9 Service availability

Clause 9 describes functional requirements to achieve interoperable service availability guarantees in EPON systems. Clause 9 specifically addresses functions and requirements related to device and transceiver monitoring, definitions of associated alarms and warnings, and optical link protection.

9.3 Optical link protection

9.3.1 Introduction

This subclause defines optical link protection mechanisms, their functional description, and the associated OLT and ONU requirements. Two types of optical link protection are introduced, namely, a trunk protection (see 9.3.3) and a tree protection (see 9.3.4), each addressing a different application space and providing different types of functionality.

9.3.1.1 Terminology

In the remainder of this subclause, the terms *primary* and *backup* are used to describe the physical modules involved in the protection scheme whereas the terms *working* and *standby* describe the state of the physical modules. The working module refers to the module currently carrying subscriber traffic, and the standby module is not carrying subscriber traffic. During the actual switch event, both the primary and backup modules may be carrying active traffic, depending on the actual implementation; however, this condition is transient.

The switching time between the working OLT and the standby OLT is defined as the time between the last bit of the last envelope transmitted on the working OLT_MDI and the first bit of the first envelope transmitted on the standby OLT_MDI, assuming continuous flow of data to a single connected ONU. The time taken by the switching condition detection process is accounted for in the switching time. Note that the switching time measurement may not be accurate with multiple connected ONUs.

The switching time between the working L-ONU and the standby L-ONU is defined as the maximum time interval among the following:

- Time interval between reception of the last bit of the control message (*PON Interface Administrate* TLV, defined in 14.4.9.3**Error! Reference source not found.**) by the working L-ONU, requesting the ONU to perform switchover, and the first bit of the PLID envelope transmitted by the standby L-ONU and containing a *REPORT* MPCPDU reflecting the nonzero queue length.
- Time interval between the detection of loss of signal by the working L-ONU and the first bit of the PLID envelope transmitted by the standby L-ONU and containing a *REPORT* MPCPDU reflecting the nonzero queue length.
- Time interval between the reception of the first bit of a data frame by the standby L-ONU and the first bit of the PLID envelope transmitted by the standby L-ONU and containing a *REPORT* MPCPDU reflecting the nonzero queue length.

The above time intervals are measured under continuous flow of data to a single connected ONU.

9.3.2 Device architecture and requirements

EPON devices should support optical link protection. If optical link pritection is supporter, the EPON devices incorporate a protection switch function in specific locations in the MAC Client allowed for by the model defined in Clause 6 and instantiate the appropriate number of OAM and MAC Control Clients.

Optical link protection mechanisms are defined in 9.3.3 and 9.3.4. Specific requirements for the ONU and OLT devices are different, depending on the type of supported protection mechanism.

9.3.2.1 Line and Client protection

This subclause describes Line ONU/OLT protection and Client ONU/OLT protection schemes and their representation in the MAC Client reference model. In both cases, the operation of the protection function is controlled and provisioned via mechanisms specified in the MAC Client reference model.

Functional blocks within the MAC Client reference model may be categorized into two groups, based on their logical behavior:

- Functional blocks with *combinatorial logic*, where the output of a functional block only depends on the input. Such functional blocks are marked with white boxes in Figure 9-1 and Figure 9-2. Input/Output, Modifier, and CrossConnect implement combinatorial logic.
- Functional blocks with *sequential logic*, where the status of the output of a functional block depends on the status of the input, past history, or internal state of the block. Such functional blocks are shown as shaded boxes in Figure 9-1 and Figure 9-2. Classifier, Queues, Policer/Shaper, and Scheduler implement sequential logic.

Device behavior during the protection switchover event and its impact on data traffic are different depending on whether the sequential logic blocks are duplicated or shared among the primary and backup ESPs. These behavioral differences are detailed below. In the Line ONU/OLT protection scheme, all the sequential logic blocks are shared, while in the Client ONU/OLT protection scheme all the sequential logic blocks are duplicated.

9.3.2.1.1 Line device protection

In the case of Line ONU/OLT protection, the protection switch function is located between the Input/Output ports connected to the `MADI`/`MADR` primitives, as shown in Figure 9-1. The Classifier, Modifier, Policer/Shaper, Queues, and Shaper blocks are shared among the primary and backup ESPs, providing the required redundancy for the Line device elements only.

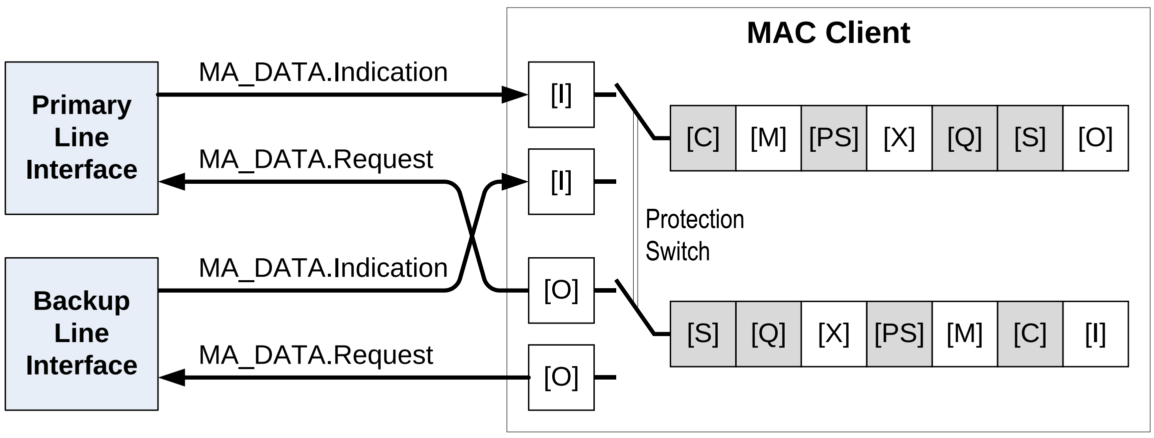


Figure 9-1—Line device protection architecture

After the switchover event, data stored in the Queues block of the primary path is available for the backup path as well, preventing data loss. Likewise, since the Policer/Shaper and Scheduler blocks are shared between the primary and backup paths, the size of the generated data burst (in the case of ONUs) does not exceed the maximum burst size allowed by Policer/Shaper parameters provisioned for the given device. In this way, the MAC Client maintains the state of individual functional blocks before and after the protection switching takes place.

9.3.2.1.2 Client device protection

In the case of Client ONU/OLT protection, the protection switch function is instantiated between the Input/Output ports connected to the UNI ports of the ONUs and NNI ports of the OLT, as shown in Figure 9-2. The Classifier, Modifier, Policer/Shaper, Queues, and Shaper blocks are duplicated, providing the required redundancy for the Client device elements.

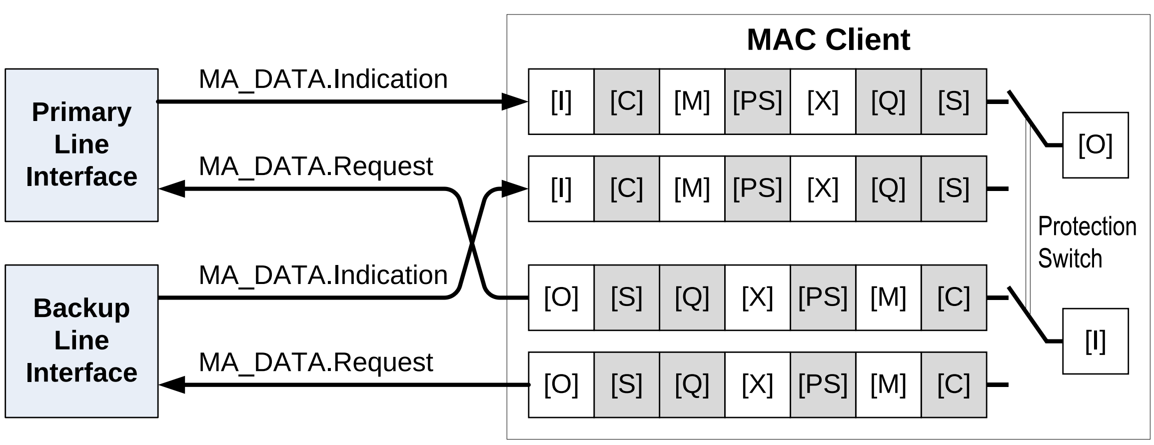


Figure 9-2—Client device protection architecture

After the switchover event, data stored in the Queues block of the primary path is not available for the backup path, allowing some data loss for frames already stored in the Queues block for the primary path. Likewise, since the Policer/Shaper blocks are duplicated, the size of the generated data burst can be double what was provisioned (the primary and backup Policer/Shaper each may admit maximum-size burst, right before and right after the protection switchover event).

9.3.2.2 Line fault detection

Both the working C-OLT and the working C-ONU observe the status of the working optical link, using available mechanisms for detection of the link failure in the upstream and downstream directions. The link failure detection may take place at both ends of the link or on one end of the link only. In either case, the side detecting link failure notifies the link peer about this event using the messages and mechanism specific to a given protection scheme.

9.3.2.2.1 OLT detection conditions

The working OLT shall be able to detect the fault condition on the working optical line using each of the mechanisms defined below. Each of these mechanisms is sufficient to indicate a fault condition.

a) Optical LoS: the working OLT fails to receive valid optical signal within $T_{LoS\_Optical}$ (two milliseconds by default), as identified by the Signal Detect Threshold value in IEEE Std 802.3, Table 141-17 and Table 141-18.

b) MAC LoS: the working OLT fails to receive a *REPORT* MPCPDU or any other frame from the L-ONU in eight (see the MISSED_REPORT_LIMIT constant defined in IEEE Std 802.3, 144.3.7.1) consecutive grants for which the `ForceReport` flag in the corresponding *GATE* MPCPDU was set to `1`. Note that the time required to detect MAC LoS condition depends on the frequency of *REPORT* MPCPDUs. If it is desirable to detect MAC LoS within a T_{LoS_MAC} window (50 ms by default), the OLT is expected to generate at least one *GATE* MPCPDU (with `ForceReport` flag set to `1`) per ONU every $0.125 \times T_{LoS\_MAC}$ ms (6.25 ms by default).

The OLT may also use the signal quality degradation metrics, which identify whether the power of the received optical signal exceeds the lowest/highest threshold or the BER of the received signal exceeds a certain operator-defined threshold. The values of $T_{LoS\_Optical}$, T_{LoS_MAC}, the time thresholds of optical signal loss, and BER on the OLT side are configured via NMS and are outside the scope of this standard.

9.3.2.2.2 ONU detection conditions

The ONU shall detect the fault condition on the working optical line using any of the mechanisms defined below:

a) Optical LoS: the ONU fails to receive any valid optical signal within $T_{LoS\_Optical}$ (two milliseconds by default), as identified by the Signal Detect Threshold value in IEEE Std 802.3, Table 141-21 and Table 141-22.

b) MAC LoS: the working ONU fails to receive a *GATE* MPCPDU or any other frame from the OLT within T_{LoS_MAC} (50 ms by default). Note that to avoid a situation where a single lost *GATE* MPCPDU causes a protection switchover, the OLT is expected to generate at least one *GATE* MPCPDU to the ONU every $0.125 \times T_{LoS\_MAC}$ ms (6.25 ms by default).

The values for $T_{LoS\_Optical}$ and T_{LoS_MAC} parameters should be configured using messages specific to a given protection scheme.

9.3.3 Trunk protection scheme

In the trunk protection scheme, the ODN span between the C-OLT and the 2:*N* optical splitter, used to join the two trunk segments, is protected. The C-ONU and the branch fiber (ODN span between the splitter and the ONU) are not protected. There are two types of trunk protection schemes, as shown in Figure 9-3 and Figure 9-4.

Figure 9-3 presents a trunk protection scheme with redundant L-OLT and trunk segments. In this scheme, the MAC, MAC Control, and OAM Clients in the C-OLT are shared by the primary and the backup L-OLTs and are not protected against failures. This trunk protection scheme reduces the implementation cost and targets protection only against the failures having highest potential impact: OLT optical transceiver failures and trunk fiber cuts. In this scheme, the OLT uses a line protection architecture (see 9.3.2.1.1).

