1	M2	M3	T	U1	U2	...
Port	1	2	3	0	0	0	...

Port 0

Bridge X
(VLC-unaware)

Port 0 · Port 1

MAC	Port
M1	0
M2	0
M3	0
T	2
U1	2
U2	2
...	...

← VLCPDU →
Subtype = OAM_SUBTYPE;

← VLCPDU →
Subtype = OAM_SUBTYPE;

Port 3 · Port 2

ONU U1
(VLC-unaware)

OAM Entity

MAC U1

Egress tunnel exit and Ingress tunnel entrance rules for OAM

OLT T
(VLC-aware)

OAM Entity

OAMPDU →
← OAMPDU

LLID1

LLID...

MAC T WAN port

Logical Links (LLIDs)

MAC	Port
M2	WAN
M3	WAN
U1	LLID1
U2	LLID2

LLID2

ONU U2
(VLC-aware)

OAM Entity

VLCPDU →
← VLCPDU

PON port

MAC U2

- ONU U2 egress tunnel entrance rule for OAM
- No ingress tunnel exit rule is necessary

- OLT T egress tunnel entrance rule for OAM
- No ingress tunnel exit rule is necessary

1

2 **Figure 8A-5**—Remote EPON Management over VLC

3

1 **8A.5.2 VLC provisioning to establish tunnels**

2 Since the Manager is not directly connected to the managed OLT and ONUs, the OAM messages need to
3 be carried over VLC tunnels (i.e., as VLCPDUs). In case of a VLC-aware ONUs, these VLCPDUs are
4 carried transparently through the intermediate bridges and the OLT all the way to the destination ONUs. In
5 case of a VLC-unaware ONUs, the OLT is responsible for converting downstream VLCPDUs into
6 OAMPDUs, and for converting upstream OAMPDUs into VLCPDUs for all such ONUs. Therefore, before
7 the Manager is able to manage EPON OLT and ONUs, the following VLC tunnels need to be provisioned:

8   — A forward VLC tunnel for the management of the OLT
9   — A reverse VLC tunnel for the management of the OLT
10   — A forward VLC tunnel for the management of the VLC-unaware ONU
11   — A reverse VLC tunnel for the management of the VLC-unaware ONU
12   — A forward VLC tunnel for the management of the VLC-aware ONU
13   — A reverse VLC tunnel for the management of the VLC-aware ONU

14 In general, the establishment of each VLC tunnel involves provisioning of rules to configure the VLC
15 tunnel entrance points and exit points. However, the VLC Receive and Transmit processes include a
16 number of optimizations that allow to reduce of the number of rules necessary to provision the tunnels.
17 Specifically, for the tunnels that terminate at the ingress to the device that is also the consumer of the
18 VLCPDU payload (i.e, VLCPDU DstAddress value is equal to the MAC address of the port that
19 received this VLCPDU) and that carry VLC payload of subtypes SUBTYPE_VLC, SUBTYPE_OAM, or
20 SUBTYPE_OMCI, no ingress tunnel exit rule is necessary.

21 Subclauses 8A.5.2.1 through 8A.5.2.6 provide the details of the location of the tunnel entrance and exist
22 points, as well as contents of the rules necessary to establish the above mentioned six tunnels. Each rule is
23 provisioned using a separate *VLC_CONFIG* message.

24 **8A.5.2.1 Rules for the forward VLC tunnel for the management of the OLT**

25 The forward VLC tunnel for the management of the OLT carries OAM messages from the Manager, OAM
26 entity 1 (MAC M1) to the OLT's WAN port (MAC T) as shown in Figure 8A-5.

27 The entrance rule for the VLC tunnel is provisioned in the Manager at the egress of OAM entity 1 (MAC
28 M1) and its action is to convert OAMPDUs into VLCPDUs. Specifically, this rule replaces the Slow
29 Protocol destination address value (SP_ADDR) with the MAC address of OLT T and it replaces the Slow
30 Protocol Ethertype (ETHERTYPE_SP) with the VLC Ethertype (ETHERTYPE_VLC). The entrance rule is
31 shown in Table 8A-17.

