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Fifth Generation Fixed Network (F5G); Intelligent Management for PON based Industrial Network

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Foreword

This Group Specification (GS) has been produced by ETSI Industry Specification Group (ISG) Fifth Generation Fixed Network (F5G).

Modal verbs terminology

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1 Scope

The present document defines the Intelligent Management for PON based industrial network. The present document primarily focuses on new management requirements in PON based industrial network which have not been addressed so far. The present document identifies and specifies new features and solutions to enhance the efficiency and intelligence of PON based industrial network management.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found in the ETSI docbox.

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The following referenced documents are necessary for the application of the present document.

[1] IETF RFC 7950: "The YANG 1.1 Data Modeling Language".

[2] ETSI GS F5G 022 (V1.1.1): "Fifth Generation Fixed Network (F5G); Specification for PON based Industrial Network".

[3] ETSI GS F5G 011 (V1.1.1): "Fifth Generation Fixed Network (F5G); Telemetry Framework and Requirements for Access Network".

[4] IETF RFC 6241: "Network Configuration Protocol (NETCONF)".

[5] ISO/IEC 20922:2016: "Message Queuing Telemetry Transport". .

[6] IETF RFC 6022: "YANG Module for NETCONF Monitoring".

[7] BBF TR-383: "Common YANG Modules for Access Networks".

[8] BBF TR-385: "ITU-T PON YANG Modules".

[9] Recommendation ITU-T G.984.1: "Gigabit-capable Passive Optical Networks (G-PON): General characteristics".

[10] IETF RFC 7223: "A YANG Data Model for Interface Management".

[11] BBF TR-069: "CPE WAN Management Protocol".

[12] IETF RFC 7371: "A YANG Data Model for System Management".

[13] IETF RFC 8348: "A YANG Data Model for Hardware Management".

[14] IETF RFC 8648: "A YANG Data Model for Alarm Management".

[15] ETSI GS F5G 016 (V1.1.1): "Fifth Generation Fixed Network (F5G); Data Models of Telemetry for Access Network".

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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[i.1] ETSI GS F5G 004 (V1.1.1): "Fifth Generation Fixed Network (F5G); F5G Network Architecture".

[i.2] Recommendation ITU-T G.984.3 (2014): "Gigabit-capable passive optical networks (G-PON): Transmission convergence layer specification".

[i.3] Recommendation ITU-T G.9804.2 (2021): "Higher speed passive optical networks - Common transmission convergence layer specification".

[i.4] Recommendation ITU-T G.Sup51 (06/17): "Passive optical network protection considerations".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in ETSI GS F5G 004 [i.1] and the following apply:

aging time: validity period of a measurement instance, after which the measurement instance automatically becomes inactive

container: interior data node that has no value of its own but contains a list of child nodes in the YANG schema tree IETF RFC 7950 [1]

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

BBF	Broadband-Forum
CPE	Customer Premises Equipment
ID	Identifier
IETF	Internet Engineering Task Force
INIT	In-band Network Information Telemetry
IP	Internet Protocol
ITU-T	International Telecommunication Union - Telecommunication Standardization Sector
MAC	Media Access Control
MQTT	Message Queuing Telemetry Transport
MTU	Maximum Transmission Unit
NBI	Northbound Interface
NETCONF	Network Configuration protocol
OAM	Operation Administration and Maintenance
OLT	Optical Line Terminal
ONIT	Out-of-band Network Information Telemetry
OMCI	ONU Management and Control Interface

ONU	Optical Network Unit
PMS	PON Management System
PON	Passive Optical Network
P-ONU	Primary Optical Network Unit
SDN	Software Defined Network
SNMP	Simple Network Management Protocol
SVM	Support Vector Machine
TC	Transmission Convergence
T-CONT	Transmission Container
TR	Technical Report
UNI	User Network Interface
VLAN	Virtual Local Area Network
WAN	Wide Area Network
WTR	Wait-To-Restore
XGEM	10-Gigabit Encapsulation Method
YANG	Yet Another Next Generation data modelling language

4 Intelligent Management Architecture

4.1 Hierarchical Architecture Overview

4.1.1 Management Architecture for PON based Industrial Network

ETSI GS F5G 022 [2] defines the industrial PON system architecture. The PMS is an instance of management plane in industrial PON system. It provides equipment access, network monitoring, efficient configuration, secure access control, high reliability, and network latency and service quality assurance capabilities.

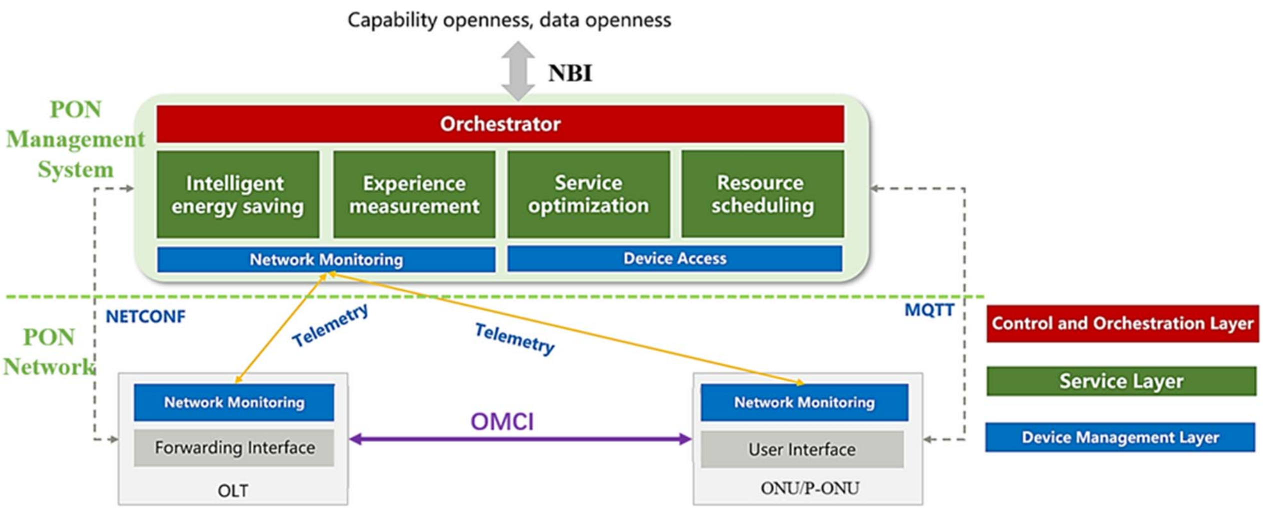

Figure 1: SDN Architecture of PMS in PON based Industrial Network

Figure 1 illustrates the SDN architecture of PMS in PON based Industrial Network. It is structured to efficiently handle the complexities and unique requirements of industrial environments. The management architecture can be visualized as a multi-layered structure comprising several key components:

- **Device Management Layer:**
  - Network Monitoring: The management system in the PON based Industrial Network should support network monitoring, including monitoring the operational status of devices, network link status, and network service status. The operational status of devices includes the status of OLTs and ONUs. The network link status includes optical link metrics and optical module status. The network service status includes port and service rates, bandwidth utilization and service latency, including the latency of both north-south and east west traffic.
  - Device Access: The PON based Industrial Network management system should support connecting to devices via a local internal network. These devices include OLTs and ONUs, and the management protocols include, but are not limited to, SNMP, NETCONF/YANG, and MQTT. Additionally, for the security of the industrial PON network, the PMS should perform security authentication of devices before establishing a complete connection to ensure device access authorization.
- **Service Layer:** The core of the service layer is the SDN-based control service, which enables the expansion of new industrial applications, intelligent management process, and industry service value to be created. Typical industrial services include intelligent energy saving, experience measurement, service optimization, and resource scheduling. The service layer uses the YANG model fundamentals to obtain the collection of the configuration operation descriptions required to implement the service functions. It should construct a tree-structured process model of service functions based on the execution sequence of the corresponding configuration operations using each configuration operation description. The execution sequence is based on the service process specification in relevant standard documents. By traversing the process model in accordance with such execution sequence, the service layer implements these service functions. Additionally, by performing a backward traversal of the process model, the service layer should support the rollback of configurations. This rollback capability ensures that any changes can be reversed safely, reducing the risk of errors and maintaining system stability.
- **Control and Orchestration Layer:** The Control and Orchestration Layer integrates service layer interfaces and provides common northbound interfaces for other platforms to use. Its goal is to make capabilities and data in PON based Industrial Network accessible, allowing different management systems to work together easily. This layer helps streamline network management and improve service delivery efficiency by offering consistent service configuration workflows.

4.1.2 Management Protocols and Functions

4.1.2.1 NETCONF

The NETCONF [4] protocol defines a simple mechanism through which a network device shall be managed. The NETCONF Controller is a part of the PMS which shall use the NETCONF protocol to initiate a session to the access device. The YANG models are developed for specifying NETCONF operations and define the capabilities that the access device may implement. The NETCONF controller should set up a standard YANG file library in advance by using the various equipment types and the corresponding standard YANG model files for each equipment type. The NETCONF controller should search the standard YANG file library (e.g. IETF, BBF, ETSI) based on the equipment type to determine the type of the access device and its corresponding YANG model files.

4.1.2.2 Telemetry

Telemetry [3] protocol defines a network performance collection mechanism. Telemetry system is a part of the PMS. It shall use this protocol to receive high-precise network performance data. The Telemetry data models are developed for specifying the device implementation.

Note that in ETSI GS F5G 016 [15], it has developed a couple of Telemetry data models. In the present document, it augments a few network latency measurement features for PON based Industrial Network.

4.1.2.3 MQTT

MQTT [5] is a lightweight messaging protocol. It may be used for the management and information collection of P-ONUs and standard ONUs in industrial PON environments. The detailed technical requirements and functions are for further study.