The trunk protection with redundant L-OLT scheme supports only the *intra-chassis* protection scheme, where the primary L-OLT and backup L-OLT are located within the same chassis (either on the same line card or on separate line cards).

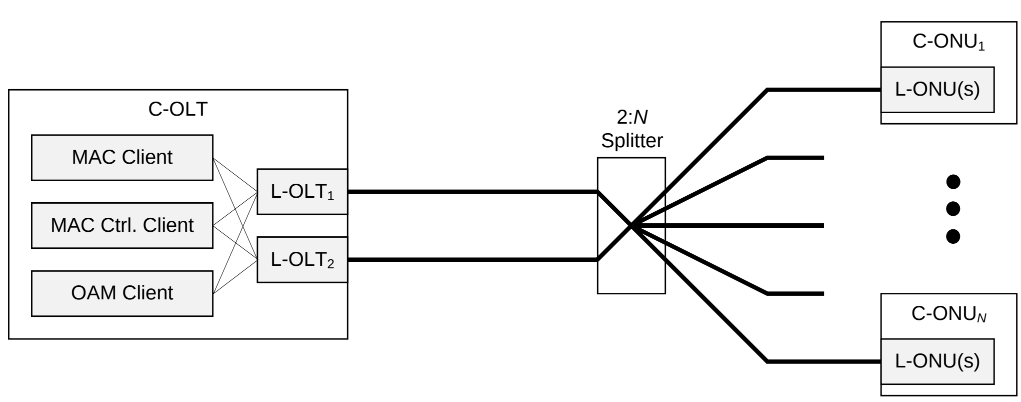


Figure 9-3—Trunk protection with redundant L-OLT

An alternative configuration of the trunk protection scheme is shown in Figure 9-4. This scheme provides added robustness as the whole C-OLT is duplicated, including the L-OLT and all MAC Clients.

In addition to intra-chassis protection, the trunk protection with redundant C-OLT scheme supports the inter-chassis protection, where the primary C-OLT and backup C-OLT are located in different chassis (either within the same central office or geographically different locations). The inter-chassis protection scheme requires coordination of the protection states and functions among the primary and backup C-OLTs comprising the trunk protection group and may require communication over LANs and/or wide area networks (WANs) using public or proprietary protocols. The nature of information, data formats, and communications protocols used to coordinate protection functions among the primary and backup C-OLTs are outside the scope of this standard.

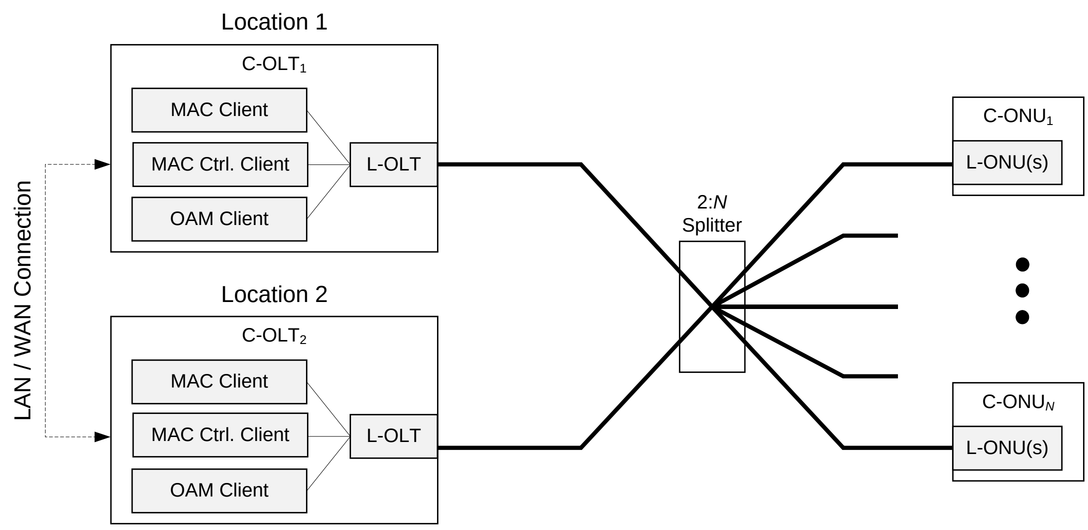


Figure 9-4—Trunk protection with redundant C-OLT

In the trunk protection scheme, the backup C-OLT acquires the round-trip time (RTT) values for individual ONUs without executing the MPCP discovery and registration process. Two possible approaches to acquire RTT are covered in Annex 9A; however, their selection and implementation details are outside the scope of this standard.

There are no ONU configuration differences between the trunk protection schemes shown in Figure 9-3 and Figure 9-4. Connected C-ONUs are configured in precisely the same manner.

The following subclauses provide technical requirements for the C-ONU and C-OLT devices participating in this protection scheme.

9.3.3.1 Functional requirements

Trunk protection in EPON requires the following basic functionalities:

— Ability to measure the standby path RTT (bRTT) in a way that does not affect live services. While the measurement of bRTT through re-registration of the affected ONUs is certainly possible, it would have a high impact on services (i.e., longer interruption) and is, therefore, not recommended. Annex 9A presents examples of dynamic bRTT measurement mechanisms.

— Ability to switch the ONU between working and standby paths in under 150 ms, thus minimizing the impact on the operating services.the the

The process of protection switching in the trunk protection scheme may be executed in the following ways:

— Automatically, when both the OLT and the ONU detect the fault condition on the working optical line using any of the mechanisms specified in the following subclauses; or

— On-demand, when the OLT is requested by the NMS to switch to the standby path. This protection switch is executed typically for operational reasons, e.g., fiber repairs, maintenance of OLT cards.

9.3.3.1.1 C-OLT requirements

In the trunk protection mechanism, as defined in 9.3.3, the OLT is connected to two optical links, the primary and backup link, from which only one is active at any time, carrying OAM, eOAM, CCP, and MPCP control frames together with subscriber traffic.

The protection function present in the Operation, Administration, and Management block is responsible for switching between the primary and backup paths for subscriber and control frames. Both the Line ONU/OLT protection and Client ONU/OLT protection schemes can be supported by the OLT in the case of trunk protection, as defined in 9.3.2.1.1 and 9.3.2.1.2, respectively.

The protection function additionally instantiates the state diagram per Figure 9-5, controlling the operation of the MAC Client and L-OLTs.

The standby OLT and the working OLT participating in the trunk protection group exchange configuration details continuously, i.e., the standby OLT is informed by the working OLT of any changes in its configuration, registration, and authentication status of individual ONUs, etc. The specific method of communication between the standby OLT and the working OLT is outside the scope of this standard.

The primary OLT and backup OLT may be provisioned by the NMS in exactly the same manner, using the same configuration parameters, except that one OLT is provisioned as working and the other OLT is provisioned as standby to minimize the preparation time for the backup OLT to come online after the protection switchover.

The standby OLT may be in a cold standby mode or in a warm standby mode. In the first mode, the standby OLT remains powered off until protection switching is requested. In the second mode, the standby OLT remains powered on with minimum functions enabled and operational, i.e., the OLT has the capability of receiving and parsing upstream transmissions from the PON branch it is connected to, but does not send any data downstream. It is recommended that the standby OLT operates in the warm standby mode to facilitate fast response times to the optical protection switchover events:

- Electronic subsystems are fully operational.
- Optical subsystem is partially active, i.e., transmitter is powered down (no downstream transmission is needed), while receiver is powered up (receiving upstream transmissions from connected ONUs).

Assume the initial state of the network is such that the primary OLT is in the working state and the backup OLT is in the standby state in the following discussion. The working OLT monitors the status of the optical line according to 9.3.2.2.1, and once any of the line fault conditions are detected, the working OLT disables its optical transmitter and stops any downstream transmission. The working OLT then causes the standby OLT to enter into the full operating mode. The switching time between the working OLT and the standby OLT shall be lower than or equal to 150 ms. The definition of the switching time can be found in 9.3.1.1.

To complete the switchover process, the working OLT informs the NMS about the switchover event. It is recommended that the time between the events of the working OLT's switching its laser off and the standby OLT's switching its laser on be at least equal to the largest value of $T_{LoS\_Optical}$ for all connected ONUs, as defined in 9.3.2.2.2, to guarantee that connected ONUs can properly detect the line fault condition.

Information, notification, and alarms/warnings delivered by the working OLT to the NMS in the switchover condition, as well as message formats, are outside the scope of this standard.

The new working OLT, once the switchover process is complete, shall send one or more *GATE* MPCPDUs to force each registered ONU to resynchronize to the MPCP clock. The transmission of such *GATE* MPCPDU is recommended to take place as soon after the end of the switchover event as possible to minimize frame loss during the switchover event.

9.3.3.1.2 C-ONU requirements

In the trunk protection mechanism, as defined in 9.3.3, the ONU is connected to a single optical link. In this case, the C-ONU does not contain primary and backup ESPs and typically remains registered throughout the switchover event. All the necessary changes take place on the OLT side, and the ONU is required only to suspend upstream transmissions for a specific period of time and remain in the HOLD_OVER_START state (per Figure 9-6) until a *GATE* MPCPDU is received.

As a result, only one instance of the OAM Client and MAC Control Client is needed on the ONU side, and the protection function present in the Operation, Administration, and Management block instantiates the state diagram per Figure 9-6, controlling the operation of the MAC Client and L-ONU(s).

Upon detection of a line fault, the C-ONU enters the HOLD_OVER_START state per Figure 9-6, where all currently stored upstream envelope descriptors are purged and the transmission of data from the ONU to the OLT is suspended. All incoming subscriber upstream data frames are queued. Frame loss is allowed in trunk protection when the local ONU queues overflow.

The C-ONU leaves the HOLD_OVER_START state upon the reception of the first *GATE* MPCPDU after entering the HOLD_OVER_START state. The upstream transmission is resumed using the newly allocated upstream transmission slots.

If the C-ONU fails to receive the *GATE* MPCPDU within the provisioned duration of the HOLD_OVER_START state (expressed by the `periodHoldOver` variable), the ONU enters the local deregistration state by sending the `MCSR( MsgRegisterReq )` primitive with the `MsgRegisterReq.Flag` set to `NACK` primitive to the underlying MPCP sublayer, per Figure 9-6. The OLT deregisters the ONU independently, based on the observed link status.

9.3.3.2 Trunk switching process

9.3.3.2.1 Variables

`backupLoS`

TYPE: Boolean

This variable indicates whether the MAC LoS or optical LoS condition is observed by the backup L-OLT, as defined in 9.3.2.2.1, or by the backup L-ONU (only in tree protection case), as defined in 9.3.2.2.2. The value of `true` indicates that the LoS condition is observed, and `false` indicates that the LoS condition is not observed. By default, this variable has the value of `false`.

`primaryLoS`

TYPE: Boolean

This variable indicates whether the MAC LoS or optical LoS condition is observed by the primary L-OLT, as defined in 9.3.2.2.1, or by the primary L-ONU, as defined in 9.3.2.2.2. The value of `true` indicates that the LoS condition is observed, and `false` indicates that the LoS condition is not observed. By default, this variable has the value of `false`.

`periodHoldOver`

TYPE: 32-bit unsigned integer

This variable represents the maximum period of time that the ONU may remain in the HOLD_OVER_START state. If the ONU does not receive at least one *GATE* MPDPDU within the `periodHoldOver`, it deregisters. This variable is expressed in units of milliseconds, and its value is provisioned using the management scheme specific for the given profile.

`registered`

This variable holds the current result of the discovery process. It is set to `true` once the discovery process is completed and registration is acknowledged. This variable maps to the variable `Registered` defined in IEEE Std 802.3, 144.3.7.3.

9.3.3.2.2 Timers

`timerHoldOver`

This timer is used to force the ONU leave the HOLD_OVER_START state if the period of time spent in the HOLD_OVER_START state is longer than the provisioned value of `periodHoldOver`. Once this timer expires, the ONU deregisters.

9.3.3.2.3 Functions

`activateDataPath( portId )`

This function controls the flow of subscriber data frames egressing the port identified by `portId` parameter, which can take the following values:

- `primaryPonIF` identifies the primary physical port associated with OLT_MDI or ONU_MDI.
- `backupPonIF` identifies the backup physical port associated with OLT_MDI or ONU_MDI.
- `primaryMacPort` identifies the primary virtual port associated with OLT_LI. This port is identified by an LLID.
- `backupMacPort` identifies the backup virtual port associated with OLT_LI. This port is identified by an LLID.

