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GROUP SPECIFICATION

Fifth Generation Fixed Network (F5G); Test Specification for PON Based Industrial Network

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ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
Association à but non lucratif enregistrée à la
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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

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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1 Scope

The present document specifies the test methods for functional requirements, performance requirements, basic management functions for PON based industrial networks, which are specified in ETSI GS F5G 022 [1].

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

[2] IEEE 802.1Q™-2022: "IEEE Standard for Local and Metropolitan Area Networks -- Bridges and Bridged Networks".

[3] IEEE 802.1X™-2020: "IEEE Standard for Local and Metropolitan Area Networks -- Port-Based Network Access Control".

[4] IETF RFC 7348: "Virtual eXtensible Local Area Network (VXLAN): A Framework for Overlaying Virtualized Layer 2 Networks over Layer 3 Networks".

[5] BBF TR-423 Issue 3 (August 2025): "PON PMD Layer Conformance Test Plan".

[6] ETSI GS F5G-TEST 030: "Fifth Generation Fixed Network (F5G); Test Specification for 50G-PON Functionality and Performance".

[7] IEEE 802.3™: "IEEE Standard for Ethernet".

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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The following referenced documents may be useful in implementing an ETSI deliverable or add to the reader's understanding, but are not required for conformance to the present document.

Not applicable.

3 Definition of terms, symbols and abbreviations

3.1 Terms

Void.

3.2 Symbols

Void.

3.3 Abbreviations

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

10GE	10 Gbit/s Ethernet
50G-PON	50 Gbit/s Passive Optical Network
BPDU	Bridge Protocol Data Unit
CAN	Controller Area Network
DHCP	Dynamic Host Configuration Protocol
DSCP	Differentiated Services Code Point
DUT	Device Under Test
EAP	Extensible Authentication Protocol
EFM	Ethernet Fiber Multiplexer
EMS	Element Management System
EPON	Ethernet Passive Optical Network
FEC	Forward Error Correction
GARP	Generic Attribute Registration Protocol
GE	Gigabit Ethernet
GMRP	GARP Multicast Registration Protocl
GPON	Gigabit Passive Optical Network
GVRP	GARP VLAN Registration Protocl
HMI	Human Machine Interface
ID	Identifier
IGMP	Internet Group Management Protocol
IP	Internet Protocol
IPoE	IP over Ethernet
LACP	Link Aggregation Control Protocol
LAN	Local Area Network
MAC	Media Access Control
MQTT	Message Queuing Telemetry Transport
NAK	Negative Acknowledgement
NMS	Network Management System
O&M	Observations and Measurements
ODN	Optical Distribution Network
OLT	Optical Line Terminal
OMCI	Optical Network Unit Management and Control Interface
ONU	Optical Network Unit
OPC	Open Platform Communications
PC	Personal Computer
POTS	Plain Old Telephone Service
PPPoE	Point-to-Point Protocol over Ethernet
QoS	Quality of Service
SLA	Service-Level Agreement
SW	Switch
TCP	Transmission Control Protocol
TOS	Type Of Service
ToS	Type of Service
UA	Unified Architecture

UDP	User Datagram Protocol
UNI	User-Network Interface
USB	Universal Serial Bus
VLAN	Virtual Local Area Network
VNI	VxLAN Network Identifier
VTEP	VxLAN Tunnel End Point
VxLAN	Virtual eXtensible LAN
WLAN	Wireless Local Area Network
XG-PON	10-Gigabit-capable Passive Optical Network
XGS-PON	10-Gigabit-capable Symmetric Passive Optical Network

4 Reference Model for PON based Industrial Network

4.1 Test Reference Model for Industrial PON

The industrial PON system comprises of three key components:

- the Optical Line Terminal (OLT);
- the Optical Network Unit (ONU); and
- optical splitters.

Where the different components are located is deployment specific and does not affect the testing. It operates as a single-fiber bi-directional system, enabling efficient data transmission. The system is managed through an industrial PON management platform, which monitors the Operation and Maintenance (O&M) functions of the OLTs and ONUs. The tests specified in the present document focuses on evaluating the OLTs, ONUs, and their O&M capabilities for industrial application.