4.1.2.4 Device Access Security

For the security of industrial PON networks, the PMS should verify the device that is managed. The access device should support NETCONF Monitoring [6] feature and the NETCONF controller should retrieve the YANG model files sent by the access device. The NETCONF controller parses the received YANG model files and based on the parsing result, it allows the access device to get online and be managed by the PMS if the parsed YANG model files meet at least one of the following conditions. Otherwise, it prevents the devices from getting online in the system:

- The YANG model files contain the standard YANG model files for the equipment type of the access device.
- The YANG model files include all the nodes of the standard YANG model files, and the included tree node of the standard YANG model files is consistent with its tree node hierarchy.

4.2 Intelligent Management Processes

The intelligent management process is an important driver for autonomous network in PON based industrial network. It should provide an automatic mechanism to optimize the network performance and fault troubleshooting without human intervenes.

In the following a general set of technical aspects of the intelligent management process in the service layer of PMS in PON based Industrial Network are described:

- **Standard configuration process model:**

  The required configuration protocol shall be NETCONF [4]. The required configuration operations for industrial service functions are determined by the YANG models of the corresponding service functions. Based on the hierarchical architecture of tree nodes of YANG model files for the PON equipment in industrial networks, the path information for the standard configuration process model of the required configuration operations is determined. The configuration operations and path information are collected as the set of configuration operation descriptions required for each service function.

- **Data collection and storage:**

  Telemetry technology provides data monitoring and reporting of network performance, device status, and service performance for PON based in Industrial Networks. The service layer should support data collection, data storage, and data presence to users in real-time. The stored data should enable performance monitoring, fault analysis, and operational optimization.

- **Intelligent service management:**

  Based on the collected optical link status, proactive fault management should be supported to identify and eliminate potential risks in advance. According to the collected network status, appropriate network optimization strategies and flexible resource scheduling should be performed to achieve agile service creation and configuration.

With the introduction of intelligent management process, the following efficiency is improved for the PON based Industrial Network and creates a greener and smarter network:

- **Operational efficiency improvement:** Applications are measurable, ensuring guaranteed service quality. Network failures shall be detected remotely.
- **Energy efficiency improvement:** Reducing the total energy consumption across the infrastructure in PON based Industrial Network.
- **Bandwidth efficiency improvement:** Increase the number of value-added services.

5 Key Functions for PON Management in Industrial Network

5.1 Fundamentals

5.1.1 Deterministic Network

The ETSI ISG F5G an-xpon-deterministic-control YANG Module focuses on the deterministic network management in a PON based Industrial Network. It contains several augmentations to ietf-interfaces [10] and bbf-xpon [8] models related to the basic PON management. The presence of such augmentations indicates the configuration nodes for deterministic network latency control in the PON system:

- **accurate-maximum-differential-distance:** Defines the maximum allowed differential distance for the closest ONU and the furthest ONU from this OLT PON port, ensuring latency synchronization.

- **onu-discovery-switch:** It controls the enable/disable switch for ONU discovery of this OLT PON port channel. It is enabled by default. When disable is configured, the OLT PON port channel shall not discover the newly launched ONU.

- **quiet-window-mode:** It defines how the OLT PON channel termination [9] sorts the T-CONTs [i.2] and how the quiet window is set depending the influence state on how the quiet window influences the ONU burst transmission window during the service transmission cycle in a PON system [i.3]. There are three quiet window modes:

    1) **standard mode:** OLT PON channel termination opens a quiet window to temporarily suppress upstream transmission by the in-service ONUs during serial number acquisition or ranging [9]. Once the quiet window is activated, it influences the ONU burst transmission and it introduces an additional delay.

    2) **time-sensitive mode:** Sorting of time sensitive T-CONTs is prior to ONU discovery. The quiet window shall not affect the ONU's burst transmission window. The start point of the quiet windows is associates with the burst transmission window. Once there is enough idle timeslot for a quiet window, which means that the quiet window opening has no effect on the burst transmission window. The OLT PON channel termination should open a quiet window in the service transmission cycle and set the specific start point of the quiet window, which is later than all burst transmission window during the service transmission cycle. Once there are not enough idle timeslots for a quiet window, which means that the quiet window opening has effect on the burst transmission window, the OLT PON channel termination shall cancel the quiet window opening.

    3) **best-effort mode:** ONU discovery is prior to sorting of the time sensitive T-CONTs. If there are not enough idle timeslots for a quiet window, the time sensitive burst transmission windows are affected and causes increased network latency.

- **dba-calculation-cycle:** Defines single-frame burst count capability for this PON channel. The count of the single-frame burst of the ONU T-CONT under this PON channel shall not exceed its dba-calculation-cycle.

- **timeslot-reserve-switch:** The enable/disable switch for managing the reservation for offline ONU time slots in the PON system. It is used to maintain the network stability.

- **time-sensitive:** It indicates whether the T-CONT is time-sensitive for low latency service. The OLT should support the transmission of the sorted services in one upstream frame period which serves as a transmission resource in the PON system as shown in Figure 2. For the low latency network, the start point of the quiet window in one upstream frame period shall be later than all the uplink transmission windows. The OLT PON channel termination [9] should support sorting the uplink transmission windows of the ONU services containing both low latency services and non-low latency services according to the quiet window mode, which is user/administrator predefined sequencing logic. The starting point of all uplink transmission windows for low latency services should be adjusted before the non-low latency services. The sequence of all the uplink transmission windows for low latency services is sorted by its window size from the largest to the smallest.

- **dba-distribution-cycle:** Defines the count of single-frame bursts of the T-CONT of a particular ONU.

- **onu-distance:** Defines the distance between the ONU and the OLT, used for calculating and adjusting the network latency.
- **last-quiet-window-failed:** Track when the last time an OLT PON channel termination fails to open the quiet window, which is for troubleshoot.

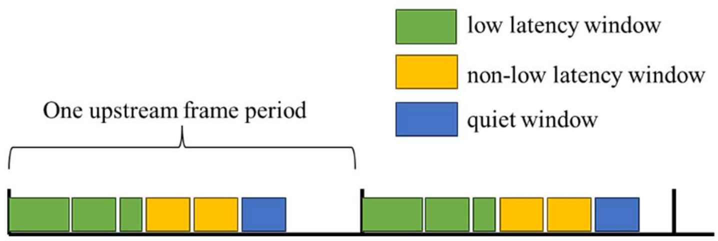

Figure 2: Upstream Frame Period (TC frame) in PON system

Furthermore, to achieve deterministic network latency in service transmission, the OLT should support the control of the timeslot allocation mechanism in the XGEM partition of the TC frame. When the OLT receives the pending service data, it should set the current timeslot in the XGEM partition of the TC frame as the candidate matching timeslot. The OLT should execute the following procedures repeatedly to determine the target timeslot for the received pending service data based on the multiple timeslots of the XGEM partition in the TC frame and encapsulate the received pending service data into the target timeslot:

1) The availability of the candidate matching slot should be determined according to the packet type of the pending service data;
2) If the candidate matching timeslot is unavailable, the next timeslot should be selected as the new candidate matching timeslot. This process should continue until an available candidate matching timeslot is found, and such available timeslot should be determined as the target timeslot for the received pending service data. Within each TC frame, the time occupied by the XGEM partition contains multiple timeslots, and each timeslot supports encapsulation of service data corresponding to its predefined packet type.
3) If the target timeslot has not yet started at the current time, the pending service data should be temporarily stored in the buffer corresponding to the target timeslot. Once the target timeslot begins, the pending service data should be encapsulated into the target timeslot for upstream transmission.

5.1.2 Protection Management

The ETSI ISG F5G Protection YANG Modules focus on the protection management in PON based Industrial Network, including protection switching, uplink port protection, PON port protection [i.4], optical link protection and ONU protection. In addition to this, dual-parents protection and protection status monitoring are also supported. Different protection members and working modes are configured in the protection group, and industrial users or OAM personnel control traffic switching manually or automatically to ensure high network stability. The presence of such nodes and items indicates the protection Management in PON based Industrial Network:

- protection-groups:
  - Each protection group is uniquely identified by a group-id. The protection group contains a description field and a definition of the type of protection object, which is an ethernet port, an aggregation group, a PON port, or an ONU.
  - protection-object: different types of protection members are defined, including ethernet ports, aggregation groups, PON ports, or ONU devices.
  - Work mode: includes three modes:
    1) time-delay: 1:1 architecture, primary and standby switching, which is for PON Type B [9] protection;
    2) port-state: 1:1 architecture, primary and standby enabled, but only the primary member carries services, which is for PON Type C [9] or Type D [9] protection;

3) load-balance: 1+1 architecture, the primary and standby members carry services at the same time, which is for PON Type C or Type D protection.

- dual-parenting-flag: indicates whether the protection group supports dual-parenting. The dual-parenting protection group switches traffic between different network elements to improve stability.
- Recovery and protection functions:
  - revertive (Recovery mode): controls whether traffic is automatically switched back to the primary member after the fault is recovered.
  - wtr-time (Protection group recovery time): a waiting period when recovery mode is enabled to avoid frequent switching after the work path has recovered.
- Protection member: each protection group contains two protection members, one of which is a working member and the other is a protecting member. Traffic switching is performed based on member status and configuration.
- Operation functions: includes commands such as freeze, lockout, forced-switch, manual-switch, which are used to manually or automatically manage the switching of traffic in the protection group under different states.
- Uplink monitoring: uplink monitoring is used to monitor the connection status between the protection group and the uplink port to ensure the availability of the uplink.
- Type B protection: Type B protection is specific to OLT PON protection architectures and be configured for standard Type B networks or vendor specified Type B networks.
- dual-parenting protection: defines the dual-parenting protection group pairs of nodes and members. This includes the handshake status of the pair-end node and communication keys, to ensure communication synchronization between dual-parenting members. These configurations enable traffic protection and switching between different OLTs to ensure service reliability.