When the function is called with the argument set to `primaryPonIF` or `primaryMacPort`, the identified primary port becomes the working port, and the corresponding backup port becomes the standby port. Similarly, when the function is called with the argument set to `backupPonIF` or `backupMacPort`, the identified backup port becomes the working port, and the corresponding primary port becomes the standby port. Implementations may choose to accomplish this switching by modifying the rules or reconfiguring the association between the CrossConnect entries and the queues.

`opticalTX( portId, param )`

This function controls the status of the optical transmitter associated with the port identified by `portId` parameter. The `portId` parameter can take values as defined in the `activateDataPath( portId )` function. When the `param` variable has the value of `enable`, the optical transmitter is enabled, allowing the data transmission across the OLT_MDI or ONU_MDI. When the `param` variable has the value of `disable`, the optical transmitter is disabled (either powered down or disabled administratively), resulting in no frames being transmitted across the OLT_MDI or ONU_MDI.

`purgeGrants()`

This function causes an L-ONU to discard all stored (pending) grants.

`sendResyncGates( portId )`

This function is responsible for transmission of refresh *GATE* MPCPDUs to all L-ONUs connected to a port identified by `portId` parameter. The `portId` parameter can take values as defined in the `activateDataPath( portId )` function. Reception of these *GATE* MPCPDUs forces the ONUs to leave the HOLD_OVER_START state, as defined in Figure 9-6.

9.3.3.2.4 Primitives

`MACI( GATE )`

The acronym `MACI` is defined in 3.4. This primitive represents a reception of a non-discovery *GATE* MPCPDU at the ONU and is equivalent to the `MCSI(MsgGate)` primitive defined in IEEE Std 802.3, 144.1.4.1 and 144.3.6.1.

`MACR( REGISTER_REQ, status )`

The `MACR` acronym is defined in 3.4. This primitive represents the transmission of a *REGISTER_REQ* MPCPDU by the ONU and is equivalent to the `MCSR(MsgRegisterReq)` primitive defined in IEEE Std 802.3, 144.1.4.1 and 144.3.6.3. The `status` parameter sets the value of the `MsgRegisterReq.Flags` field.

`NMSI( messageId, failureCode )`

This primitive is used to inform the NMS about the protection switching event, during which the previously working and standby L-OLTs exchange their functions. It uses the following parameters:

— `messageId` identifies whether the switching event was initiated by the OLT or the ONU and what the new working port is. The following messages are defined:

  — `MSG1`: The switching event was initiated at the OLT, and the `primaryPonIF` is in the working state.

  — `MSG2`: The switching event was initiated at the OLT, and the `backupPonIF` is in the working state.

— `failureCode` identifies the reason for the protection switching, per **Error! Reference source not found.**.

`NMSR( protection, switch )`

This primitive is used by the NMS to request the working OLT to initiate a protection switch, during which the previously working and standby OLTs exchange their functions.

9.3.3.2.5 State diagrams

The C-OLT shall instantiate the switching process state diagram as defined in Figure 9-5. In case Client protection is implemented at the OLT (i.e., when two C-OLTs are used as shown in Figure 9-4), the combined operation of both C-OLTs shall be as defined in Figure 9-5. The C-ONU shall instantiate the switching process state diagram as defined in Figure 9-6.

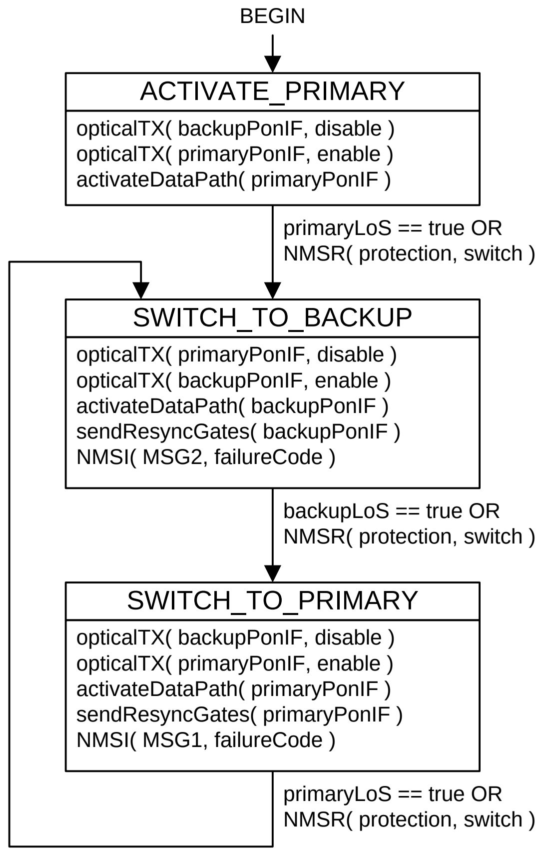


Figure 9-5—Trunk protection process operating on the OLT

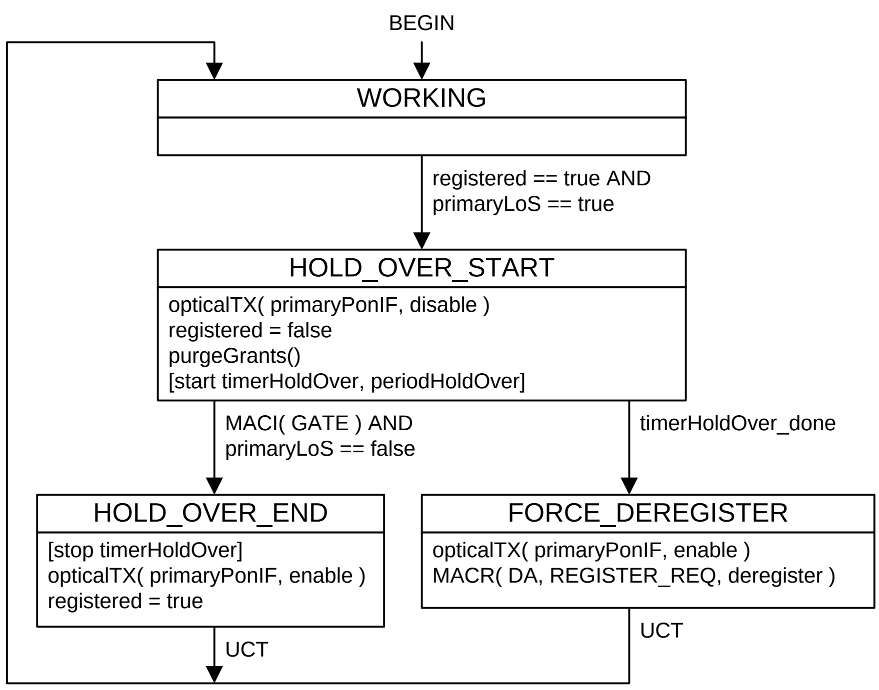


Figure 9-6—Trunk protection process operating on the ONU

9.3.4 Tree protection scheme

In the tree protection scheme, the entire ODN (trunk segment and branch segments) is protected against failure. As explained in 9.3.2.1, the OLT and ONUs may support line protection and/or client protection. The protection modes supported by an ONU is queried using the *aOnuProtectionCapability* (0xDB/0x09-00) attribute (see 14.4.9.1) and a specific mode is selected using the *aOnuConfigProtection* (0xDB/0x09-01) attribute (see 14.4.9.2).

The ONUs supporting the tree protection scheme instantiate two PON ports, i.e., each ONU contains two L-ONUs and it may also contain two C-ONUs. One of these L-ONUs is in the working state and the other L-ONU is in the standby state.

The OLT supporting the tree protection scheme instantiates two PON ports, i.e., it contains two L-OLTs and may also contain two C-OLTs. An L-OLT may serve as a working L-OLT for a subset of ONUs (a set of working L-ONUs) and simultaneously as a standby L-OLT for the remaining ONUs (standby L-ONUs), as shown in Figure 9-x.

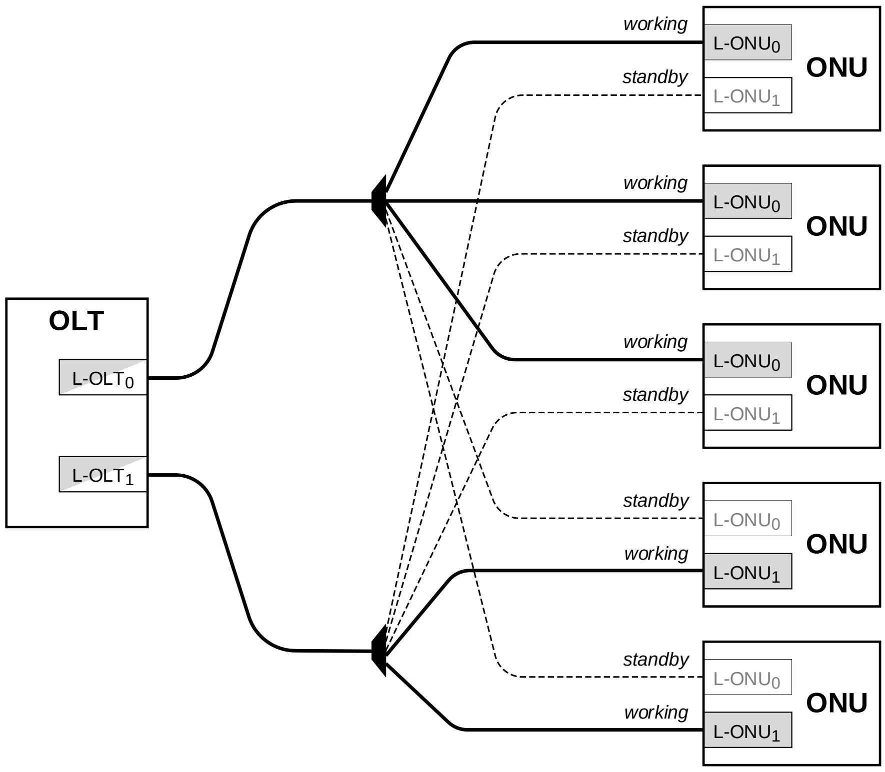


Figure 9 -x—L-OLT ports connected to working and standby L-ONUs

In the tree protection mode, the ONUs register separately on each PON interface. Both the working and the standby links are active and carry the system traffic: OAM/eOAM, CCP, and MPCP control frames. The working link also carries subscriber data frames.

9.3.4.1 Tree protection with redundant L-ONU

In the tree protection scheme that utilizes the redundant L-ONU, the OLT may comprise either the redundant L-OLT, as shown in Figure 9-7, or a redundant C-OLT, as shown in Figure 9-8.

Figure 9-7 presents a tree protection scheme with redundant L-OLTs, L-ONU, and ODN. In this scheme, the OLT and ONUs use a line protection architecture (see 9.3.2.1.1) sharing the MAC, MAC Control, and OAM Clients among the primary and the backup L-OLTs and primary and backup L-ONUs. This scheme reduces data loss during the protection switchover event since the data frames stored in MAC Client queues are redirected to another path. However, in this scheme the MAC, MAC Control, and OAM Clients are not protected against failures.