On the OLT, the industrial PON may integrate an edge computing unit, enhancing its functionality. On the ONU, a customized platform or open software platform is utilized to collect industrial data. The ONU is either directly connected to industrial terminals or functions as an industrial protocol transparent transmission gateway. In the latter case, it connects to industrial terminals via a dedicated industrial data collection gateway. The ONU may support a wide range of industrial interfaces, including Ethernet, WLAN, POTS, USB, RS232/485, and CAN, ensuring versatility in industrial applications.

During testing, the appropriate ONU type should be selected based on specific requirements. The user side of the ONU is then connected to an industrial data collection gateway, test instruments, PCs, or industrial terminal devices. Figure 1 illustrates the reference test model for the industrial PON, providing a visual guide to the system's configuration. The industrial PON technology system is compatible with both EPON/10G EPON and GPON/XG-PON, 50G-PON technology systems, making it a flexible and scalable solution for industrial networking needs.

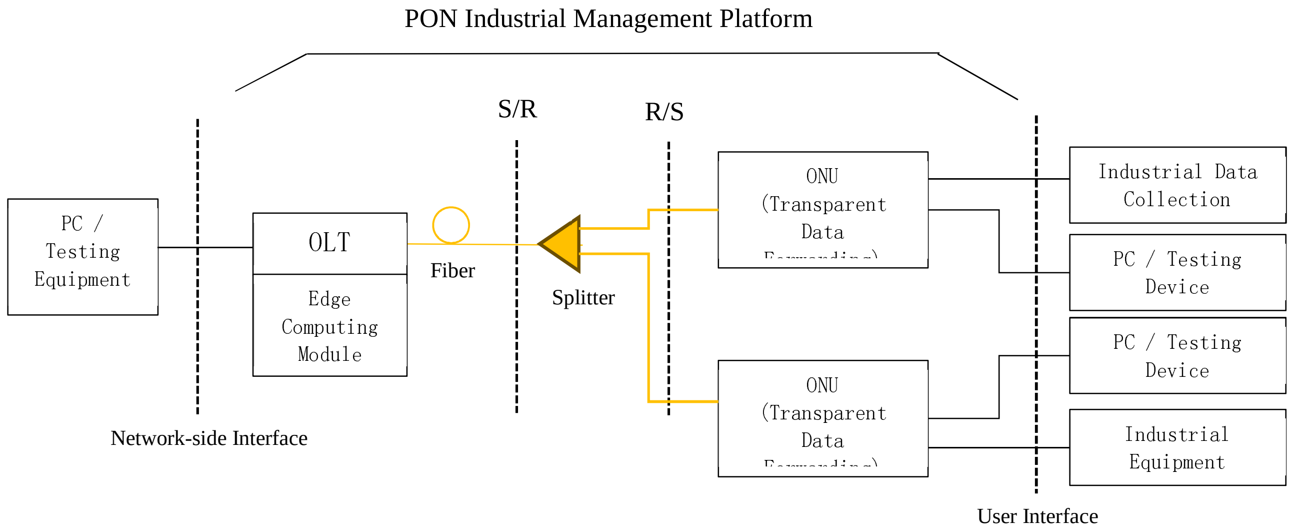

Figure 1: Reference model of the industrial PON set-up

4.2 Reference point for industrial PON testing

The reference model of industrial PON system is illustrated in Figure 1. The optical transmit signal is defined at the output end of the optical fiber, connected to the transmitter (reference point S). Unless otherwise specified, all transmitter tests outlined in the present document are conducted at point S. Similarly, the optical receiving signal is defined at the output end of the optical fiber, connected to the receiver (reference point R). Unless otherwise specified, all receiver tests described in the present document are performed at point R.

The test points of industrial PON equipment are as follows:

a) **Network-side interface:** refers to the reference point between the industrial PON OLT device and the industrial network connectivity to the enterprise network or a telecommunication network.

b) **Test point S:** indicates the fiber point close to the optical connector of the transmitter (OLT or ONU).

c) **Test point R:** indicates the fiber point that is close to the optical connector of the receiver (OLT or ONU).

d) **User-side interface:** refers to the reference point between an industrial PON device and a user terminal or other user-side devices.

5 Key function testing for industrial PON

5.1 PON interface test cases

5.1.1 OLT interface test cases

The PON interface test of 50G Industrial PON OLT shall use tests as defined in ETSI GS F5G-TEST 030 [6], clause 7.1, and the other speed rate of Industrial PON OLT shall use tests defined in BBF TR-423 [5], section 8.2.