5.1.3 Energy Saving

5.1.3.1 OLT PON Port Switching

The BBF TR-385 [8] YANG modules define the channel pairs interface management. Operators shall use enable/disable in 'ietf-interfaces' [10] for OLT PON port switching.

5.1.3.2 ONU PON Port Switching

There are two scenarios for ONU PON port channel switching management as shown in Figures 3 and 4.

- In scenarios where the ONU is managed indirectly by the OLT, the PMS sends the ONU PON channel control commands to the OLT, and the OLT translates the commands into OMCI commands to the ONU. The requirements and parameters are for further study.
- In scenarios where the PMS directly manages the ONU, the PMS sends ONU PON channel control commands containing PON channel control strategy directly to the ONU. The protocol includes MQTT, BBF TR-069 [11] and the ONU should have corresponding modules to receive the commands. The modules should control the ONU PON port channel according to the channel control strategy in the received control commands. The requirements for the modules and command parameters are for further study.

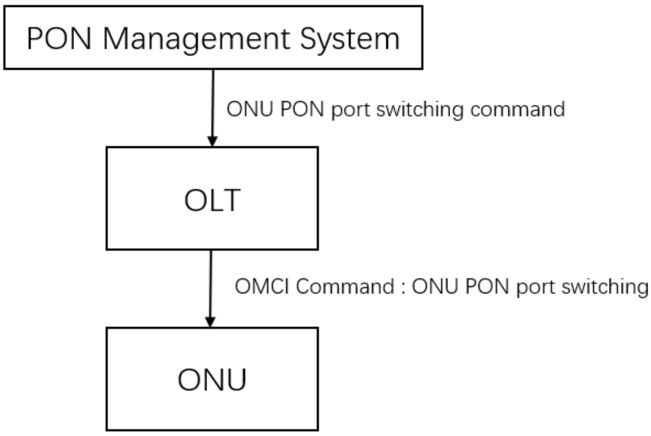

Figure 3: ONUs Managed Indirectly by OLTs

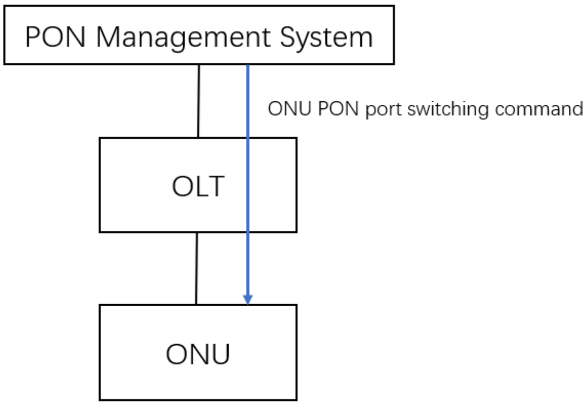

Figure 4: PMS Directly Manages ONUs

5.1.4 East to West Traffic

The ETSI ISG F5G l2-forwarding YANG Module focuses on the network interoperability for two following scenarios as shown in Figures 5 and 6. It contains two augmentations to bbf-l2-forwarding [7] related to the layer 2 forwarding. The presence of such augmentations indicates the configuration nodes of forwarding policy profile instances and pointing the profile to the corresponding forwarder instance:

- **forwarding-policy-profiles:** This augmentation introduces the ability to define multiple forwarding-policy-profiles. The profiles are designed to be flexible and extensible for the future, allowing users to apply various forwarding policies based on specific requirements, such as VLANs. Within each profile, parameters like the forwarding-horizon are configured to control east to west traffic forwarding for specified VLAN-IDs.

- **forwarder policy:** This augmentation extends the forwarder configuration by associating a forwarding-policy-profile with each forwarder instance. This allows users to assign specific forwarding policies to individual forwarder, thereby controlling the traffic flow to transmit in the OLT based on pre-defined rules. The configuration includes VLAN-ID range, allowing specified VLAN traffic to be governed by different forwarding policies, ensuring more granular and efficient traffic management across the OLT.

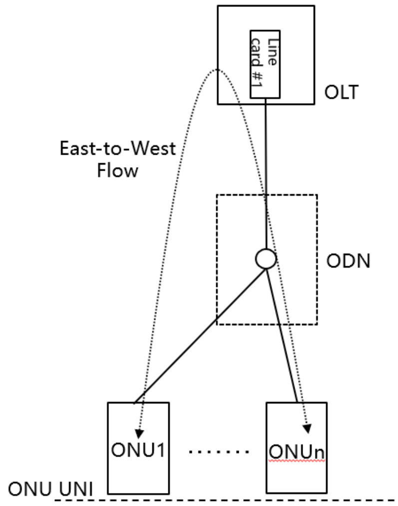

Figure 5: Intra-PON Port under the Same OLT Chassis (Source: ETSI GS FG 022 [2])

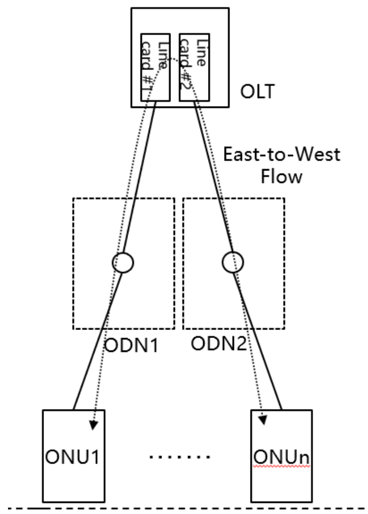

Figure 6: Cross-PON Port under the Same OLT Chassis (Source: ETSI GS FG 022 [2])

5.2 Basic Operations

5.2.1 Deterministic Latency Control

In telecommunication/home broadband operator network scenarios, the quiet window [9] function shall be enabled for discovering and activating the newly launched ONU. This function increases network latency which is based on the maximum differential distance in the OLT PON channel. In PON based Industrial Network, industrial services demand deterministic and low latency network. The OLT PON channel management and the ONU T-CONT should be optimized as following:

1) When the OLT PON channel meets one of the following conditions for the determination of the closing window, it should permanently disable the quiet window function. The conditions include the followings which are based on the specific scenarios and ONU online status under this OLT PON channel:

   a) The ONUs are already online under this OLT PON channel and there is no need to deploy new ONUs.

b) If a part of the ONUs under this OLT PON channel are not online, the PMS should enable the quiet window function for an initial custom time. During this time, the OLT PON channel should provide quiet window openings more times than the predefined threshold for activating the ONU online. If there exists offline ONU in such OLT PON channel after opening multiple times the quiet window, the OLT PON channel is determined to close the window.

To ensure that the ONUs come online, the PMS should continuously monitor the status of every ONU under the corresponding OLT PON channel to determine whether to enable the quiet window function after disabling the quiet window function for a period. When detecting offline ONUs, it is determined that the OLT PON channel meet the window opening condition and be enabled the quiet window function by the PMS.

2) When both low latency services and non-low latency services exist in the OLT PON channel and there deployment continuously install or powers-up new ONUs, the OLT PON channel should be configured with the quiet window enabled. The ONU T-CONT for low latency services should be configured with time-sensitive and corresponding quiet window mode, so that the low latency is guaranteed.

3) The PMS configures the single-frame burst count capability of the OLT PON channel, which is the 'dba-calculation-cycle' and the count of single-frame bursts of the T-CONT of a particular ONU, which is 'dba-distribution-cycle' according to the latency requirements of the services. The latency is estimated by the following formula: $C = 125\mu s \times 2^N$,where C is the latency and N is 'dba-distribution-cycle' value.

5.2.2 Protection Management

5.2.2.1 Single Protection Configuration

1) **Creating a Protection Group**

The first step in configuring a single protection group involves creating the group under the protection-groups Container. The group is identified using a unique group-id, along with attributes as the protect-object type and the working mode. This setup establishes the foundation for PON protection.

2) **Adding Work-Side Member**

The work-side member serves as the primary traffic carrier in normal operation. Configuring the member requires defining the physical interface and assigning it the work role. This ensures the interface is prepared to handle traffic during normal conditions.

3) **Adding Protect-Side Member**

The protect-side member acts as a backup interface, activated in the event of a failure on the work-side link. The member is added to the protection group by specifying its interface and assigning it the protect role. This configuration establishes a standby link to maintain service continuity.

5.2.2.2 Dual-Parenting Protection Configuration

1) **Configuring OLT-A Local and Peer Information**

In dual-parenting protection, the configuration begins with OLT-A. Local node parameters as the communication ports, IP address, and synchronization settings, are configured. Peer node information, including OLT-B's IP address and communication key, is also specified to establish coordination between the two OLTs.

2) **Configuring OLT-B Local and Peer Information**

Similarly, OLT-B is configured with its local node settings and peer information, ensuring bi-directional synchronization between OLT-A and OLT-B. This step guarantees that both OLTs are prepared for dual-parenting operation.

3) **Creating Protection Group on OLT-A**

Once the local and peer configurations are complete, a protection group is created on OLT-A. This involves enabling the dual-parenting-flag and specifying the protect object. Members, including the work-side and protect-side interfaces, are added, and synchronization with OLT-B is configured.

4) **Creating Protection Group on OLT-B**

A corresponding protection group is created on OLT-B, mirroring the settings of OLT-A. This ensures consistency across both OLTs and prepares the network for seamless traffic switchover in the event of a failure.

5.2.2.3 Typical Protection Scenarios

5.2.2.3.1 Overview

In the following clauses, the different protection mechanism as manageable by the present document are explained for reference and better understanding.