32 **Table 8A-17—Tunnel entrance rule for the forward VLC tunnel**
33 **for the management of the OLT**

Conditions	Actions
1. DstAddress == SP_ADDR 2. LengthType == ETHERTYPE_SP 3. Subtype == SUBTYPE_OAM	1.REPLACE(DstAddress, T) 2.REPLACE(LengthType, ETHERTYPE_VLC)

NOTE:

    `ETHERTYPE_SP` – Slow Protocol Ethertype value (see IEEE Std 802.3, 57A.4)

    `ETHERTYPE_VLC` – Ethertype value identifying VLCPDUs

    `SUBTYPE_OAM` – Subtype value identifying OAMPDUs (see IEEE Std 802.3, 57A.4)

    `SP_ADDR` – Destination MAC address associated with Slow Protocols (see IEEE Std 802.3, 57A.3)

    `T` – MAC address of OLT

1 The VLCPDUs are delivered to the WAN port at the OLT, where they are converted into OAMPDUs
2 without any tunnel exit rule.

3 **8A.5.2.2 Rules for the reverse VLC tunnel for the management of the OLT**

4 The reverse VLC tunnel for the management of the OLT carries OAM messages from the OLT's WAN
5 port (MAC T) to the Manager, OAM entity 1 (MAC M1) as shown in Figure 8A-5.

6 The entrance rule for the VLC tunnel is provisioned at the egress of OLT WAN port (MAC T) and its
7 action is to convert OAMPDUs into VLCPDUs. Specifically, this rule replaces the Slow Protocol
8 destination address value (`SP_ADDR`) with the MAC address of OAM entity 1 (MAC M1) and it replaces
9 the Slow Protocol Ethertype (`ETHERTYPE_SP`) with the VLC Ethertype (`ETHERTYPE_VLC`). The
10 entrance rule is shown in Table 8A-18.

11 **Table 8A-18— Tunnel entrance rule for the reverse VLC tunnel**
12 **for the management of the OLT**

Conditions	Actions
1. `DstAddress == SP_ADDR` 2. `LengthType == ETHERTYPE_SP` 3. `Subtype == SUBTYPE_OAM`	1. `REPLACE( DstAddress, M1 )` 2. `REPLACE( LengthType, ETHERTYPE_VLC )`

NOTE:
    `ETHERTYPE_SP` – Slow Protocol Ethertype value (see IEEE Std 802.3, 57A.4)
    `ETHERTYPE_VLC` – Ethertype value identifying VLCPDUs
    `SUBTYPE_OAM` – Subtype value identifying OAMPDUs (see IEEE Std 802.3, 57A.4)
    `SP_ADDR` – Destination MAC address associated with Slow Protocols (see IEEE Std 802.3, 57A.3)
    `M1` – MAC address of OAM entity 1	

13 No tunnel exit rule for the reverse VLC tunnel is necessary.

14 **8A.5.2.3 Rules for the forward VLC tunnel for the management of a VLC-unaware ONU**

15 The forward VLC tunnel for the management of the VLC-unaware ONU carries OAM messages from the
16 Manager, OAM entity 2 (MAC M2) to the OAM entity of the VLC-unaware ONU (MAC U1) as shown in
17 Figure 8A-5.

18 The entrance rule for the VLC tunnel is provisioned in the Manager at the egress of OAM entity 2 (MAC
19 M2) and its action is to convert OAMPDUs into VLCPDUs. Specifically, this rule replaces the Slow
20 Protocol destination address value (`SP_ADDR`) with the MAC address of the ONU U1 and it replaces the
21 Slow Protocol Ethertype (`ETHERTYPE_SP`) with the VLC Ethertype (`ETHERTYPE_VLC`). The entrance
22 rule is shown in Table 8A-19.