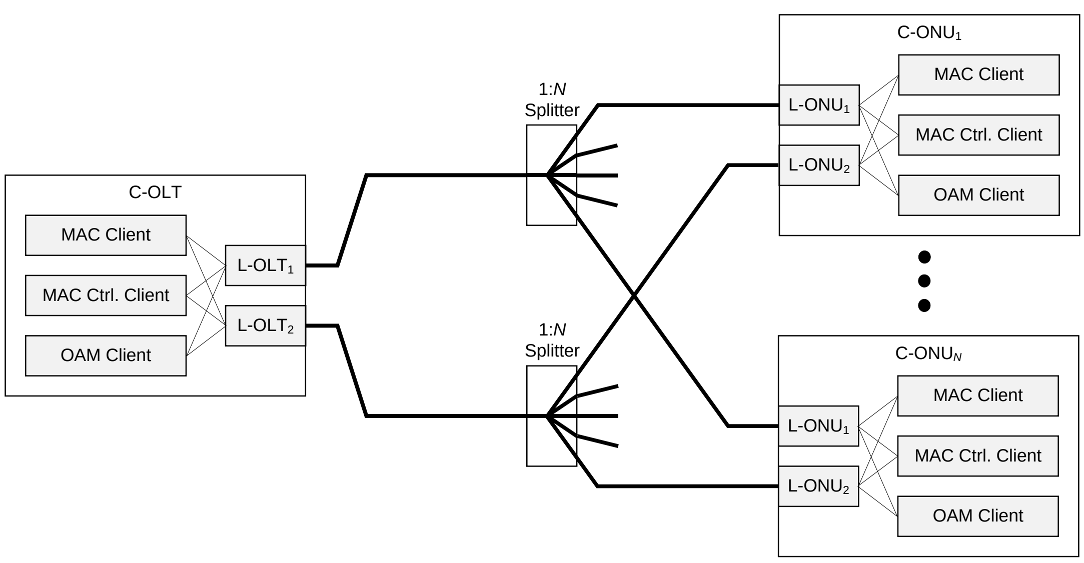


Figure 9-7—Tree protection with redundant L-OLT

An alternative configuration of the tree protection scheme is shown in Figure 9-8. This scheme provides added robustness as the whole C-OLT is duplicated, including the L-OLT and all MAC Clients. Similar to the trunk protection scheme with redundant C-OLT, the tree protection scheme with redundant C-OLT supports the inter-chassis protection, where the primary C-OLT and backup C-OLT are located in different chassis (either within the same central office or geographically different locations). The inter-chassis protection scheme requires coordination of the protection states and functions among the primary and backup C-OLTs comprising the trunk protection group and may require communication over LANs/WANs using public or proprietary protocols. The nature of information, data formats, and communications protocols used to coordinate protection functions among the primary and backup C-OLTs are outside the scope of this standard.

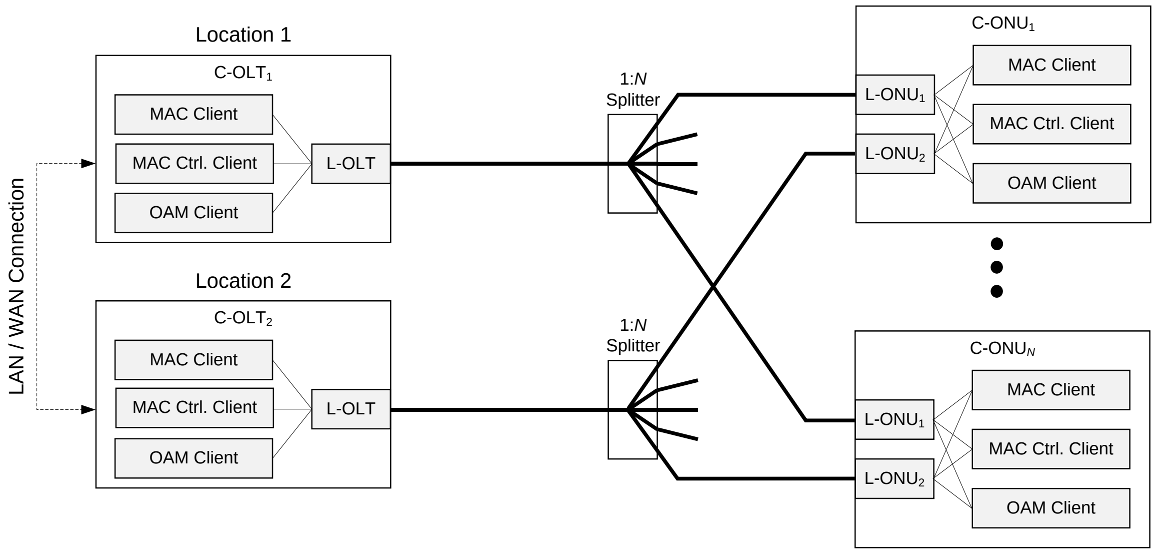


Figure 9-8—Tree protection with redundant C-OLT

9.3.4.2 Tree protection with redundant C-ONU

ONUs participating in tree protection schemes may implement Client ONU protection, in which MAC, MAC Control, and OAM Clients iare duplicated. Such schemes may have increased robustness due to added protection against ONU Client failures, at the expense of increased frame loss during the protection switchover event, as explained in 9.3.2.1.2.

The discovery, registration, as well as provisioning and configuration are performed independently for each of the C-ONU entities. Typically, both C-ONUs entities receive identical configuration.

The nature of information, data formats, and communications protocols used to coordinate protection functions among the primary and backup C-ONUs are outside the scope of this standard.

9.3.4.3 Functional requirements

The protection function present in the Operation, Administration, and Management block is responsible for switching between the primary and backup paths for subscriber data frames. The protection switching process in the tree protection scheme may be initiated in the following ways:

— Automatically, when either the OLT or the ONU detect any of the fault conditions on the working optical line using any of the mechanisms specified in the following subclauses; or

— On-demand, when the NMS issues the request to the OLT for a particular ONU to be switched to the standby path. This protection switching process is executed typically for operational reasons, e.g., fiber repairs, maintenance of OLT cards.

Upon detecting a line fault condition or for maintenance reasons, any ONU may be selectively switched from the working path to the standby path. This is accomplished using the *aOnuConfigPonActive* (0xDB/0x09-02) attribute (see 14.4.9.3). It is also possible to switch a group of ONUs simultaneously by transmitting the above attribute in an envelope with a multicast MLID (7.4.2.1.2).

The following subclauses provide technical requirements for the C-ONU and C-OLT devices participating in this protection scheme.

9.3.4.3.1 C-OLT requirements

In the tree protection mechanism, the OLT is connected to two optical links: the primary and backup link. Both the primary and the backup links are active and carry OAM, eOAM, CCP, and MPCP control frames. The working link also carries subscriber data frames.

The OLT shall execute the MPCP discovery and registration processes (per IEEE Std 802.3, 144.3.7), basic OAM discovery (per IEEE Std 802.3, Clause 57), extended OAM discovery (see TBD), and ONU authentication process (see TBD) if enabled, independently for the working and standby L-ONUs.

The OLT discovers the PON port instance number for a registered L-ONU and sets the corresponding LLIDs (PLID and MLID) to ‘primary’ if the ONU PON port instance is 0 and to ‘backup’ if the ONU PON port instance is 1. Therefore, all LLIDs associated with the primary ONU PON ports are designated as primary and all LLIDs associated with backup ONU PON ports are designated as backup.

After designating the primary and backup ports, the OLT discovers the ONU PON port instance that is currently in the working (active) state. The OLT does so by reading the value of the *aOnuConfigPonActive* attribute using the *PON Interface Administrate* TLV (see 14.4.9.3). The OLT then sets the corresponding LLID to the working (active) state. The OLT/NMS may also change the working/standby state of the PON ports in a registered ONU, for example, for load balancing purposes. When the PON port state changes, the OLT also updates the states of the LLIDs associated with this PON port.

All ULIDs or GLID provisioned using the working MLID are also designated as working ULIDs/GLIDs. The ULIDs or GLID provisioned using the standby MLID are designated as standby ULIDs/GLIDs.

The OLT shall block any downstream user traffic on standby ULIDs/GLIDs. Upon the swichover event, the state of the standby ULIDs/GLIDs changes to working and these LLIDs are allowed to carry user traffic. The LLIDs that were in the working state before the switchover event are now in standby state and are no longer allowed to carry user data.

The OLT shall issue GATE MPCPDUs for both working and standby PLIDs to ensure normal operation of the MPCP. The OLT shall suppress generation of any alarms and warnings associated with the arrival of empty/underutilized upstream transmission slots associated with the standby LLIDs.

The protection function present in the Operation, Administration, and Management block is responsible for switching the subscriber data frames between the primary and backup ULIDs provisioned in given ONU. The switching time between the working ULID and standby ULID shall be less than or equal to 50 ms. The definition of the switching time is given in 9.3.1.1.

The OLT shall monitor the status of the optical line (i.e., working LLIDs). Several failure scenarios are possible, as presented in **Error! Reference source not found.**. Unlike the trunk protection case, where all ONUs are switched from working L-OLT to standby L-OLT together, in the tree protection scheme, ONUs are switched to standby path selectively. When a line failure is detected for a particular ONU, that ONU is switched to the standby optical path, while all other ONUs continue operation without any changes.

The OLT shall notify the NMS about the detected line failure condition(s) and the line switch event for a particular ONU. This allows the operator to undertake any necessary repair/replacement tasks.

To request an ONU to switch user traffic from the working to the standby data path, the OLT sends to this ONU the *PON Interface Administrate* TLV, as defined in 14.4.9.3**Error! Reference source not found.**.

Given that the standby PLID remains at all times registered at the OLT and synchronized to the respective MPCP domain clock, the transmission of the forced synchronization *GATE* MPCPDUs as defined for the trunk protection scheme is not required (see 9.3.3.1.1).

The tree protection process is defined in 9.3.4.5. The OLT protection function instantiates the state diagram per Figure 9-13.

9.3.4.3.2 C-ONU requirements

In the tree protection mechanism, the C-ONU contains two L-ONUs: a primary L-ONU and a backup L-ONU. The ONU shall execute the MPCP discovery and registration processes (per IEEE Std 802.3, 144.3.7), basic OAM discovery (per IEEE Std 802.3, Clause 57), extended OAM discovery (see TBD), and ONU authentication process (see TBD) if it is enabled, independently for the primary and backup L-ONUs.

The primary and the backup L-ONUs remain at all times registered at the OLT and synchronized to the respective primary or backup MPCP domain clock. At all times, one of the L-ONUs is in a working state, while the other one is in the standby state. By default, the primary L-ONU is designated as the working L-ONU. Both the working and the standby L-ONUs exchange the OAM, eOAM, CCP, and MPCP control frames with the OLT; however, the subscriber traffic is carried only on the ULIDs and GLIDs instantiated in the working L-ONU.

The working L-ONU monitors the status of the upstream and downstream optical links. When the working L-ONU detects a downstream line failure using any of the mechanisms defined in 9.3.2.2.2, the working and the standby L-ONUs switch roles, and all subscriber flows are forwarded to the new working L-ONU. The ONU also may swap the working and standby states of its primary and backup L-ONUs in response to the *PON Interface Administrate* TLV (see 14.4.9.3) received from the NMS. The switching time between the working L-ONU and standby L-ONU shall be less than or equal to 50 ms. The definition of the switching time is given in 9.3.1.1.

During the switchover event, there are no changes in the registration status or operation of the primary and backup L-ONUs, except the reversing of their working and standby roles, i.e., the L-ONU previously in standby state becomes the working L-ONU and starts carrying subscriber traffic, while the L-ONU previously in working state becomes the standby L-ONU.

After the switchover completes, the new working L-ONU shall send the PON_IF_Switch event OAMPDU as defined in 13.4.4.2.8, carrying the information about the type of detected failure. This improves the reaction time of the working L-OLT to the downstream line failure condition. No automatic switchback to the original working L-ONU is performed; the working L-ONU continues forwarding subscriber traffic until it is instructed by the NMS to perform a switchover or a failure detected on its new working path.

The tree protection process is defined in 9.3.4.5. The ONU protection function instantiates the state diagram per Figure 9-14.

9.3.4.4 Operation of tree protection switching

The following subclauses describe the operation of tree protection switching under various failure detection scenarios.

9.3.4.4.1 NMS-driven tree line switchover event

Figure9-9 represents the NMS-driven protection switching scenario, where the decision to switch user traffic from the working path to the standby path is taken by the NMS, e.g., to perform routine maintenance tasks or replace line cards in the OLT shelf. In such a situation, the NMS requests the OLT to switch traffic from the working to the standby data path. The OLT performs the necessary local actions and also transmits the *PON Interface Administrate* TLV, as defined in 14.4.9.3, to the working C-ONU requesting it to perform the protection switching.