5.2.2.3.2 Type B Protection

Type B protection [9] as shown in Figure 7 provides redundancy by using two separate PON interfaces on a single OLT. The ONU connects to both interfaces, allowing traffic to switch between them in case of a failure in the primary fibre or PON port. The OLT manages the switching process based on fault detection mechanisms.

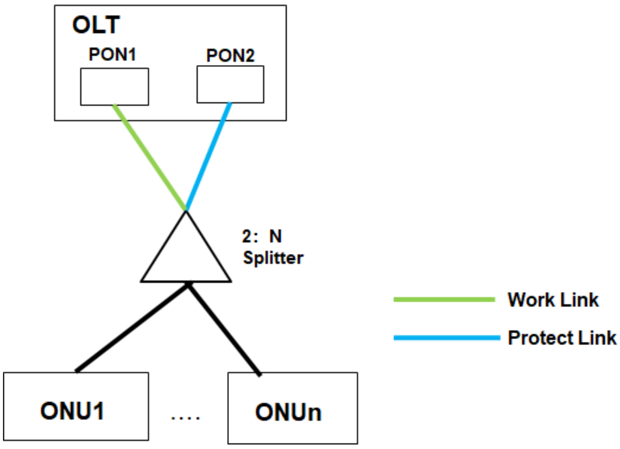

Figure 7: Type B Single Protection Scenarios

5.2.2.3.3 Type C Protection

Type C protection [9] as shown in Figure 8 extends the redundancy of Type B by using two separate ONU PON ports. Each ONU port connects to a different OLT PON interface, ensuring complete resilience against failures in both fibre and OLT hardware. Coordination between OLTs ensures seamless traffic transition during a failure.

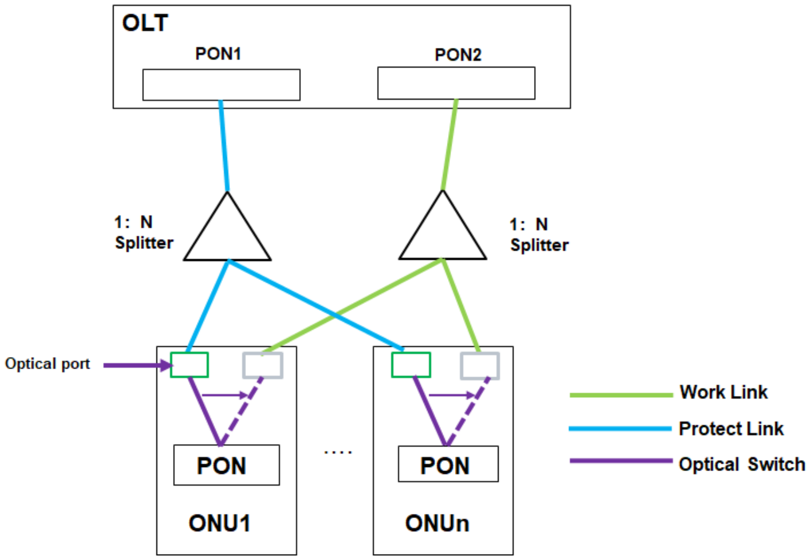

Figure 8: Type C Single Protection Scenarios

5.2.2.3.4 Type D Protection

Type D protection [9] as shown in Figures 9 and 10 further enhances network reliability by introducing multiple redundant paths, often using ring-based fibre topology. In this scenario, the OLT should deploy combo PON ports to achieve better service switching performance in cases of fibre break and port failures. The OLT uses the low-speed channel in combo PON for monitoring the trunk link recovery and the real-time optical link metrics. This method ensures continued operation and link failure monitoring even in the event of simultaneous failures in multiple fibre segments.

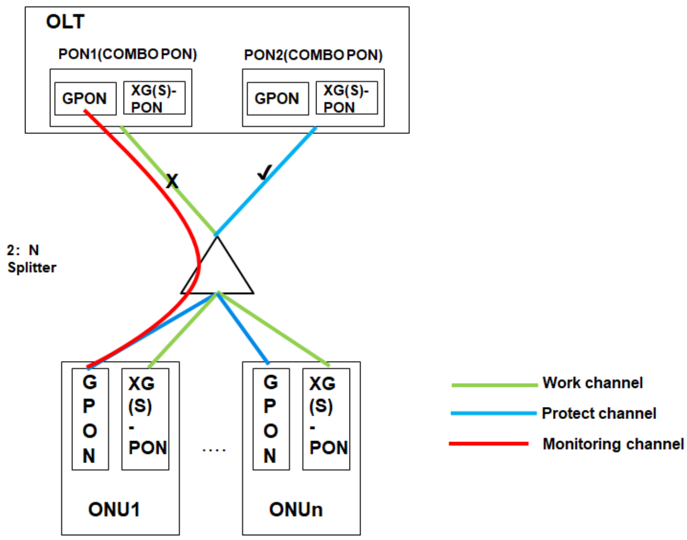

Figure 9: Type D Single Protection in Trunk Link Failure

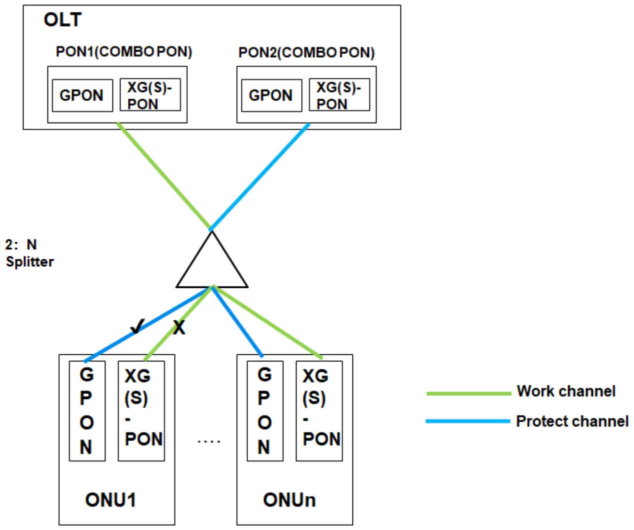

Figure 10: Type D Single Protection in Distribution Link Failure

5.2.2.3.5 Dual-Parent Protection

Dual-master protection as shown in Figures 11 to 14 involves two OLTs operating in an active-active mode, where each OLT independently serves a portion of the ONU's traffic. This approach improves bandwidth utilization and load balancing while maintaining redundancy.