5.1.2 ONU interface test cases

The PON interface test of 50G Industrial PON ONU shall use tests as defined ETSI GS F5G-TEST 030 [6], clause 7.2, and the other speed rate of Industrial PON ONU shall use tests as defined BBF TR-423 [5], section 7.2.

5.2 VLAN Function

5.2.1 Port-based VLAN function of the OLT (IEEE 802.1Q)

5.2.1.1 Test Purpose

To verify functions of the OLT on the IEEE 802.1Q [2] VLAN and port-based VLAN division, and to validate the OLT's support for VLAN port connection modes such as Access, Trunk, and Hybrid.

5.2.1.2 Test Configuration

The test configuration is shown in Figure 2.

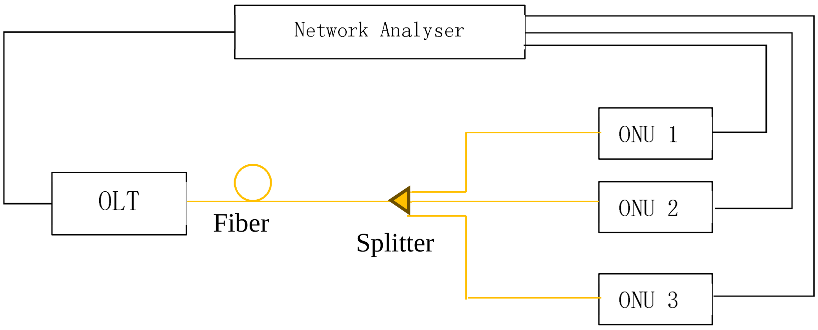

Figure 2: Test Configuration for Port-based VLAN Assignment on the OLT

5.2.1.3 Test Procedure

The test procedure shall be as follows:

1) Connect the ONU according to the configuration shown in Figure 2. Set the upstream port of the OLT to the VLAN Trunk mode and disable the VLAN tag function of the ONU.

2) On the OLT, set the following:

   a) ONU 1 to Access mode and add it to VLAN 1.

   b) ONU 2 to Trunk mode and add it to VLAN 2.

   c) ONU 3 to Hybrid connection mode and add it to VLAN 3 and VLAN 4. VLAN 3 is the default VLAN of the port.

3) Use the network analyser to transmit three data streams with VLAN 1, VLAN 2 and VLAN 3 tags in the downstream direction. Observe the receiving status of the data streams.

4) Use the network analyser to transmit an untagged upstream data stream to the ONU 1.

5) Use the network analyser to transmit an upstream data stream with VLAN tag 2 to the ONU 2.

6) Use the network analyser to transmit two data streams to the ONU 3:

   a) Data stream X does not carry the VLAN tag.

   b) Data stream Y carries the VLAN tag 4.

   Observe the receiving status of the two devices.

5.2.1.4 Expected Result

The expected result shall be as follows:

- In step 3, in the downstream direction shall be as follow:
  a) The ONU 1 receives only the data stream of VLAN 1 without VLAN tags.
  b) The ONU 2 receives only the data stream of VLAN 2 with VLAN tags.
  c) The ONU 3 receives only the data stream of VLAN 3 without VLAN tags.
- In step 4, the data stream received by the upstream direction from the ONU 1 carries the VLAN 1 tag.
- In step 5, the data stream received by the upstream direction in the upstream direction from the ONU 2 carries the VLAN2 tag.
- In step 6, one data stream X received by the upstream direction from the ONU 3 carries a VLAN 3 tag, and the other data stream Y carries a VLAN 4 tag.

5.2.2 OLT VLAN function based on the Ethernet MAC frame encapsulation protocol

5.2.2.1 Test Purpose

To test the capability of the OLT to divide VLANs based on the Ethernet frame encapsulation protocol.

5.2.2.2 Test Configuration

The test configuration is shown in Figure 3.