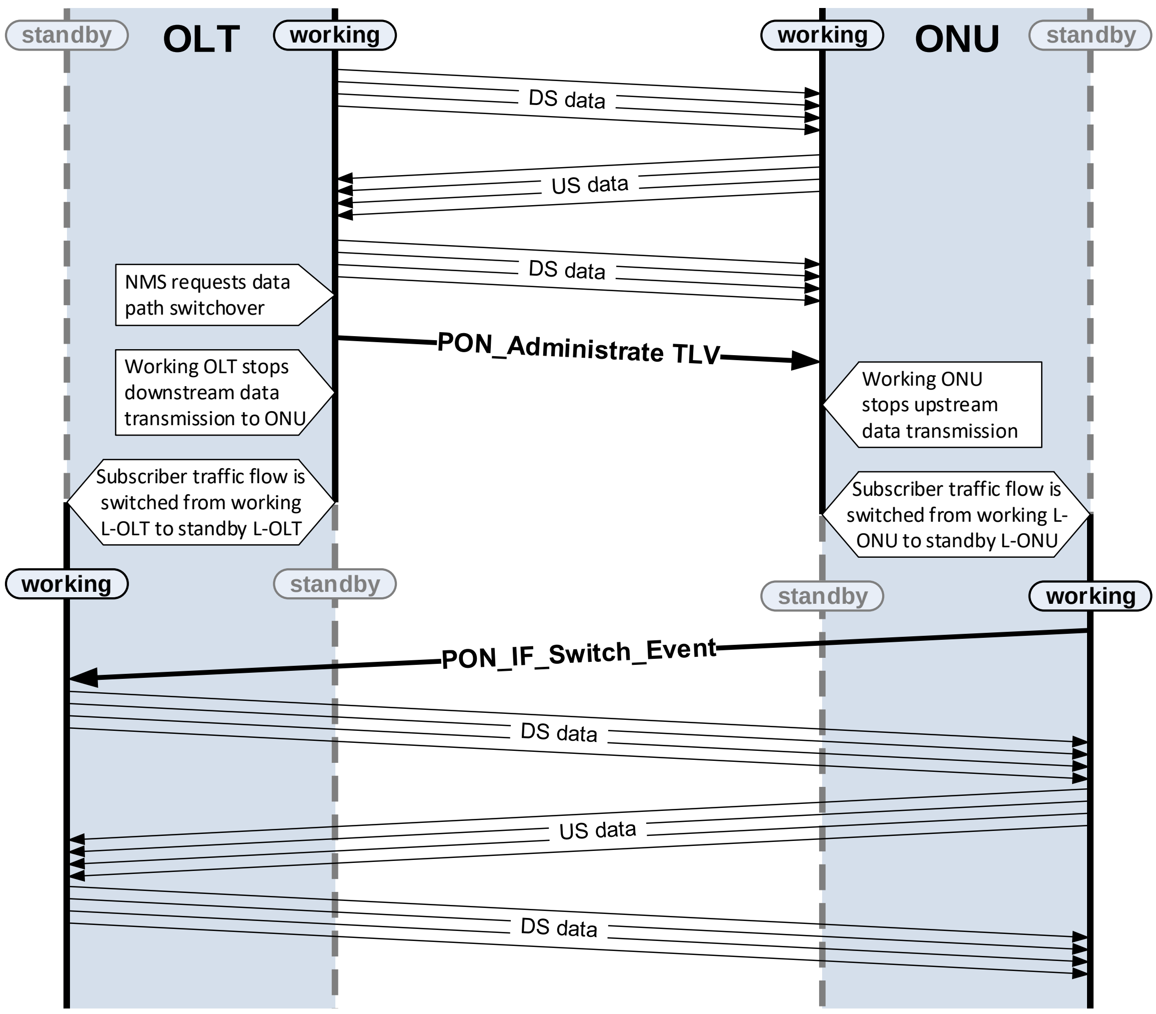


Figure 9-9—An example of tree protection switching: NMS driven request

9.3.4.4.2 Automated tree line switching with line failure detection

When both the downstream and upstream data paths fail, both the working OLT and working ONU can detect the link fault condition. In such a case, both the working OLT and working ONU perform protection switching, as shown in Figure 9-10.

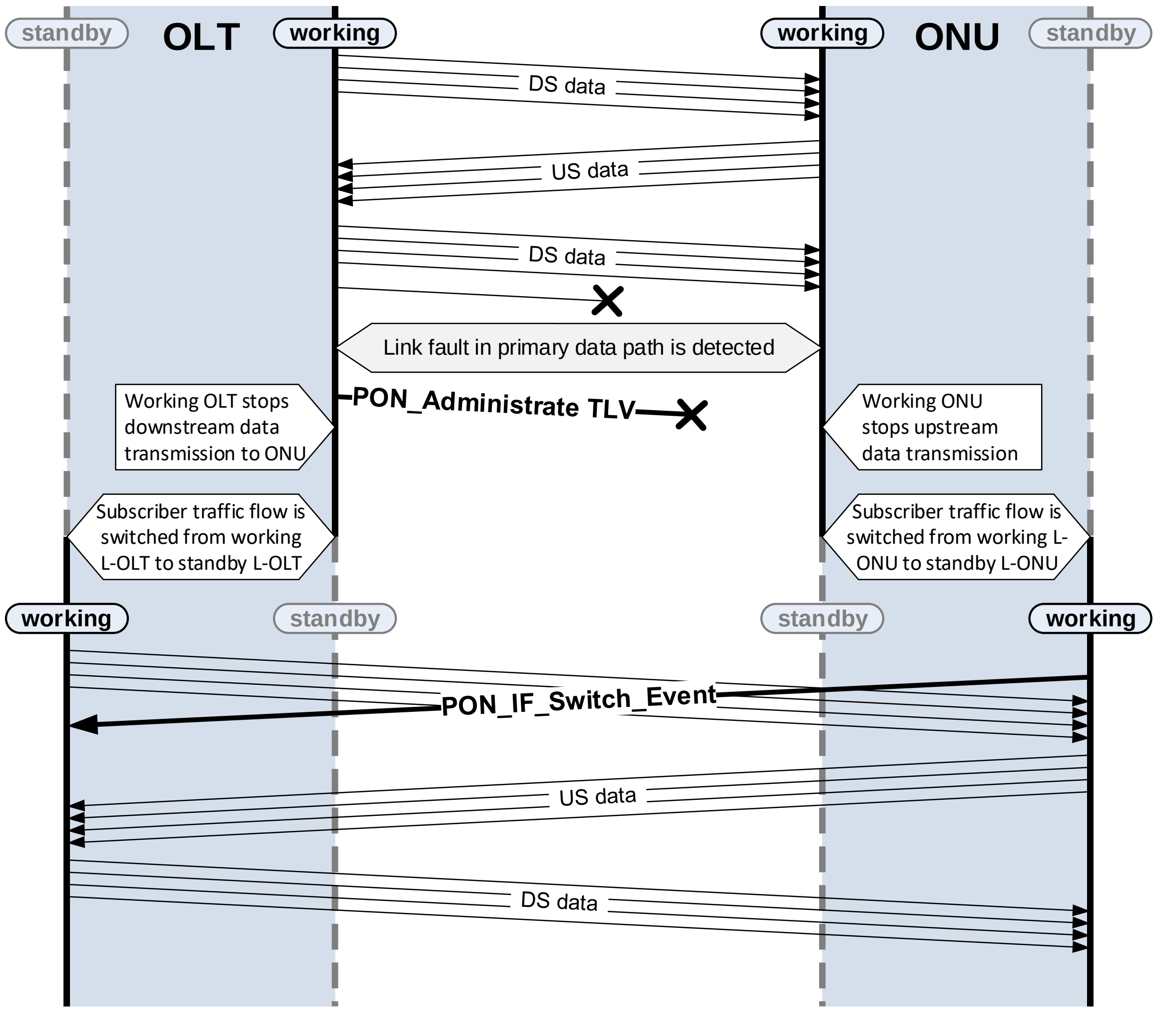


Figure 9-10—An example of tree protection switching: link failure detected by working OLT and working C-ONU

9.3.4.4.3 Automated tree line switching with upstream line failure detection

When the upstream data path suffers a failure (e.g., ONU transmitter fails or OLT receiver fails), the working OLT can detect such an occurrence and initiate the protection switching process. As indicated before, the working OLT sends the *PON Interface Administrate* TLV, as defined in 14.4.9.3, downstream to the working ONU, forcing it to switch all its traffic to the standby data path. Once the process is complete, the new working ONU sends the

PON_IF_Switch event notification, allowing the OLT to confirm that the process was successfully completed on the ONU side. This scenario is shown in Figure 9-11.

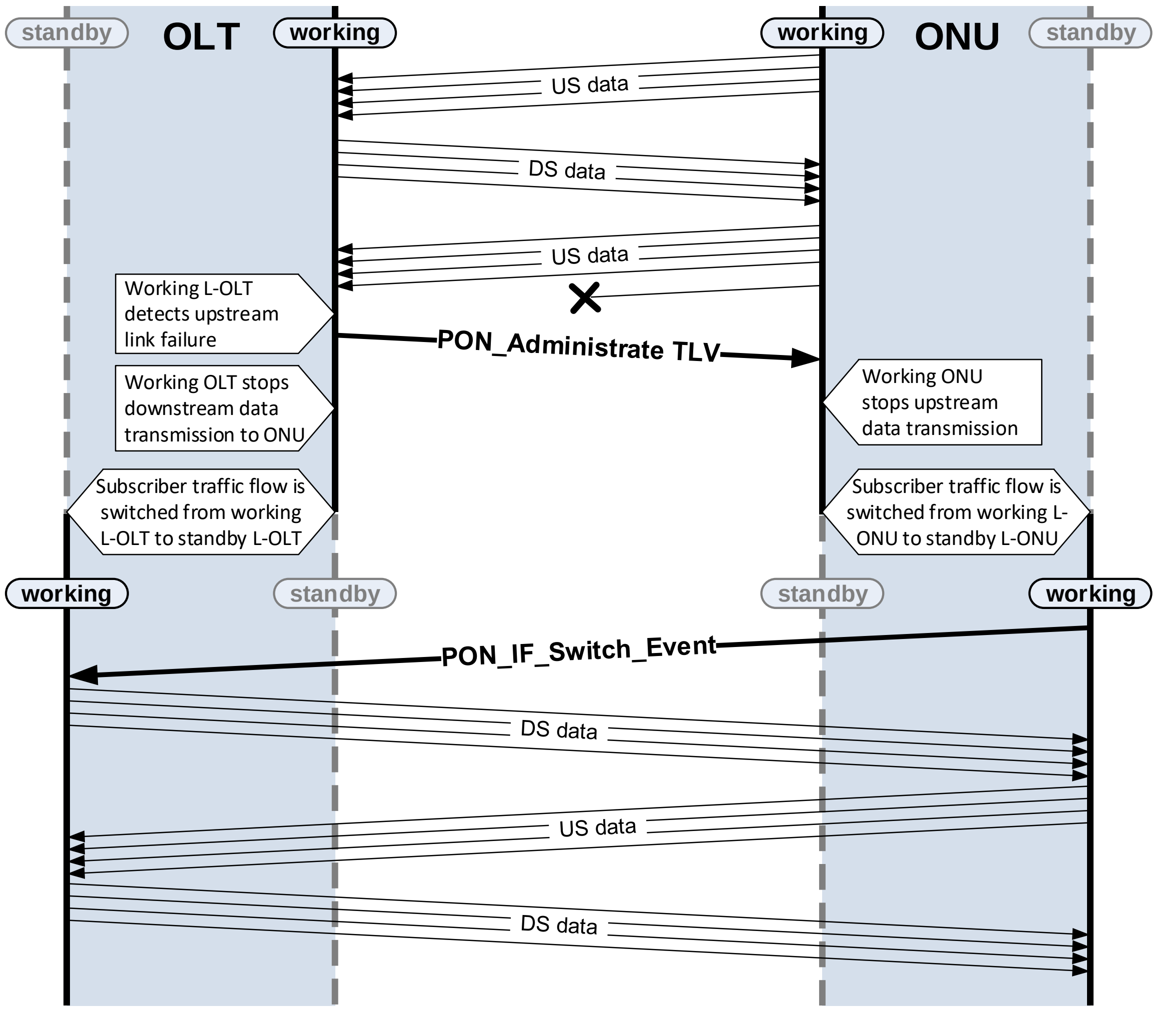


Figure 9-11—An example of tree protection switching: upstream link failure detected by working OLT

9.3.4.4.4 Automated tree line switching with downstream line failure detection

In a scenario when the downstream data path suffers a failure (e.g., ONU receiver fails or OLT transmitter fails), only the working ONU can detect such an occurrence and initiate the protection switching process. In this case, it is the working ONU that starts the protection switching by suspending any upstream transmissions to the working OLT once the downstream channel is found to be defective. At this stage, the working ONU switches the traffic to the standby ONU and transmits the PON_IF_Switch event notification to the working OLT. Upon reception of the PON_IF_Switch event notification from its current standby MAC port, the OLT suspends the data transmission to the corresponding working MAC port and activates the standby MAC port. This scenario is shown in Figure 9-12.