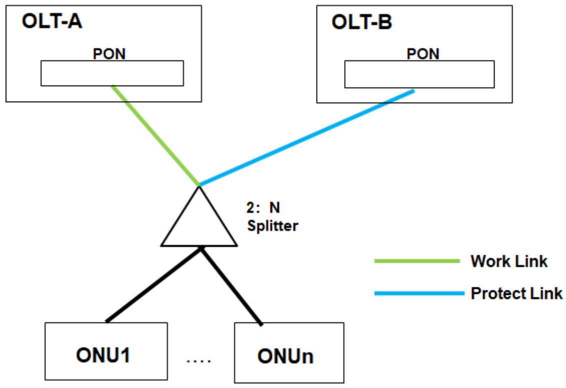

Figure 11: Type B Dual-Parent Protection Scenarios

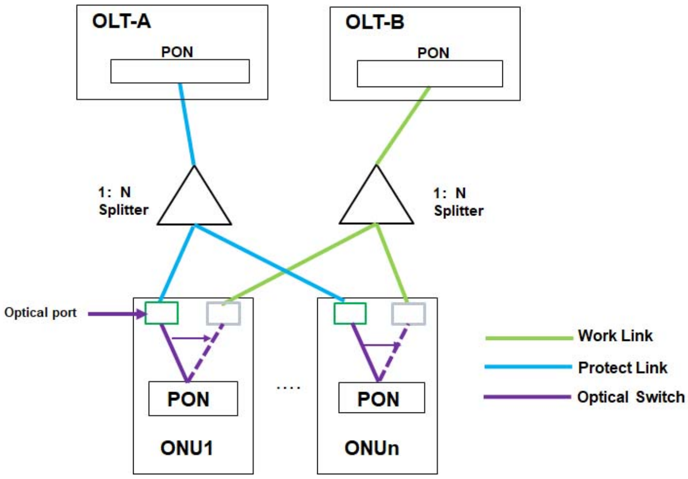

Figure 12: Type C Dual-Parent Protection Scenarios

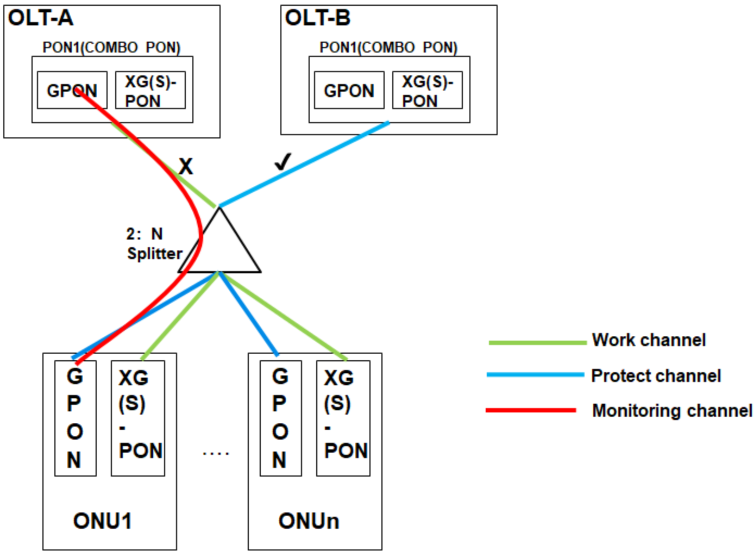

Figure 13: Type D Dual-Parent Protection in Trunk Link Failure

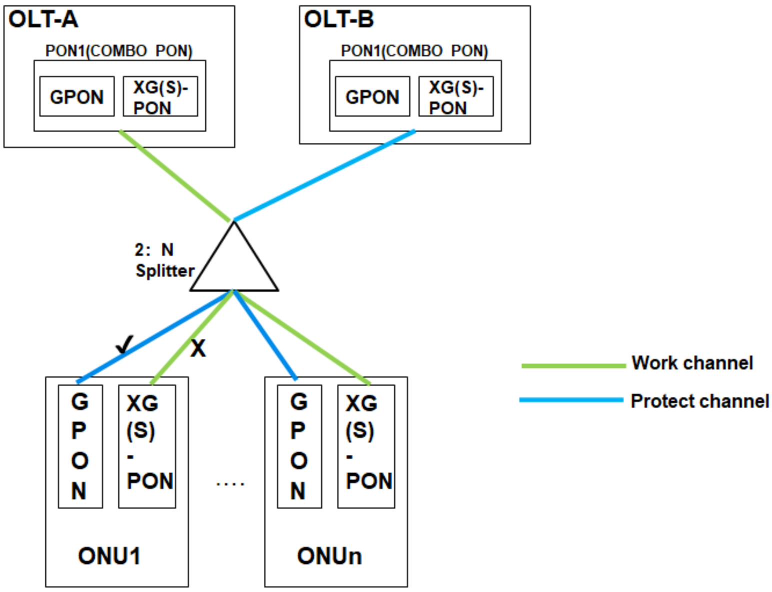

Figure 14: Type D Dual-Parent Protection in Distribution Link Failure

5.2.2.4 Functional Behaviour of Protection Groups

In the access network, there are two kinds of failures:

- Trunk Fibre Failure: Disruptions in the trunk fibre link caused by PON port failure leads to a broader network outage, requiring an OLT-level protection switch to a standby PON port as a protect-side member in protection group or an alternate OLT in dual-parenting scenarios.
- Distribution Branch Fibre Failure: Failures in the distribution fibre impact ONU connectivity, requiring an immediate switchover to the protect-side channel which is a protect-side member in protection group.

The following is how the protection group deals with the failure:

- **Behaviours in Trunk Fibre Break Failure:** The OLT continuously perform the connectivity and break detection of the trunk fibre link using the low-speed standby channel of its primary PON port. If a trunk fibre break failure is detected, the OLT initiates a switchover from its primary PON port to the standby PON port and switches all ONU service traffic from the high-speed primary channel of the primary PON port to the high-speed primary channel of the standby PON port, ensuring the traffic continuity for all connected ONUs. Meanwhile, the OLT continues connectivity and break detection of the trunk fibre link by the low-speed standby channel under the standby PON port for verifying the restoration of the link.

- **Behaviours in Distribution Branch Fibre Break Failure:** During normal operations, ONU uses its local high-speed primary channel to perform service interactions with the primary channel in the primary PON port of the OLT. Meanwhile, the ONU utilizes the local low-speed standby channel to perform the connectivity and break detection of the primary distribution branch fibre link. When an ONU detects a break failure in the primary distribution branch fibre link, it switches service traffic from the local primary channel to the local standby channel. The ONU then sends a distribution branch fibre break failure alarm to the OLT. According to the received alarms, the OLT redirects the ONU's service traffic to the standby channel which belongs to the OLT's primary PON port.

5.2.3 Energy Saving

5.2.3.1 ONU Traffic Prediction

The PMS collects real-time and historical network traffic data of each ONU corresponding to the energy-efficient OLT based on the Telemetry technology. In addition to the traffic statistics for each historical point in time, the historical traffic data also includes the location and area of the ONU and the type of the day and the date of the historical point in time.

EXAMPLE: The type of the day will be as weekday, weekend, or public holiday.

The PMS should support inputting the collected historical and real-time traffic data into the SVM to classify each ONU and create multiple ONU groups to distinguish, which ONUs are able to be configured for energy efficiency. For any ONU in each ONU group, the PMS should support inputting the collected historical and real-time traffic data into the traffic prediction models for predicting its traffic in future time slot based on its historical traffic data and generate the bandwidth configuration for both this ONU and the other ONUs in the same group. The generated bandwidth configuration, used for bandwidth allocation, is an important foundational step for the subsequent energy-saving configuration.

5.2.3.2 OLT and ONU PON Port Mode Switching

Based on the real-time and the predicted future network traffic, the PMS should determine the management and control strategy of the ONU PON port channel and corresponding target operational mode of the OLT PON port connected to the ONU. Based on the determined control strategy and operational mode of the OLT PON port, the PMS switches the mode of the ONU PON Port.

The PMS determines whether a PON port is low-traffic state and determines the corresponding operational mode of the OLT PON port and the control strategy of the ONU PON port channel based on confirming the size relationships between the real-time network traffic and the preset traffic thresholds. The traffic thresholds include at least a low traffic determination threshold and a high traffic determination threshold, where the low traffic determination threshold shall be lower than the high traffic determination threshold. There are two following scenarios:

1) When the real-time network traffic of the OLT PON port is less than the low traffic determination threshold, it is determined to be a low traffic state, and the target operation mode of the OLT PON port is determined to be the low-speed mode. And by predicting that the network traffic will be less than the low traffic determination threshold in the future period, such operation mode should be maintained. Meanwhile, the PMS should determine the PON channel control strategy of the ONU PON port is to disable the high-speed channel of the ONU PON port, and switches the service traffic to the low-speed channel for energy saving. According to the target operation mode of the OLT PON port and the determined strategy, the PMS should send the corresponding control commands. The power consumption per unit time of the OLT in the low-speed mode is less than that in the high-speed mode.

2) When the real-time network traffic of the OLT PON port is greater than the low traffic determination threshold, it is determined to leave the low traffic state, and the target operation mode of the OLT PON port is determined to be switched from the current low-speed operation mode to the high-speed operation mode. And by predicting that the network traffic in the future period will be greater than the low traffic determination threshold, such operation mode should be maintained. For more precise control, the high traffic determination threshold should be used instead of the low traffic determination threshold in the above traffic size judgment. Meanwhile, the PMS should determine the PON channel control strategy of the ONU PON port is to enable the high-speed channel of the ONU PON port, and switches the service traffic to the high-speed channel for service stability. According to the target operation mode of the OLT PON port and the determined strategy, the PMS should send the corresponding control commands.

5.2.4 East to West Service Configuration

The ETSI ISG F5G YANG Models should be used along with the BBF TR-383 [7] and BBF TR-385 [8] to provision the East to West Ethernet service over the PON system. As outlined in BBF TR-383 [7], a vlan-sub-interface is the logical interface for handling the service flow associated with a specific VLAN-ID as received from the ONU and a service forwarder is responsible for the OLT to forward the service flow traffic sent by the source ONU to the destination ONU's vlan-sub-interface associated with the VLAN-ID of the service flow in this scenario, while BBF TR-385 [8] covers the PON adaptation of the service mapping. The OLT should be configured by the PMS and create the appropriate service flows and the service forwarder accordingly to the received configuration commands in the following steps:

1) The PMS should send a configuration command which contains the service forwarder identification. A service forwarder which is based on the received service forwarder identification is created in the OLT.

2) The PMS should send a configuration command to the OLT, which contains the target VLAN-ID of the east to west service flow and corresponding interface identifications to create the service flows in the OLT. At least two vlan-sub-interfaces from two different ONUs which are source ONU and destination ONU should be created. The service forwarder, which is created in step 1 should be configured with the received VLAN-ID to forward the specific service flow with this VLAN-ID.

3) The PMS should send a configuration command, which contains the interface identifications of vlan-sub-interfaces created in step 2 to add the corresponding vlan-sub-interfaces in the service forwarder. Based on the VLAN-ID of the service flow, the target vlan-sub-interfaces for east to west service in this forwarder should be forwarded.

4) The PMS should send a configuration command to create a forwarding policy profile for east to west data forwarding and bind this profile with the service forwarder. The forwarding policy profile should be configured with a switch field that controls whether the east to west traffic is able to be forwarded. When the switch is enabled, the OLT should associate the switch field with the vlan-sub-interfaces corresponding to the VLAN-ID of the service flows in the service forwarder and allow such service flow to be sent to the destination ONU.

6 Key Functions for Network Latency Measurement in Industrial Network

6.1 Fundamentals

6.1.1 Out-of-band Network Information Telemetry

The ETSI ISG F5G ONIT YANG Modules focus on managing measurement flows and instances to monitor the network latency. The out-of-band network information telemetry supports the network latency measurement both inside one PON network as shown in Figure 15 and across the different PON networks as shown in Figure 16. Every OLT will be configured with its own node ID. The modules contain two augmentations to 'ietf-interfaces' [10] related to the PON infrastructure. The presence of such augmentations indicates the ONIT-specific configurations for ONU and OLT interfaces:

- The onit-mac-address leaf is used as the source or destination mac address of a measure flow.

- The onit-roles Container specifies the role type (ingress-egress or transit) of the interface, the interface contains ONU LAN port, ONU, PON port and Ethernet Port.

In addition to this, the ONIT YANG Modules define two key components: 'measure-flows' and 'measure-instances':

- measure-flows: defines how to establish an out-of-band measurement flow with attributes such as: source and destination, MAC address and VLAN configurations.

- measure-instances: defines the measurement instance with attributes such as flow rate, frame size.

The ETSI ISG F5G ONIT Telemetry Module focuses on the time-delay statistics of measurement flows. It describes the delay statistics in both directions for the configured measurement flow to each node. The node contains both remote and local PON port and Ethernet port.

In this measurement scenario, the OLT shall support both ETSI ISG F5G ONIT YANG Modules and ETSI ISG F5G ONIT Telemetry Module and the ONU shall support the packet sending function.