1 **Table 8A-19—Tunnel entrance rule for the forward VLC tunnel**
2 **for the management of the VLC-unaware ONU**

Conditions	Actions
1.DstAddress == SP_ADDR 2.LengthType == ETHERTYPE_SP 3.Subtype == SUBTYPE_OAM	1.REPLACE(DstAddress, U1) 2.REPLACE(LengthType, ETHERTYPE_VLC)

NOTE:
   ETHERTYPE_SP – Slow Protocol Ethertype value (see IEEE Std 802.3, 57A.4)
   ETHERTYPE_VLC – Ethertype value identifying VLCPDUs
   SUBTYPE_OAM – Subtype value identifying OAMPDUs (see IEEE Std 802.3, 57A.4)
   SP_ADDR – Destination MAC address associated with Slow Protocols (see IEEE Std 802.3, 57A.3)
   U1 – MAC address of VLC-unaware ONU	

3 Since the VLC-unaware ONU U1 is unable to parse and process VLCPDUs, the VLCPDUs carrying the
4 OAM messages for this ONU are converted into the OAMPDUs at the OLT. Within the OLT, the
5 VLCPDU's DstAdddress field value U1 is used to determine the exact PON port (e.g., LLID 1) to
6 which this VLCPDU is to be relayed. The tunnel exit rule is provisioned at the egress of the OLT's PON
7 port (LLID 1). This rule is shown in Table 8A-20.

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8 **Table 8A-20—Tunnel exit rule for the forward VLC tunnel**
9 **for the management of the VLC-unaware ONU**

Conditions	Actions
1.DstAddress == U1 2.LengthType == ETHERTYPE_VLC 3.Subtype == SUBTYPE_OAM	1.REPLACE(DstAddress, SP_ADDR) 2.REPLACE(LengthType, ETHERTYPE_SP)

NOTE:
   ETHERTYPE_SP – Slow Protocol Ethertype value (see IEEE Std 802.3, 57A.4)
   ETHERTYPE_VLC – Ethertype value identifying VLCPDUs
   SUBTYPE_OAM – Subtype value identifying OAMPDUs (see IEEE Std 802.3, 57A.4)
   SP_ADDR – Destination MAC address associated with Slow Protocols (see IEEE Std 802.3, 57A.3)
   U1 – MAC address of VLC-unaware ONU	

10

11 **8A.5.2.4 Rules for the reverse VLC tunnel for the management of a VLC-unaware ONU**

12 The reverse VLC tunnel for the management of the VLC-unaware ONU carries OAM messages from the
13 OAM entity of the VLC-unaware ONU (MAC U1) to the OAM entity 2 (MAC M2) at the Manager as
14 shown in Figure 8A-5.

15 Since the VLC-unaware ONU is unable to create VLCPDUs, the tunnel entrance rule for the VLC tunnel is
16 provisioned at the egress of PON port (e.g., LLID 1) at the OLT. This rule converts the OAMPDUs into
17 VLCPDUs. Specifically, this rule replaces the Slow Protocol destination address value (SP_ADDR) with
18 the MAC address of the OAM entity 2 (MAC M2) at the Manager and it replaces the Slow Protocol
19 Ethertype (ETHERTYPE_SP) with the VLC Ethertype (ETHERTYPE_VLC). The entrance rule is shown in
20 Table 8A-21.

1
2

**Table 8A-21—Tunnel entrance rule for the forward VLC tunnel
for the management of the VLC-unaware ONU**

Conditions	Actions
1.DstAddress == SP_ADDR 2.LengthType == ETHERTYPE_SP 3.Subtype == SUBTYPE_OAM	1.REPLACE(DstAddress, M2) 2.REPLACE(LengthType, ETHERTYPE_VLC)

NOTE:
 	
    ETHERTYPE_SP – Slow Protocol Ethertype value (see IEEE Std 802.3, 57A.4)
 	
    ETHERTYPE_VLC – Ethertype value identifying VLCPDUs
 	
    SUBTYPE_OAM – Subtype value identifying OAMPDUs (see IEEE Std 802.3, 57A.4)
 	
    SP_ADDR – Destination MAC address associated with Slow Protocols (see IEEE Std 802.3, 57A.3)
 	
    M2 – MAC address of OAM entity 2 for responsible for managing the VLC-unaware ONU	

3   No tunnel exit rule for the reverse VLC tunnel is necessary.

4   **8A.5.2.5 Rules for the forward VLC tunnel for the management of a VLC-aware ONU**

5   The forward VLC tunnel for the management of the VLC-aware ONU carries OAM messages from the
6   Manager, OAM entity 2 (MAC M3) to the OAM entity of the VLC-unaware ONU (MAC U2) as shown in
7   Figure 8A-5.