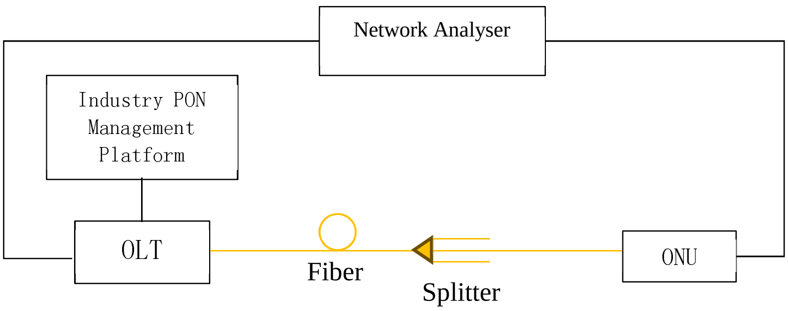

Figure 3: Test Configuration for VLAN Assignment Based on the Ethernet MAC Frame Encapsulation Protocol

5.2.2.3 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit according to the test configuration shown in Figure 3.
2) Activate the function of VLAN division based on the Ethernet MAC frame encapsulation protocol on the OLT, and disable the ONU-related functions. Then, set the MAC frame protocol and VLAN/S-VLAN ID mapping parameters.
3) Use the network analyser to transmit two data streams that use different Ethernet frame encapsulation protocols to the Ethernet port of the ONU. The data streams are encapsulated in IPoE mode and encapsulated in PPPoE mode respectively.
4) Check the VLAN ID of the received flow on the upstream port of the OLT.

5.2.2.4 Expected Results

The two data streams received by the OLT shall carry different VLAN IDs.

5.2.3 VLAN ID switching function

5.2.3.1 Test Purpose

To test the function of modifying the VLAN ID tag of the user data streams on the OLT.

5.2.3.2 Test Configuration

The test configuration is shown in Figure 3.

5.2.3.3 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit according to the test configuration shown in Figure 3.
2) Enable the VLAN ID switching function in the OLT. If the ONU supports the VLAN ID switching function - disable it on the ONU. Configure the OLT to forcibly change the VLAN ID of all traffic from the ONU user port to A.
3) Use the network analyser to transmit the upstream data with VLAN ID B to the user port of the ONU.
4) Check the VLAN ID of the received data stream on the upstream port of the OLT.
5) Use the network analyser to transmit the downstream data with VLAN ID A to the OLT.
6) Check the VLAN ID of the received data stream on the ONU.

5.2.3.4 Expected Result

The expected result shall be as follows:

- In step 4, the VLAN ID value of the data stream received by the OLT upstream port is changed to A.
- In step 6, the VLAN ID value of the data stream received by the ONU is modified to B.

5.3 OLT Upstream Port Link Aggregation Functionality

5.3.1 Test Purpose

To verify that the OLT upstream port supports the link aggregation function specified in IEEE 802.3 [7] when it has multiple Ethernet ports. To test the ability to load-balance upstream traffic from the ONU across the member links of the aggregation group. The resilience of the upstream link to the failure of one or more links.

5.3.2 Test Configuration

The test configuration is shown in Figure 4.

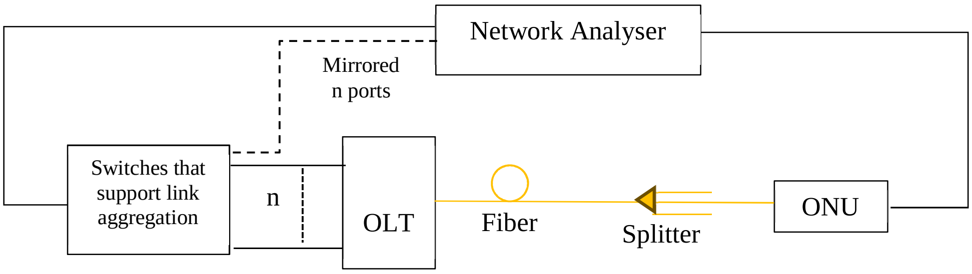

Figure 4: Configuration for testing the link aggregation function of the OLT uplink port

5.3.3 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit according to the test configuration illustrated in Figure 4.

2) Set up identical link aggregation configurations on both, the OLT and the switch that supports link aggregation, ensuring that the link aggregation groups at both ends include an equal number of ports. The ONU has the capability to trigger link aggregation.

3) Physically connect the switch and the n link aggregation group ports at both ends of the OLT.

4) Generate a high-rate upstream data stream from the ONU. This traffic is sufficient to saturate a single upstream link.

5) On the switch, configure a traffic mirroring session that copies the received traffic from all physical ports in the link aggregation group to a separate monitoring port connected to the network analyser.