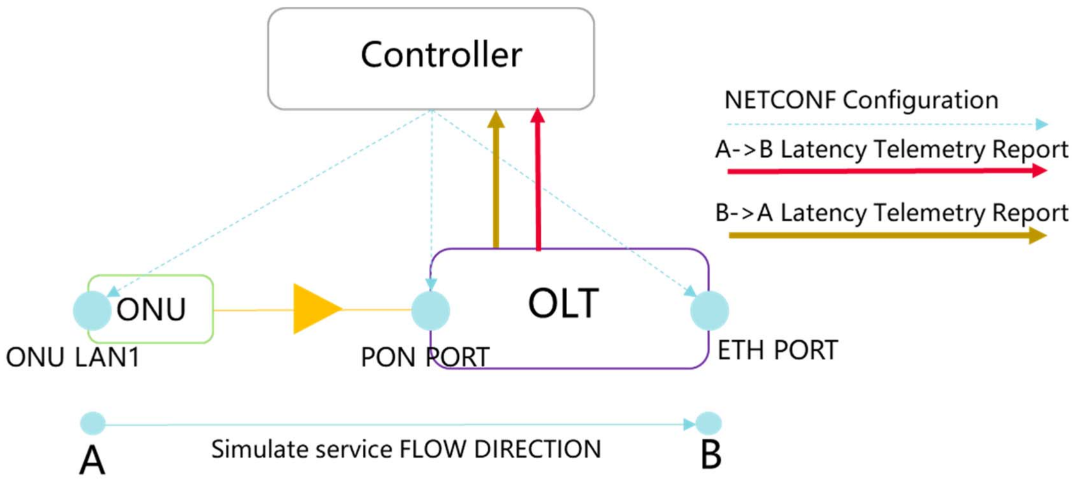

Figure 15: Out-of-band Network Latency Measurement inside one PON Access Network

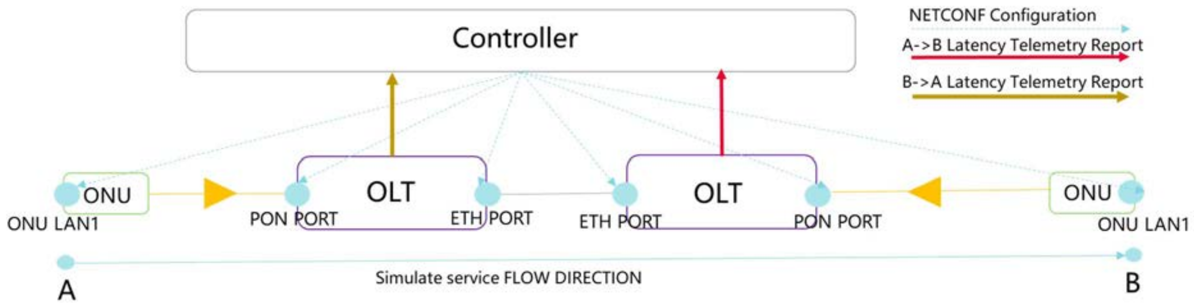

Figure 16: Out-of-band Network Latency Measurement between the Different PON Access Networks

6.1.2 In-band Network Information Telemetry

The ETSI ISG F5G INIT YANG Modules focus on network latency measurements on actual service flows. The in-band network information telemetry supports the network latency measurement both inside one PON network as shown in Figure 17 and across the different PON networks as shown in Figure 18.

Every OLT shall be configured with its own node ID and time synchronization shall be configured in scenarios across the different PON networks. The modules contain one augmentation to 'ietf-interfaces' [10] related to the PON infrastructure. The presence of such augmentations indicates the INIT-specific configurations for ONU and OLT interfaces:

- The init-roles Container specifies the role type (ingress-egress or transit) of the interface, the interface contains ONU LAN port, ONU PON port, OLT PON port and OLT Ethernet Port.

In addition to this, the INIT YANG Modules define the static instances configuration related to the INIT. It contains configuration parameters for delay measurement and parameters for actual service flow filtering. The INIT allows both MAC filtering and IP filtering for actual service flow.

The ETSI ISG F5G INIT Telemetry Module focuses on the time-delay statistics of actual service flows. It describes the flow information and delay statistics across the different nodes in both directions. The node contains both remote and local PON port and Ethernet port.

In this measurement scenario, the OLT shall support both ETSI ISG F5G INIT YANG Modules and ETSI ISG F5G INIT Telemetry Module and the ONU shall support adding additional IP packet header information for INIT, which shall not influence message forwarding. Additional header information should have the following information:

- Timestamp: Provides precise timing information required for network latency measurement, recording the time when the packet passes through a specific node.
- Original message protocol: Identifies the original protocol type of the packet, ensuring that the packet shall be correctly parsed and processed at the destination node.

Typically, in end-to-end scenarios, the maximum IP packet size is generally set to 1 500 bytes. In the access networks, the supported maximum packet size is between 1 800 and 1 900 bytes, which allows for additional headers or telemetry information without requiring packet fragmentation. To avoid fragmentation which may influences the network performance, the configurations should ensure that the total packet size, including INIT-specific headers, remains within this range. Proper configuration of MTU across the network is essential to maintain consistent performance and avoid latency issues caused by fragmentation.

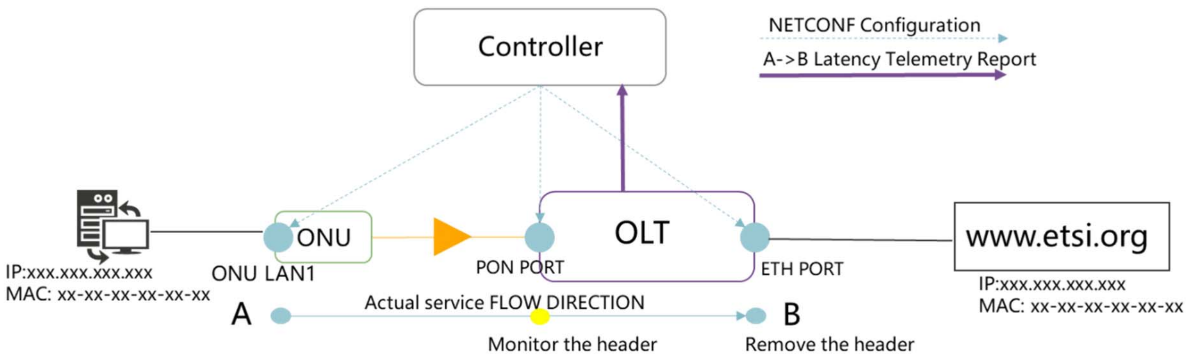

Figure 17: In-band Network Latency Measurement inside one PON Access Network

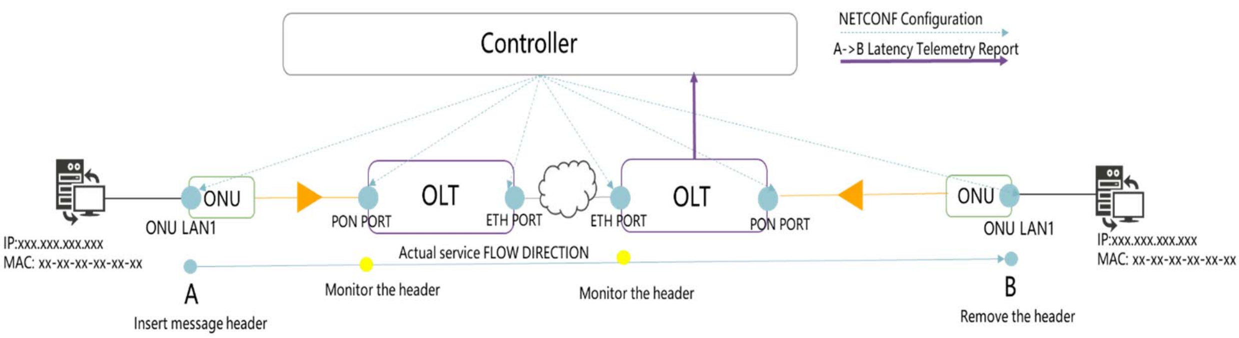

Figure 18: In-band Network Latency Measurement between the Different PON Access Networks

6.2 Basic Operations

6.2.1 Out-of-band Network Information Telemetry

6.2.1.1 Port Role Configuration

Network latency measurement requires determining the measurement boundaries, that is, identifying the start and end points of the measurement. The network nodes at the start and end points should be configured with ingress or egress roles. The ONIT supports network latency measurement in trace mode, which network performance statistics between each network node in a flow. The intermediate network nodes that need to be measured should be configured as the role of transit.

6.2.1.2 Out-of-band Measurement Flow Initialization

This clause explains how an out-of-band measurement flow initializes. A measurement flow shall contain destination MAC address of the flow, source MAC address of the flow and service VLAN configurations to describe the attributes of the measurement flows.

6.2.1.3 Measure-instances Initialization

Each measure-instances includes a reference to a measurement flow. To accurately simulate and test network performance under different data volumes and loads, a measure-instance can configure the frame size and rate of the measurement flow. This helps to more precisely reflect the performance in PON based Industrial Network.

6.2.2 In-band Network Information Telemetry

6.2.2.1 Global Parameters Configuration

Based on the different network latency measurement scenarios, every OLT shall be configured the node ID, time mode and aging time of the measurement instance.

6.2.2.2 Port Role Configuration

Network latency measurement requires determining the measurement boundaries, that is, identifying the start and end points of the measurement. The network nodes at the start and end points should be configured with ingress or egress roles. The INIT supports network latency measurement in trace mode, which network performance statistics between each network node in a flow. The intermediate network nodes that need to be measured should be configured as the role of transit.