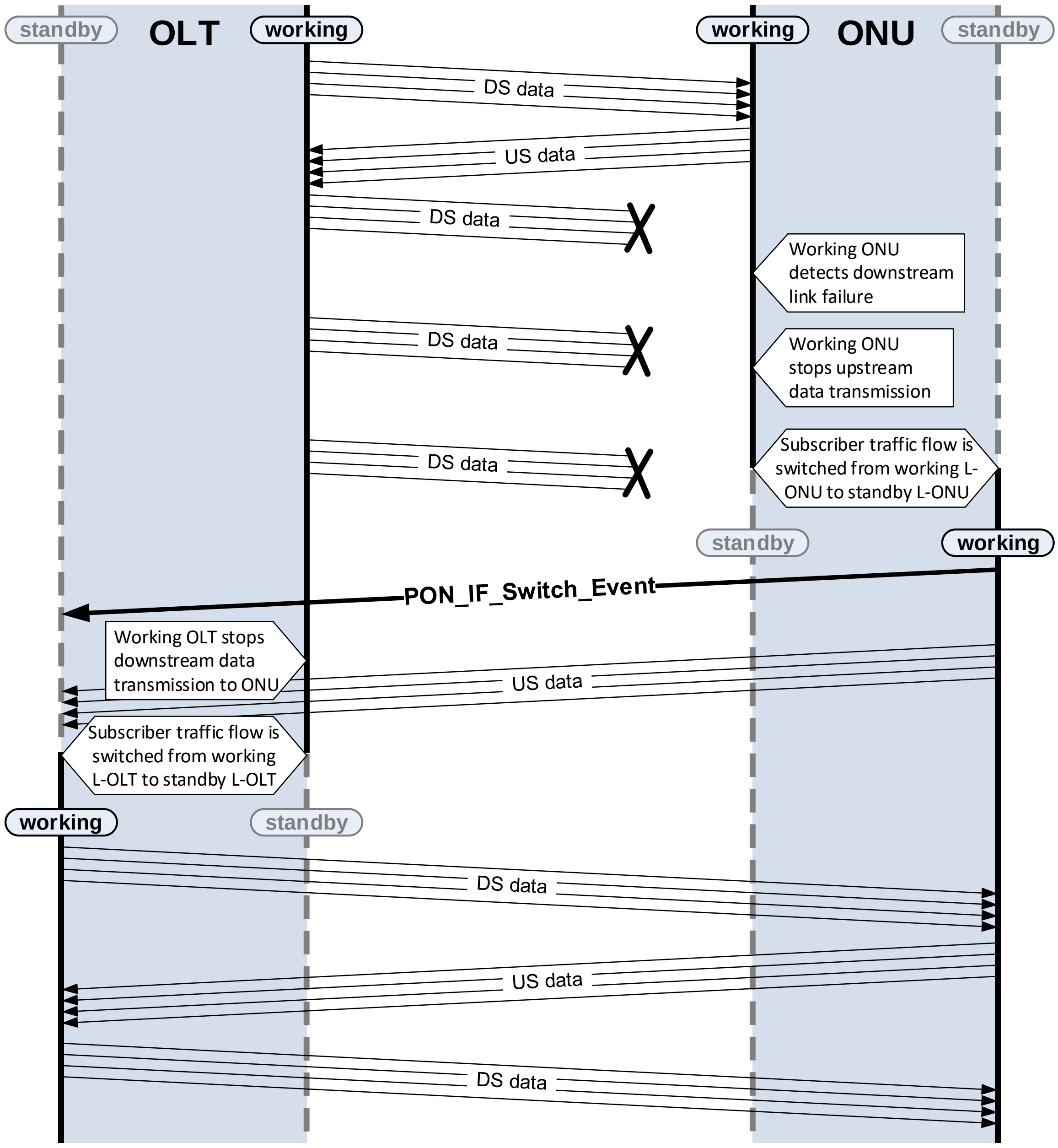


Figure 9-12—An example of tree protection switching: downstream link failure detected by working ONU

9.3.4.5 Tree protection process

The OLT shall instantiate an independent tree protection process per each connected ONU. At the OLT, all the constants, variables, and functions defined in 9.3.4.5.1 through 9.3.4.5.4 are instantiated per each connected ONU.

An instance of the state diagram defined in Figure 9-18.a shall be associated with the primary PON port of each connected ONU, and an instance of the state diagram defined in Figure 9-18.b shall be associated with the backup PON port of each connected ONU. At the OLT implementing the client protection (9.3.2.1.2), the above-mentioned state diagrams may be located in separate C-OLTs, possibly in geographically separate locations. In the OLT implementing the line protection (9.3.2.1.1), the two state diagrams are combined within a single C-OLT.

The ONU shall instantiate the tree protection process state diagram as defined in Figure 9-14.a for the primary L-ONU instantiated in this C-ONU, and it shall instantiate the tree protection process state diagram as defined in Figure 9-14.b for the backup L-ONU instantiated in this C-ONU. In the case where Client ONU protection is implemented (i.e., when two C-ONU are used), the combined operation of both C-ONUs shall be as defined in Figure 9-14.

9.3.4.5.1 Constants

`backupPort`

TYPE: 8-bit unsigned integer

This constant identifies the backup port in the OLT or in the ONU. The backup port in the OLT represents a virtual PON port that is connected to the backup PON port in a given ONU (L-ONU), i.e., both ports are attached to the same physical media.

VALUE: 0x01

`primaryPort`

TYPE: 8-bit unsigned integer

This constant identifies the primary port in the OLT or in the ONU. The primary port in the OLT represents a virtual PON port that is connected to the primary port in a given ONU (L-ONU), i.e., both ports are attached to the same physical media.

VALUE: 0x00

9.3.4.5.2 Variables

`backupPortStatus`

TYPE: Enumerated

This variable represents current status of the backup port in the OLT (virtual port) or in the ONU (physical port). It can take the following values:

- `OK` (0x00-00-00-00): backup port operates normally.
- `LOS` (0x00-00-00-01): indicates that the MAC LoS or optical LoS condition is observed by the backup port at the OLT, as defined in 9.3.2.2.1, or by the backup port at the ONU, as defined in 9.3.2.2.2.
- `MPCP` (0x00-00-00-02): indicates that the `mpcp_timeout` condition, as defined in IEEE Std 802.3, 64.3.4.2, is observed by the backup L-OLT or by the backup L-ONU.
- `BER` (0x00-00-00-03): indicates that the BER of the signal received by the backup port at the OLT or at the ONU exceeds a certain, operator-defined threshold.
- `PORT` (0x00-00-00-04): indicates that the power levels of the signal received by the backup port at the OLT or at the ONU exceeds a certain, operator-defined high or low threshold.
- `OLT_REQ` (0x00-00-00-05): indicates that the backup port is placed in the standby mode (deactivated) based on OLT (NMS) request. At the OLT, `backupPortStatus` is set to `OLT_REQ` upon the reception of `NMSR( switch, primaryPort, indexONU )` primitive defined in 9.3.4.5.4. At the ONU, `backupPortStatus` is set to `OLT_REQ` upon the reception of `eOAMI_Switch_Request( primaryPort )` primitive on either the primary or the backup port.
- `ONU_REQ` (0x00-00-00-06): indicates that the OLT's backup port is placed in the standby mode (deactivated) based on the ONU's request.

`dataFrameReceived`

TYPE: Boolean

This variable indicates that a frame other than the MPCPDU, CCPDU, or OAMPDU is received at the given port. When the data frame is received, this variable is set to `true`. It retains the value until explicitly reset.

`primaryPortStatus`

TYPE: Enumerated

This variable represents current status of the primary port in the OLT (virtual port) or in the ONU (physical port). It can take the following values:

- `OK` (0x00-00-00-00): primary port operates normally.
- `LOS` (0x00-00-00-01): indicates that the MAC LoS or optical LoS condition is observed by the primary port at the OLT, as defined in 9.3.2.2.1, or by the primary port at the ONU, as defined in 9.3.2.2.2.
- `MPCP` (0x00-00-00-02): indicates that the `mpcp_timeout` condition, as defined in IEEE Std 802.3, 64.3.4.2, is observed by the primary L-OLT or by the primary L-ONU.
- `BER` (0x00-00-00-03): indicates that the BER of the signal received by the primary port at the OLT or at the ONU exceeds a certain, operator-defined threshold.
- `PORT` (0x00-00-00-04): indicates that the power levels of the signal received by the primary port at the OLT or at the ONU exceeds a certain, operator-defined high or low threshold.
- `OLT_REQ` (0x00-00-00-05): indicates that the primary port is placed in the standby mode (deactivated) based on OLT (NMS) request. At the OLT, `primaryPortStatus` is set to `OLT_REQ` upon the reception of `NMSR( switch, backupPort, indexONU )` primitive defined in 9.3.4.5.4. At the ONU, `primaryPortStatus` is set to `OLT_REQ` upon the reception of `eOAMI_Switch_Request( backupPort )` primitive on either the primary or the backup port.
- `ONU_REQ` (0x00-00-00-06): indicates that the OLT's primary port is placed in the standby mode (deactivated) based on the ONU's request.

`workingPort`

TYPE: 8-bit unsigned integer

This variable represents the currently working port in the OLT or in the ONU. It can take values `primaryPort` or `backupPort` (see 9.3.4.5.1). In the ONU, this variable retains its value across the reset or reboot. By default, this variable has the value of `primaryPort`.

9.3.4.5.3 Functions

`activateDataPath( portId )`

This function activates, i.e., places into the working state, the port identified by the `portId` parameter. In the working state, a port is able to transmit MPCPDUs, CCPDUs, OAMPDUs, and subscriber data frames. In the OLT, activating the data path for a given virtual PON port involves updating the states of all LLIDs associated with the corresponding L-ONU from standby to working. This action permits the ULIDs and GLIDs to carry user traffic.

`deactivateDataPath( portId )`

This function deactivates, i.e., places into the standby state, the port identified by the `portId` parameter. In the standby state, a port is able to transmit MPCPDUs, CCPDUs, and OAMPDUs, but not subscriber data frames. In the OLT, deactivating the data path for a given virtual PON port involves updating the states of all LLIDs associated with the corresponding L-ONU from working to standby. This action forbids the ULIDs and GLIDs to carry user traffic.

9.3.4.5.4 Primitives

`eOAMI_Switch_Event()`

This primitive represents the reception of an eOAMPDU containing a PON_IF_Switch event, as defined in 9.2.4.8. `SIEPON_Event_TLV` represents the SIEPON-specific *Event Notification* TLV as defined in 13.4.4.2. This primitive replaces the following code:

```
OPI( source_address, flags, code, sequence_number | SIEPON_Event_TLV )
AND

source_address                       == ONU_MAC AND
code                                 == 0x01 AND
SIEPON_Event_TLV.Type                == 0xFE AND
SIEPON_Event_TLV.Length              == 0x06 AND
SIEPON_Event_TLV.OUI                 == OUI_1904_4 AND
SIEPON_Event_TLV.EventCode           == 0x84 AND
SIEPON_Event_TLV.EventRaised         == 0x00 AND
SIEPON_Event_TLV.ObjectType          == 0x00-00 AND
SIEPON_Event_TLV.ObjectInstance      == 0x00-00
```

The eOAMPDU containing a PON_IF_Switch event may also contain other *Link Event* TLVs, as defined in IEEE Std 802.3, 57.4.3.2.