6) Use the network analyser to continuously transmit upstream and downstream data streams whose bandwidth is greater than the bandwidth of the upstream port to the user port of ONU and the upstream port of the switch.

7) Mirror the link aggregation ports of the switch to another port, and analyse the incoming traffic from the mirrored ports using the network analyser.

8) To test resilience, disconnect the network cables one by one from the link aggregation ports between the switch and the OLT, and then use the network analyser to observe the data forwarding status of the remaining aggregation links through the mirrored ports.

5.3.4 Expected Results

The expected result shall be as follows:

- In step 4, the network analyser receives upstream and downstream data streams and no packet loss occurs.
- In step 7, the average values of the traffic statistics on each mirrored port obtained from the network analyser shall be the same with variance plus or minus 5 %.
- In step 8, the average traffic statistics obtained from the network analyser for the remaining link aggregation mirrored ports gradually increases, but the average traffic statistics among the mirrored ports shall be the same with variance plus or minus 5 %.

5.4 Quality of Services Functions -Traffic classification and priority marking

5.4.1 Priority marking for upstream service flows based on the Ethernet MAC frame encapsulation protocol

5.4.1.1 Test Purpose

To test the capability of the OLT and ONU to perform the upstream service flow classification and priority marking according to the Ethernet MAC frame encapsulation protocol.

5.4.1.2 Test Configuration

The test configuration is shown in Figure 5.

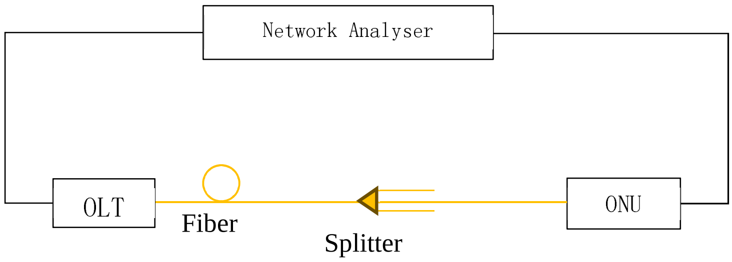

Figure 5: Test configuration for evaluating OLT and ONU upstream services

5.4.1.3 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit according to the test configuration illustrated in Figure 5.

2) Activate the function of marking the priority of upstream service flows based on the Ethernet MAC frame encapsulation protocol on the OLT to configure different IEEE 802.1Q [2] priorities for upstream service flows that use IPoE, IEEE 802.1X [3] and L2TP (optional) encapsulation protocols. If the ONU supports this function, disable this function on the ONU.

3) Use the network analyser to transmit two upstream traffic streams from the same Ethernet port of the ONU. Use the IPoE, IEEE 802.1X [3] and L2TP (optional) encapsulation modes. Check the IEEE 802.1Q [2] priority tag carried in the test frames received from the OLT upstream port.

4) If the ONU supports the function of marking the priority of the upstream service flow based on the Ethernet MAC frame encapsulation protocol, activate the function of the ONU and disable the function of the OLT.

5) Repeat step 3.

5.4.1.4 Expected Results

In steps 3 and 5, on the OLT uplink port, upstream that uses different encapsulation protocols shall carry different IEEE 802.1Q [2] priority marks.

5.4.2 MAC address-based upstream service flow classification and priority marking

5.4.2.1 Test Purpose

To test the capability of the OLT and ONU to perform upstream service flow classification and priority marking based on the MAC address.

5.4.2.2 Test Configuration

The test configuration is shown in Figure 5.

5.4.2.3 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit according to the test configuration illustrated in Figure 5.

2) To activate the function of marking the priority of upstream service flows based on the MAC address on the OLT, run the corresponding command and configure the corresponding IEEE 802.1Q [2] priority marking parameters for the corresponding source and destination MAC addresses. If the ONU supports this function, disable this function on the ONU.

3) Use the network analyser to transmit two upstream streams with different source and destination MAC addresses from the same Ethernet port of the ONU. Check the IEEE 802.1Q [2] priority carried in the test frames received from the upstream port of the OLT.

4) If the ONU supports the function of marking the priority of the upstream service flow based on the MAC address, activate the function on the ONU and disable the function on the OLT.

5) Repeat step 3.