6.2.2.3 Static-instances Initialization

Each static-instance represents one network latency measurement. It is identified by an instance-id which shall be configured unique within one OLT. Measure-mode and interval for measurement should be configured. The INIT support delay measurement for per packet which is configured for static-instance.

6.2.2.4 Flow Filtering for In-band Measurement

Each static-instance has its own flow filter conditions which contains flow-type, MAC address or IP address, and related logic for flow matching. With the above steps, a static-instance of network latency measurement is successfully configured and work according to the specified measurement intervals and filtering conditions.

7 F5G YANG Modules for PON Management in Industrial Network

7.1 Overviews

The ETSI ISG F5G YANG Models for PON based Industrial Network provide the new functionalities for industrial network scenarios. The modules address the service configurations, PON protection and power management for PON based Industrial Network. They are used in the device management layer of the OLT and facing the NBI of the OLT and subtending ONUs. These modules are published on the Forge platform at https://forge.etsi.org/rep/f5g/f5g-intelligent-management-for-pon-based-industrial-network/-/tree/v1.1.1/PON%20Management?ref_type=tags.

7.2 Relationship with Other YANG Models

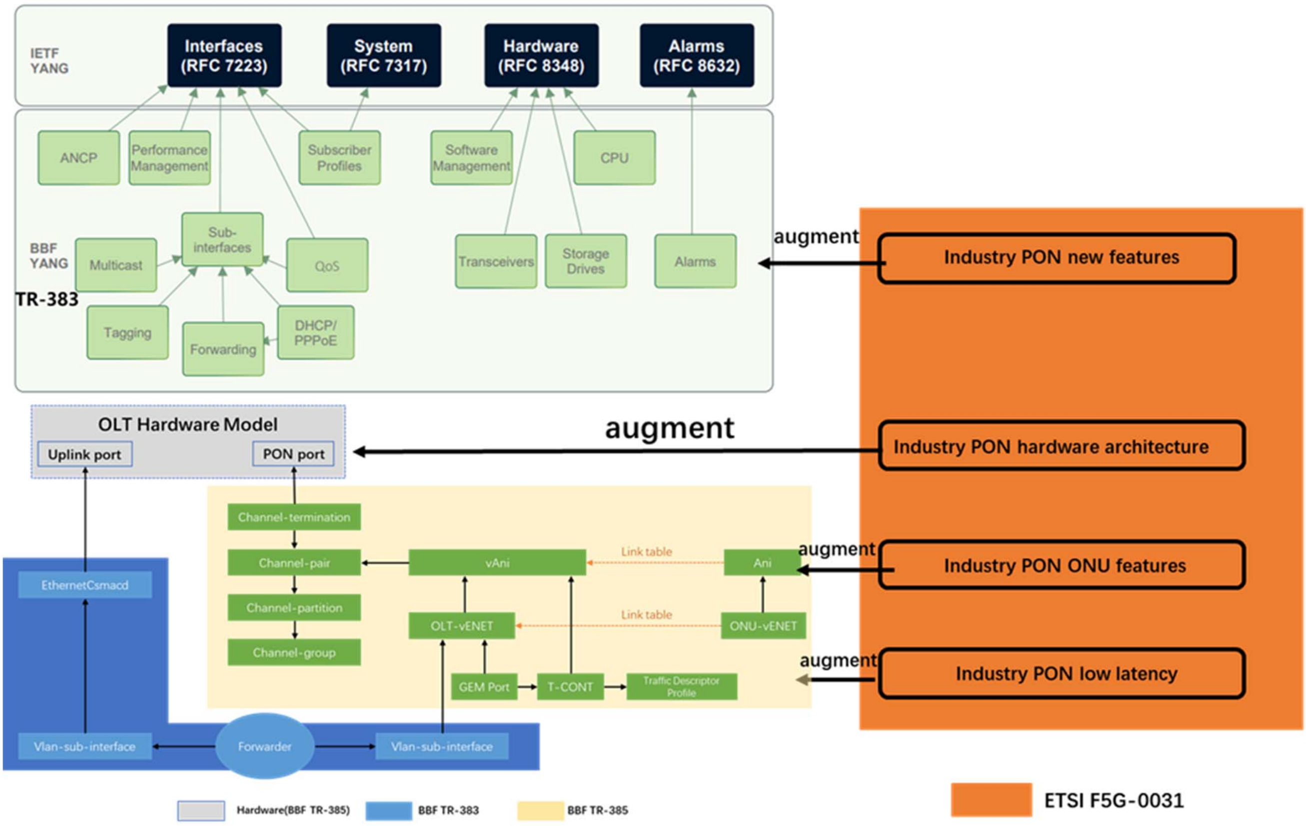

Figure 19: Relationship with Other YANG Models

The present document defines the ETSI ISG F5G YANG models for the PON based industrial network, augmenting the new features defined in BBF TR-383 [7] and BBF TR-385 [8] as shown in Figure 19. The BBF TR-383 [7] and BBF TR-385 [8] models should be used alongside the ETSI ISG F5G YANG models to provide new services and features for the PON based industrial network.

7.3 Modules and Sub-modules

7.3.1 Deterministic Network Models

7.3.1.1 Module an-xpon-deterministic-control.yang

This YANG module contains several augmentations for ietf-interfaces [10] and bbf-xpon [8]. As such, this module is specific to the OLT.

The data model has the following overall structure:

```
module an-xpon-deterministic-control
   augment /if:interfaces/if:interface/bbf-xpon:channel-partition
      +--ro accurate-maximum-differential-distance? union
   augment /if:interfaces/if:interface/bbf-xpon:channel-termination
      +--ro onu-discovery-switch? boolean
      +--ro quiet-window-mode? quiet-window-mode
      +--ro dba-calculation-cycle? dba-cycle
      +--ro timeslot-reserve-switch? Boolean
   augment /bbf-xpongemtcont:xpongemtcont/bbf-xpongemtcont:tconts/bbf-xpongemtcont:tcont
      +--ro time-sensitive? boolean
   augment /bbf-xpongemtcont:xpongemtcont/bbf-xpongemtcont:traffic-descriptor-profiles/bbf-
xpongemtcont:traffic-descriptor-profile
      +--ro dba-distribution-cycle? dba-cycle
   augment /if:interfaces-state/if:interface/bbf-xponani:ani
      +--ro onu-distance? uint16
   augment /if:interfaces-state/if:interface/bbf-xpon:channel-termination
      +--ro last-quiet-window-failed? yang:date-and-time
```

7.3.2 Protection Management Models

7.3.2.1 Module an-pon-protection-group.yang

This YANG module contains a collection of YANG definitions and augmentations of configurations for protection management in PON system. As such, this module is specific to the OLT.

7.3.2.2 Module an-protection-group.yang

This YANG module contains the 'protection-groups' Container for protection management in general scenarios. As such, this module is specific to the OLT.

The data model has the following overall structure:

```
module an-protection-group
   +--rw protection-groups
      +--rw protection-group* [group-id]
      |  +--rw group-id                    uint32
      |  +--rw description?                bbf-yang:string-ascii64-or-empty
      |  +--rw protect-object              identityref
      |  +--rw work-mode                   identityref
      |  +--rw dual-parenting-flag?        boolean
      |  +--rw revertive?                  boolean
      |  +--rw wtr-time?                   uint32
      |  +--rw lockout-on-startup?         boolean
      |  +--ro frozen?                     boolean
      |  +--ro oper-status?                oper-status
      |  +--rw member* [if-name]
      |  |  +--rw if-name         leafref
      |  |  +--rw role            member-role-type
      |  |  +--ro running-status? running-status
      |  |  +--ro oper-status?    enumeration
      |  +---x freeze
      |  |  +--ro input
      |  |  +--ro output
      |  |     +--ro result? string
      |  +---x clear-freeze
      |  |  +--ro input
      |  |  +--ro output
      |  |     +--ro result? string
      |  +---x lockout
      |  |  +--ro input
      |  |  +--ro output
      |  |     +--ro result? string
      |  +---x forced-switch
      |  |  +--ro input
      |  |  +--ro output
      |  |     +--ro result? string
      |  +---x manual-switch
      |  |  +--ro input
      |  |  |  +--ro target  member-role-type
      |  |  +--ro output
      |  |     +--ro result? string
```

```
|  +---x exercise
|  |  +--ro input
|  |  +--ro output
|  |     +--ro result? string
|  +---x clear
|  |  +--ro input
|  |  +--ro output
|  |     +--ro result? string
|  +--rw an-pon-pg:uplink-monitor
|  |  +--rw (uplink-monitor-cfg)?
|  |  |  +--:(bfd)
|  |  |  |  +--rw an-pon-pg:session-name?         string
|  |  |  +--:(eth-port)
|  |  |  |  +--rw an-pon-pg:name?                 if:interface-ref
|  |  |  +--:(mep)
|  |  |     +--rw an-pon-pg:md-index?             uint32
|  |  |     +--rw an-pon-pg:ma-index?             uint32
|  |  |     +--rw an-pon-pg:mep-index?            uint32
|  |  +--ro an-pon-pg:uplink-monitor-state? enumeration
|  +--rw an-pon-pg:typeb
|  |  +--rw an-pon-pg:stand-typeb?                    boolean
|  |  +--rw an-pon-pg:standby-port-suppress-flapping? suppress-flapping-type
|  +--rw an-pon-pg:dual-parenting
|  |  +--rw an-pon-pg:peer-node-name?   leafref
|  |  +--rw an-pon-pg:peer-member?      string
|  |  +--ro an-pon-pg:handshake-status? session-status
|  +--rw an-pon-pg:onu-forward-mode? enumeration
+--rw an-pon-pg:dual-parenting-sync
|  +--rw an-pon-pg:local-node-ports*            uint32
|  +--rw an-pon-pg:local-node-ip-addr?          inet:ipv4-address-no-zone
|  +--rw an-pon-pg:local-node-communication-key? ianach:crypt-hash
|  +--rw an-pon-pg:syn-switch?                  enumeration
+--rw an-pon-pg:dual-parenting-peer-node* [name]
   +--rw an-pon-pg:name               string
   +--rw an-pon-pg:ip-addr?           inet:ipv4-address-no-zone
   +--rw an-pon-pg:port?              uint32
   +--rw an-pon-pg:communication-key? ianach:crypt-hash
   +--ro an-pon-pg:connect-status?    session-status
```

7.3.3 East to West Traffic Models

7.3.3.1 Module an-l2-forwarding-policies.yang

This YANG module contains two augmentations for bbf-l2-forwarding [7]. As such, this module is specific to the OLT.