`eOAMI_Switch_Request( portId )`

This primitive represents the reception of an eOAMPDU containing the *PON Interface Administrate* TLV (0xDB/0x09-02), as defined in 14.4.9.3. This primitive replaces the following code:

```
OPI( source_address, flags, code, OUI_1904_4 | Opcode | PON_IF_TLV )
AND

source_address                       == OLT MAC AND
code                                 == 0xFE AND
Opcode                               == 0x03 AND
PON_IF_TLV.Branch                    == 0xDB AND
PON_IF_TLV.Leaf                      == 0x00-16 AND
PON_IF_TLV.Length                    == 0x01 AND
PON_IF_TLV.PonPortActive             == portId
```

`eOAMR_Switch_Event( failureCode )`

This primitive represents the transmission of an eOAMPDU containing a PON_IF_Switch event as defined in 9.2.4.8. `SIEPON_Event_TLV` represents the SIEPON-specific *Event Notification* TLV as defined in 13.4.4.2. This primitive replaces the following code:

```
source_address                              = ONU_MAC
code                                        = 0x01
SIEPON_Event_TLV.Type                       = 0xFE
SIEPON_Event_TLV.Length                     = 0x06
SIEPON_Event_TLV.OUI                        = OUI_1904_4
SIEPON_Event_TLV.EventCode                  = 0x84
SIEPON_Event_TLV.EventRaised                = 0x00
SIEPON_Event_TLV.ObjectType                 = 0x00-00
SIEPON_Event_TLV.ObjectInstance             = 0x00-00
SIEPON_Event_TLV.EventInfo                  = failureCode

OPR( source_address, flags, code, sequence_number | SIEPON_Event_TLV )
```

The eOAMPDU containing a PON_IF_Switch event may also contain other *Link Event* TLVs, as defined in IEEE Std 802.3, 57.4.3.2.

`eOAMR_Switch_Request( portId )`

This primitive represents the transmission of an eOAMPDU containing the *PON Interface Administrate* TLV (0xDB/0x09-02), as defined in 14.4.9.3. This primitive replaces the following code:

```
source_address                              = OLT_MAC
code                                        = 0xFE
Opcode                                      = 0x03
PON_IF_TLV.Branch                           = 0xDB
PON_IF_TLV.Leaf                             = 0x00-16
PON_IF_TLV.Length                           = 0x01
PON_IF_TLV.PonPortActive                    = portId

OPR( source_address, flags, code, OUI_1904_4 | Opcode | PON_IF_TLV )
```

`NMSI_1( failureCode, indexONU )`

This primitive informs the NMS about the protection switching event, initiated by the OLT, that placed the `primaryPort` in the working state. This primitive uses the following parameters:

— `failureCode` identifies the reason for the protection switching, per 9.2.4.7;

— `indexONU` identifies the affected L-ONU.

`NMSI_2( failureCode, indexONU )`

This primitive informs the NMS about the protection switching event, initiated by the ONU, that placed the `primaryPort` in the working state. This primitive uses parameters identical to the parameters defined for the `NMSI_1` primitive.

`NMSI_3( failureCode, indexONU )`

This primitive informs the NMS about the protection switching event, initiated by the OLT, that placed the `backupPort` in the working state. This primitive uses parameters identical to the parameters defined for the `NMSI_1` primitive.

`NMSI_4( failureCode, indexONU )`

This primitive informs the NMS about the protection switching event, initiated by the ONU, that placed the `backupPort` in the working state. This primitive uses parameters identical to the parameters defined for the `NMSI_1` primitive.

`NMSR( switch, portId, indexONU )`

This primitive is used by the NMS to perform the protection switching of the L-ONU, identified by the `indexONU` parameter, from its current working port to the port indentified by the `portId` parameter.

9.3.4.5.5 State diagrams

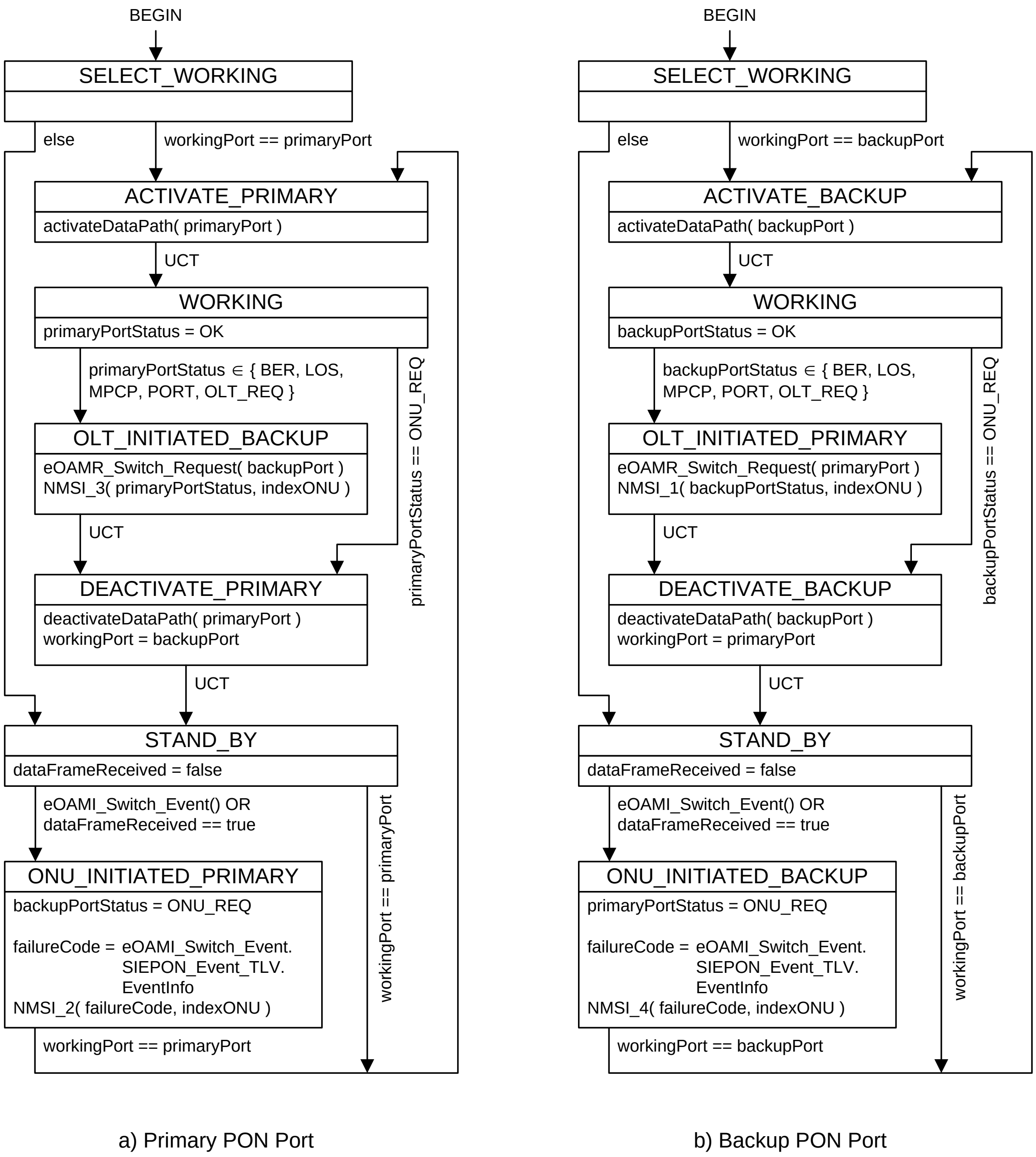
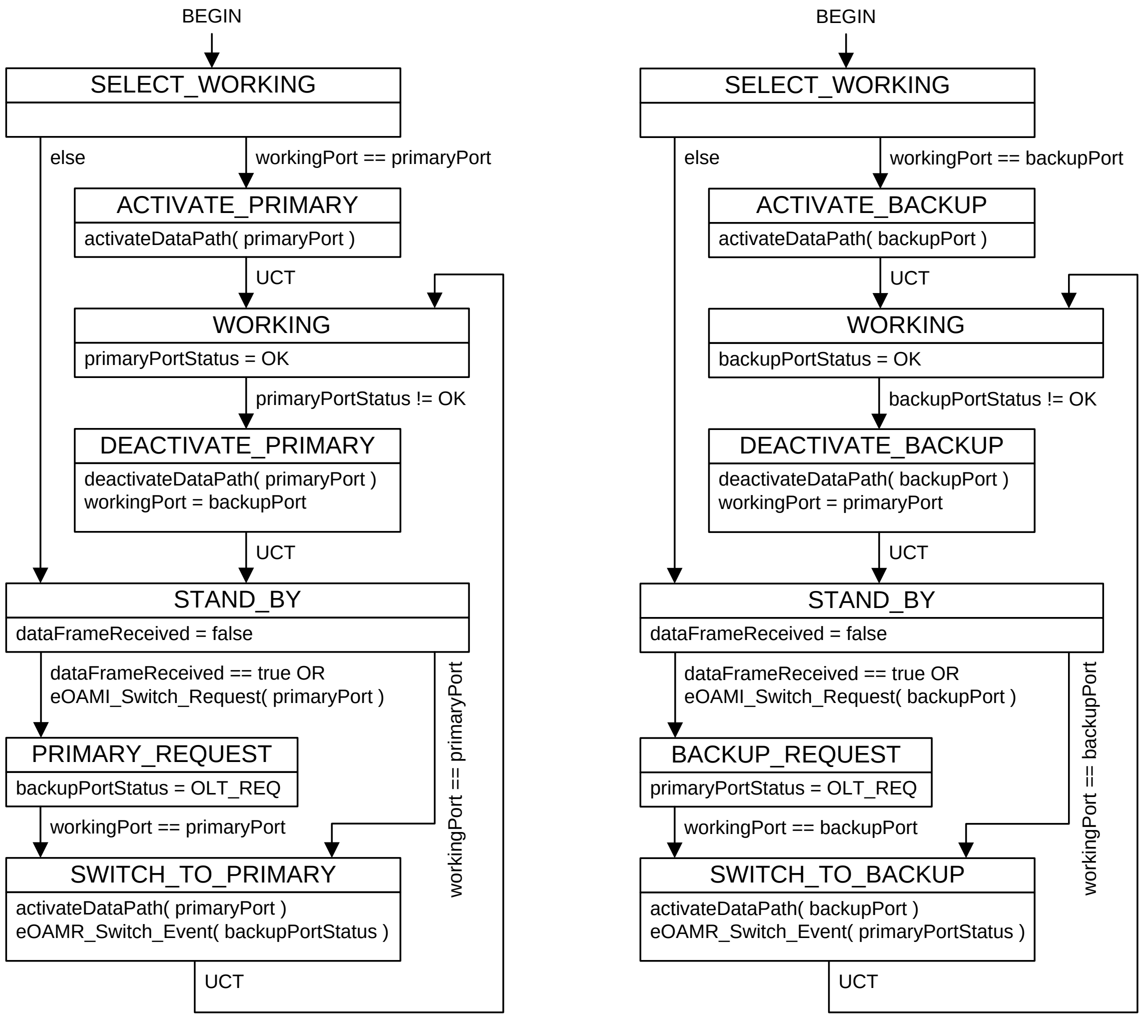


Figure 9-13—Tree protection process operating on the OLT



a) Primary PON Port b) Backup PON Port

Figure 9-14—Tree protection process operating on the ONU

13 Extended OAM for Nx25G-EPON

13.1 Introduction

13.2 Requirements

13.3 Device discovery and capability discovery

13.4 eOAMPDU structure

13.4.1 Extended OAM organizationally-unique identifier (OUI)

13.4.2 eOAMPDU frame format

13.4.3 TLV-oriented structure

13.4.4 TLVs for 802.3 OAMPDUs

13.4.4.1 *Extended Information* TLV

13.4.4.2 *Event Notification* TLV

The basic structure of the *Organization Specific Event* TLV shall be as specified in IEEE Std 802.3, 57.5.3.5. Specific fields in the *Organization Specific Event* TLV shall be as shown in Figure 13-15 and specified below.