8   The entrance rule for the VLC tunnel is provisioned in the Manager at the egress of OAM entity 3 (MAC
9   M3) and its action is to convert OAMPDUs into VLCPDUs. Specifically, this rule replaces the Slow
10   Protocol destination address value (SP_ADDR) with the MAC address of the ONU U2 and it replaces the
11   Slow Protocol Ethertype (ETHERTYPE_SP) with the VLC Ethertype (ETHERTYPE_VLC). The entrance
12   rule is shown in Table 8A-22.

13
14

**Table 8A-22—Tunnel entrance rule for the forward VLC tunnel
for the management of the VLC-unaware ONU**

Conditions	Actions
1.DstAddress == SP_ADDR 2.LengthType == ETHERTYPE_SP 3.Subtype == SUBTYPE_OAM	1.REPLACE(DstAddress, U2) 2.REPLACE(LengthType, ETHERTYPE_VLC)

NOTE:
 	
    ETHERTYPE_SP – Slow Protocol Ethertype value (see IEEE Std 802.3, 57A.4)
 	
    ETHERTYPE_VLC – Ethertype value identifying VLCPDUs
 	
    SUBTYPE_OAM – Subtype value identifying OAMPDUs (see IEEE Std 802.3, 57A.4)
 	
    SP_ADDR – Destination MAC address associated with Slow Protocols (see IEEE Std 802.3, 57A.3)
 	
    U2 – MAC address of VLC-aware ONU	

15   The VLCPDUs are delivered to the VLC-aware ONU where they are converted into OAMPDUs without
16   any tunnel exit rule.

17

1 **8A.5.2.6 Rules for the reverse VLC tunnel for the management of a VLC-aware ONU**

2 The reverse VLC tunnel for the management of the VLC-aware ONU carries OAM messages from the
3 OAM entity of the VLC-aware ONU (MAC U2) to the OAM entity 3 (MAC M3) at the Manager as shown
4 in Figure 8A-5.

5 The tunnel entrance rule for the VLC tunnel is provisioned at the egress of egress of VLC-aware ONU U2.
6 This rule converts the OAMPDUs into VLCPDUs. Specifically, this rule replaces the Slow Protocol
7 destination address value (SP_ADDR) with the MAC address of the OAM entity 3 (MAC M3) at the
8 Manager and it replaces the Slow Protocol Ethertype (ETHERTYPE_SP) with the VLC Ethertype
9 (ETHERTYPE_VLC). The entrance rule is shown in Table 8A-23.

10 **Table 8A-23—Tunnel entrance rule for the forward VLC tunnel**
11 **for the management of the VLC-unaware ONU**

Conditions	Actions
1.DstAddress == SP_ADDR 2.LengthType == ETHERTYPE_SP 3.Subtype == SUBTYPE_OAM	1.REPLACE(DstAddress, M3) 2.REPLACE(LengthType, ETHERTYPE_VLC)

NOTE:
    ETHERTYPE_SP – Slow Protocol Ethertype value (see IEEE Std 802.3, 57A.4)
    ETHERTYPE_VLC – Ethertype value identifying VLCPDUs
    SUBTYPE_OAM – Subtype value identifying OAMPDUs (see IEEE Std 802.3, 57A.4)
    SP_ADDR – Destination MAC address associated with Slow Protocols (see IEEE Std 802.3, 57A.3)
    M3 – MAC address of OAM entity 3 for responsible for managing the VLC-aware ONU	

12 No tunnel exit rule for the reverse VLC tunnel is necessary.

13