The data model has the following overall structure:

```
module an-l2-forwarding-policies
  augment /bbf-l2-fwd:forwarding
  +--ro forwarding-policy-profiles
     +--ro forwarding-policy-profile* [name]
        +--ro name                string
        +--ro forwarding-horizon {forwarding-horizon}?
           +--ro forwarding-horizon-switch? Boolean
  augment /bbf-l2-fwd:forwarding/bbf-l2-fwd:forwarders/bbf-l2-fwd:forwarder
  +--ro forwarding-policy * [name]
     +--ro name                      string
     +--ro vlan-id?                  bbf-dot1qt:vlan-id-range
     +--ro forwarding-policy-profile? Leafref
```

8 F5G Telemetry Models for Latency Measurement in Industrial Network

8.1 Overviews

The F5G Telemetry Models for Latency Measurement in Industrial network provide the functionality to configure the latency measurement and the data schema for the measurement results. These modules are published on the Forge platform at https://forge.etsi.org/rep/f5g/f5g-intelligent-management-for-pon-based-industrial-network/-/tree/v1.1.1/Low%20Latency%20Measurement?ref_type=heads.

8.2 Relationship with Other Telemetry Models

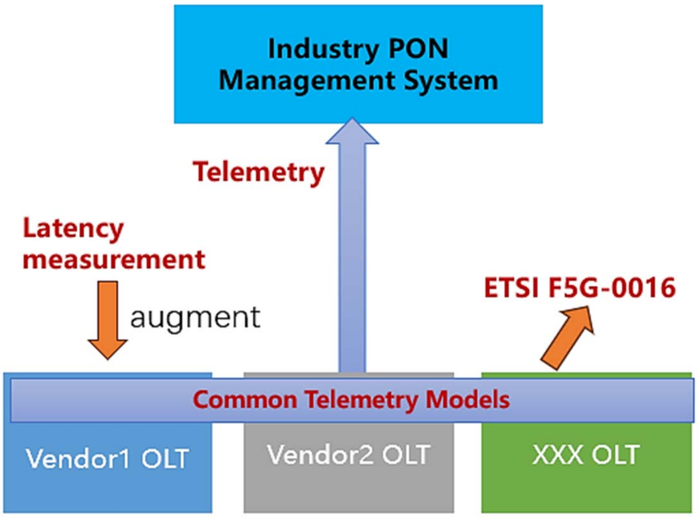

Figure 20: Relationship with Other Telemetry Models

The F5G Telemetry Models for Latency Measurement in Industrial network defined by the present document augments the latency measurement schema in ETSI GS F5G 016 [15] as shown in Figure 20. The basic mechanisms and models for Telemetry technology shall support ETSI GS F5G 016 [15].

8.3 Latency Measurement

8.3.1 ONIT Models

8.3.1.1 Module an-onu-uni.yang

This YANG module contains a collection of YANG definitions and augmentations of configurations for ONU-UNI interface. As such, this module is specific to the OLT.

8.3.1.2 Module an-onit.yang

This YANG module contains a collection of YANG definitions and augmentations of configurations for out-of-band network information telemetry. As such, this module is specific to the OLT.

The data model has the following overall structure:

```
module an-onit
   +--rw onit {an-onit}?
      +--rw enabled?           boolean
```

```
      +--rw global
      |  +--rw node-id? uint32
      +--rw measure-flows
      |  +--rw measure-flow* [name]
      |     +--rw name                     string
      |     +--rw destination-mac-address  yang:mac-address
      |     +--rw source-mac-address       yang:mac-address
      |     +--rw vlan-tag* [index]
      |        +--rw index    bbf-classif:tag-index
      |        +--rw vlan-id  bbf-dot1qt:vlan-id
      |        +--rw pbit?    bbf-dot1qt:pbit
      +--rw measure-instances
         +--rw measure-instance* [instance-id]
            +--rw instance-id      uint32
            +--rw measure-flow?    leafref
            +--rw enable?          boolean
            +--rw rate             uint32
            +--rw frame-size       uint32
            +--rw sample-interval? uint16
```

8.3.1.3 Module an-onit.proto

This protobuf module defines the data model for network statistics of out-of-band network information telemetry. As such, this module is specific to the OLT.

It has the following structure:

message: FlowStatistics	
--message: FlowStatistic	repeated
--flow_id	UINT64
--interval	UINT32
--measure_mode	UINT64
--direction	ENUM
--source_mac	String
--destination_mac	String
--vlan_tag_0	UINT32
--vlan_tag_1	UINT32
--rate	UINT32
--frame_length	UINT32
--packet_count	UINT64
--byte_count	UINT64
--min_delay	UINT32
--max_delay	UINT32
--avg_delay	UINT32
--if_name	String

8.3.2 INIT Models

8.3.2.1 Module an-init-common.yang

This YANG module contains a collection of YANG definitions and augmentations of configurations for INIT Container in 'an-init.yang'. As such, this module is specific to the OLT.

8.3.2.2 Module an-init.yang

This YANG module contains the 'init' Container for in-band network information telemetry. As such, this module is specific to the OLT.

The data model has the following overall structure:

```
module an-init
   +--rw init {an-init}?
      +--rw enabled?                  boolean
      +--rw init-common:init-common
         +--rw init-common:global
         |  +--rw init-common:node-id?                       uint32
         |  +--rw init-common:dynamic-flow-aging-multiplier? uint16
         |  +--rw init-common:clock-mode?                    clock-mode
         +--rw init-common:static-instances
```

```
+--rw init-common:static-instance* [instance-id]
   +--rw init-common:instance-id             uint32
   +--rw init-common:interval?               uint16
   +--rw init-common:measure-mode?           measure-mode
   +--rw init-common:delay-per-packet-enable? boolean
   +--rw init-common:flow
      +--rw init-common:flow-type    flow-type
      +--rw init-common:enabled?     boolean
      +--rw (flow-filter)
      |  +--:(filter-condition)
      |     +--rw init-common:mac-address
      |     |  +--rw init-common:filter-match?            boolean
      |     |  +--rw init-common:source-mac-address
      |     |  |  +--rw init-common:mac-address-value? yang:mac-address
      |     |  |  +--rw init-common:mac-address-mask?  yang:mac-address
      |     |  +--rw init-common:destination-mac-address
      |     |     +--rw init-common:mac-address-value? yang:mac-address
      |     |     +--rw init-common:mac-address-mask?  yang:mac-address
      |     +--rw init-common:ip-address
      |     |  +--rw init-common:filter-match?          boolean
      |     |  +--rw (ip-address-type)
      |     |  |  +--:(ipv4-type)
      |     |  |  |  +--rw init-common:source-ip?            inet:ipv4-address-no-zone
      |     |  |  |  +--rw init-common:destination-ip        inet:ipv4-address-no-zone
      |     |  |  |  +--rw init-common:source-mask?          uint8
      |     |  |  |  +--rw init-common:destination-mask?     uint8
      |     |  |  +--:(ipv6-type)
      |     |  |     +--rw init-common:source-ipv6           inet:ipv6-address-no-zone
      |     |  |     +--rw init-common:destination-ipv6      inet:ipv6-address-no-zone
      |     |  |     +--rw init-common:source-ipv6-mask?     uint8
      |     |  |     +--rw init-common:destination-ipv6-mask? uint8
      |     |  +--rw init-common:protocol?             uint8
      |     |  +--rw init-common:source-port?          uint16
      |     |  +--rw init-common:destination-port?     uint16
      |     |  +--rw init-common:dscp?                 uint16
      |     +--rw init-common:vlan-tag* [index]
      |        +--rw init-common:index    bbf-classif:tag-index
      |        +--rw init-common:vlan-id  bbf-dot1qt:vlan-id
      |        +--rw init-common:pbit?    bbf-dot1qt:pbit
      +--rw init-common:ifname?      if:interface-ref
      +--rw init-common:direction?   port-direction
```

8.3.2.3 Module an-init.proto

This protobuf module defines the data model for network statistics of in-band network information telemetry. As such, this module is specific to the OLT.

It has the following structure:

message: Init	
--message: FlowStatistics	
--message: FlowStatistic	repeated
--flow_id	UINT64
--interval	UINT32
--measure_mode	ENUM
--direction	ENUM
--source_mac	String
--source_mac_mask	String
--destination_mac	String
--destination_mac_mask	String
--addressFamily	ENUM
--source_ip	String
--destination_ip	String
--source_mask	UINT32
--destination_mask	UINT32
--source_port	UINT32
--destination_port	UINT32
--protocol	UINT64
--dscp	UINT32
--period_id	UINT64
--packet_count	UINT64
--byte_count	UINT64
--timestamp_second	UINT32
--timestamp_nanosecond	UINT32
--disorder_count	UINT64

--min_delay	UINT32
--max_delay	UINT32
--avg_delay	UINT32
--if_name	String

History

Document history		
V1.1.1	December 2025	Publication