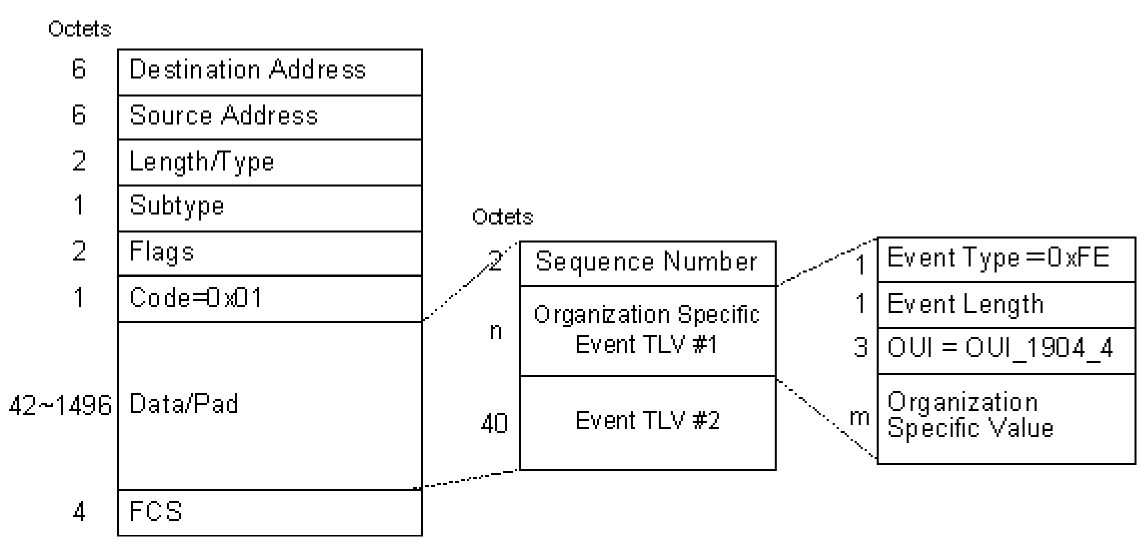


Figure 13-15—Relationship between *Organization Specific Event* TLV and the *Event Notification* OAMPDU

a) `Event Type` = 0xFE, according to the encoding of this field as defined in IEEE Std 802.3, Table 57–12.

b) `Event Length`. This one-octet field indicates the length (in octets) of this TLV-tuple.

c) `OUI` value, equal to OUI_1904_4.

d) `Organization Specific Value` carries the specific set of event-associated information. Further, the structure of the `Organization Specific Value` shall be as specified in Table 13-1 and described below.

Table 13-1—Internal structure of the `Organization Specific Value` field

Octet(s)	Field	Notes
1	EventCode	This field identifies the type of alarm that was identified by the source OAM client. See Table 13-2 for definition of individual values for the `EventCode` field. These alarm codes are grouped into link faults, critical events, and Dying Gasp alarm types, with code values numbered accordingly. Only the values listed in the table are supported. Other values are reserved and ignored on reception.
1	EventRaised	This field indicates whether the given event was raised. The following values are supported: 0x00: The given event was cleared. 0x01: The given event was raised. Other values are reserved and ignored on reception.
2	ObjectType	This field identifies the object element generating the alarm in question.
1, 2, or 4	ObjectInstance	This field identifies the object element instance generating the alarm in question.

Octet(s)	Field	Notes
2	EventTimeStamp	Identifies the time at which the given event occurred.
0 or 4	EventInfo	Provides additional information related to the given alarm or warning event.

— `ObjectType` field identifies the object that generated the given event, as defined in 14.2.1.1. Other values of the `ObjectType` are reserved and ignored on reception.

— `ObjectInstance` field identifies the specific instance of the object that generated the given event, as defined in 14.2.1.2.

— `EventTimeStamp` field identifies the time at which the given event occurred. This field shall be filled in by the ONU at the time the given event notification OAMPDU is created, using the same clock as the basic OAM Link Event TLVs (see IEEE Std 802.3, 57.5.3).

— `EventInfo` optional field provides additional information related to the given alarm/warning event. The content of this field depends on the definition of the given alarm/warning as specified in 9.2.3, 9.2.4, and 9.2.5.

Table 13-2—Code points for the `EventCode` field

Event Group	Event Name	Code	Defined in
Link Fault Alarms	LoS	0x11	13.4.4.2.1
	Key Exchange Failure	0x12	13.4.4.2.2
Critical Event Alarms	Port Disabled	0x21	13.4.4.2.3
Dying Gasp Alarms	Power Failure	0x41	13.4.4.2.4
Other Alarms	Statistics Alarm	0x81	13.4.4.2.5
	ONU Busy	0x82	13.4.4.2.6
	MAC Table Overflow	0x83	13.4.4.2.7
	PON_IF_Switch	0x84	13.4.4.2.8

An ONU may transmit any alarm via any L-ONU, i.e., on any bi-directional MLID registered at that ONU.

13.4.4.2.1 LoS (0x11)

For the PON port, a loss of signal (LoS) condition is detected by lack of incoming optical power or loss of clock and data recovery lock to the downstream bit clock. The transceiver status monitoring for the ONU and the OLT is as specified in 9.1.3. On any of the UNI ports, the LoS condition corresponds to the Link Down condition detected by the UNI port PHY.

13.4.4.2.2 Key Exchange Failure (0x12)

The Key Exchange Failure alarm indicates that a scheduled key exchange has failed. Encryption continues with the previous key for another key exchange interval. Another key exchange is attempted at the next key exchange time.

13.4.4.2.3 Port Disabled (0x21)

The Port Disabled event indicates that one of the ONU ports has been disabled by management action. If the PON port is disabled, then this event notification is not transmitted, and this alarm is visible only locally on the ONU.

13.4.4.2.4 Power Failure (0x41)

A Power Failure alarm indicates that the ONU lost power and is imminently going to be removed from the EPON. An ONU makes every attempt to send this *Event Notification* TLV when it detects loss of power. An ONU may not be able to actually send this *Event Notification* TLV if the required transmission grants are not allocated by the OLT before the ONU runs out of power.

13.4.4.2.5 Statistics Alarm (0x81)

The Statistics Alarm indicates a crossing of predefined thresholds on a specific statistic, as indicated by the *Alarm* TLV, as defined in Table 13-3. Typically, these thresholds would be set for counters for error conditions such as CRC errors.

Table 13-3—*Alarm* TLV structure

Size (octets)	Field (name)	Value
1	Branch	Branch of statistic that crossed threshold
2	Leaf	Leaf of statistic that crossed threshold

13.4.4.2.6 ONU Busy (0x82)

The ONU Busy alarm may be raised by an ONU to inform the OLT that it has been busy for an extended period and may have problems responding to any further OAM requests in the usual timely fashion.

13.4.4.2.7 MAC Table Overflow (0x83)

The MAC Table Overflow alarm is raised by an ONU to inform the OLT that an ingress MAC address has not been learned because the total number of MAC addresses has been exceeded. For example, if the ONU was provisioned to allow four MAC addresses on a particular UNI port, then the first four addresses seen would be learned; the fifth address would cause this alarm to be raised.

13.4.4.2.8 PON_IF_Switch (0x84)

The PON_IF_Switch alarm is raised by the ONU to inform the OLT that the PON interface on the ONU was switched from the active interface to backup interface, according to the tree protection mechanism defined in 9.3.4.

14 Management entities

14.4 Branch 0xDB "extended attributes"

14.4.9 Optical Link Protection

14.4.9.1 Attribute *aOnuProtectionCapability* (0xDB/0x09-00)

This attribute represents the ONU's optical link protection capabilities, including support for trunk and tree protection modes. This attribute consists of the following sub-attributes: *sSupportTrunk*, *sSupportTreeLine*, and *sSupportTreeClient*.

Sub-attribute *aOnuProtectionCapability.sSupportTrunk*:

Syntax: Boolean
Remote access: Read-Only
Description: This sub-attribute indicates whether the ONU supports the trunk protection scheme (see 9.3.3). The following values are defined:

`supported`: Trunk protection scheme is supported.
`not_supported`: Trunk protection scheme is not supported.

Sub-attribute *aOnuProtectionCapability.sSupportTreeLine*:

Syntax: Boolean
Remote access: Read-Only
Description: This sub-attribute indicates whether the ONU supports the tree protection scheme (see 9.3.4) utilizing L-ONU protection switching (9.3.2.1.1). The following values are defined:

`supported`: Tree protection scheme with L-ONU protection switching is supported.
`not_supported`: Tree protection scheme with L-ONU protection switching is not supported.

Sub-attribute *aOnuProtectionCapability.sSupportTreeClient*:

Syntax: Boolean
Remote access: Read-Only
Description: This sub-attribute indicates whether the ONU supports the tree protection scheme (see 9.3.4) utilizing C-ONU protection switching (9.3.2.1.2). The following values are defined:

`supported`: Tree protection scheme with C-ONU protection switching is supported.
`not_supported`: Tree protection scheme with C-ONU protection switching is not supported.

The *aOnuProtectionCapability* attribute is associated with the ONU object (see 14.2.1). The Variable Container TLV for the *aProtectionCapability* attribute shall be as specified in Table 14-4.

Table 14-4—*ONU Protection Capability* TLV (0xDB/0x09-00)

Size (octets)	Field (name)	Value	Notes
1	Branch	0xDB	Branch identifier
2	Leaf	0x09-00	Leaf identifier
1	Length	0x03	The size of TLV fields following the `Length` field
1	SupportTrunk	Varies	Value of *sSupportTrunk* sub-attribute, defined as follows: `supported`: 0x01 `not_supported`: 0x00
1	SupportTreeLine	Varies	Value of *sSupportTreeLine* sub-attribute, defined as follows: `supported`: 0x01 `not_supported`: 0x00
1	SupportTreeClient	Varies	Value of *sSupportTreeClient* sub-attribute, defined as follows: `supported`: 0x01 `not_supported`: 0x00

14.4.9.2 Attribute *aOnuConfigProtection* (0xDB/0x09-01)

This attribute represents the protection function configuration of the ONU, including the duration of the optical and MAC loss-of-signal detection thresholds. This attribute consists of the following sub-attributes: *sProtectionMode*, *sLosOptical*, and *sLosMac.*

Sub-attribute *aOnuConfigProtection.sProtectionMode*:

Syntax: Enumeration

Default value: none
Remote access: Read/Write
Description: On read, this sub-attribute indicates the currently confiugred ONU protection mode (see 9.3). On write, this sub-attribute indicates the ONU protection mode intended to be configured on the ONU. The following values are defined:

none: the PON protection function disabled
trunk: the trunk PON protection function is used
l_onu_tree: the L-ONU tree PON protection function is used
c_onu_tree: the C-ONU tree PON protection function is used

Sub-attribute *aOnuConfigProtection.sLosOptical*:

Syntax: Unsigned integer
Range: 0x00-00 to 0x03-E8 (1 second)
Default value: 0x00-02
Unit: 1 ms
Remote access: Read/Write
Description: This sub-attribute indicates the period of time that has to elapse before the ONU moves to the HOLD_OVER_START state (see 9.3.3.1.2) if no optical signal is detected.

Sub-attribute *aOnuConfigProtection.sLosMac*:

Syntax: Unsigned integer
Range: 0x00-00 to 0x03-E8 (1 second)
Default value: 0x00-32 (50 ms)
Unit: 1 ms
Remote access: Read/Write
Description: This sub-attribute indicates the period of time that has to elapse before the ONU moves to the HOLD_OVER_START state if no *GATE* MPCPDU is received. This attribute corresponds to the gate_timeout as specified in IEEE Std 802.3, 64.3.5.1 and 77.3.5.1.

The *aOnuConfigProtection* attribute is associated with the ONU object (see 14.2.1). The Variable Container TLV for the *aOnuConfigProtection* attribute shall be as specified in Table 14-5.

Table 14-5—*ONU Protection Configuration* TLV (0xDB/0x09-01)

Size (octets)	Field (name)	Value	Notes
1	Branch	0xDB	Branch identifier
2	Leaf	0x09-01	Leaf identifier
1	Length	0x05	The size of TLV fields following the Length field
1	ProtectionMode	Varies	Value of sProtectionMode sub-attribute, defined as follows: none: 0x00 trunk: 0x01 l_onu_tree: 0x02 c_onu_tree: 0x03
2	LosOptical	Varies	Value of *sLosOptical* sub-attribute
2	LosMac	Varies	Value of *sLosMac* sub-attribute