5.4.2.4 Expected Results

In steps 3 and 5, on the OLT upstream port, upstream with different source and destination MAC addresses shall carry different IEEE 802.1Q [2] priority marks.

5.4.3 IP address-based upstream service flow classification and priority marking

5.4.3.1 Test Purpose

To test the capability of the OLT and ONU to perform upstream service flow classification and priority marking based on IP addresses.

5.4.3.2 Test Configuration

The test configuration is shown in Figure 5.

5.4.3.3 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit according to the test configuration illustrated in Figure 5.

2) Activating the Function of marking the priority of upstream service flows based on the IP Address on the OLT. If the ONU supports this function, disable this function on the ONU. Configure the corresponding IEEE 802.1Q [2] priority marking parameters for different sources and destination IP addresses.

3) Use the network analyser to transmit two upstream streams with different sources and destination IP addresses from the same Ethernet port of the ONU. Check the IEEE 802.1Q [2] priority carried in the test frames received from the OLT upstream port.

4) If the ONU supports the function of marking the priority of the upstream service flow based on the IP address, activate this function on the ONU and disable this function on the OLT.

5) Repeat step 3.

5.4.3.4 Expected Results

In steps 3 and 5, on the OLT upstream port, upstream flows with different source and destination IP addresses shall carry different IEEE 802.1Q [2] priority marks.

5.4.4 ToS/DSCP field-based upstream service flow classification and priority marking

5.4.4.1 Test Purpose

To test the capability of the OLT and ONU to perform upstream service flow classification and priority marking based on ToS/DSCP fields.

5.4.4.2 Test Configuration

The test configuration is shown in Figure 5.

5.4.4.3 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit according to the test configuration illustrated in Figure 5.

2) Activating the function of marking the priority of upstream service flows based on the ToS/DSCP Field of IP Packets on the OLT. If the ONU supports this function, disable this function on the ONU. Configure the mapping table from the TOS/DSCP field to the IEEE 802.1Q [2] priority marking parameter.

3) Use the network analyser to transmit two upstream flows with different ToS/DSCP fields from the same Ethernet port of the ONU. Ensure that the ToS/DSCP fields of the two flows are mapped to different IEEE 802.1Q [2] priority parameters. Check the IEEE 802.1Q [2] priority carried in the test frame received from the OLT upstream port.

4) If the ONU supports the function of marking the priority of upstream service flows based on the ToS/DSCP field of IP packets, activate this function on the ONU and disable this function on the OLT.

5) Repeat step 3.

5.4.4.4 Expected Results

In steps 3 and 5, on the OLT upstream port, upstream flows with different ToS/DSCP fields shall carry different IEEE 802.1Q [2] priority tags.

5.4.5 Upstream service flow classification and priority marking based on TCP/UDP ports

5.4.5.1 Test Purpose

To test the OLT and ONU's capability of classifying upstream service flows and marking priorities based on the TCP/UDP ports of IP packets.

5.4.5.2 Test Configuration

The test configuration is shown in Figure 5.

5.4.5.3 Test Procedure

The test procedure is as follows:

1) Connect the circuit according to the test configuration illustrated in Figure 5.

2) Activate the function of marking the priority of upstream service flows based on the TCP/UDP port of IP packets on the OLT and configure the mapping table from TCP/UDP ports to IEEE 802.1Q [2] priority marking parameters. If the ONU supports this function, disable this function on the ONU.

3) Use the network analyser to transmit two upstream flows with different TCP/UDP port numbers from the same Ethernet port on the ONU. Ensure that the TCP/UDP port numbers of the two flows are mapped to different IEEE 802.1Q [2] priority parameters. Check the IEEE 802.1Q [2] priority carried in the test frame received from the OLT upstream port.

4) If the ONU supports the function of marking the priority of upstream service flows based on the TCP/UDP port of the IP packet, activate the function on the ONU and disable the function on the OLT.

5) Repeat step 3.

5.4.5.4 Expected Results

In steps 3 and 5, on the OLT upstream port, upstream flows with different TCP/UDP ports shall carry different IEEE 802.1Q [2] priority tags.

5.5 Quality of Services Functions -Service priority marking processing

5.5.1 Service Priority marking modification

5.5.1.1 Test Purpose

To test the function of modifying the priority of the upstream service flow on the OLT and ONU.

5.5.1.2 Test Configuration

The test configuration is shown in Figure 6.

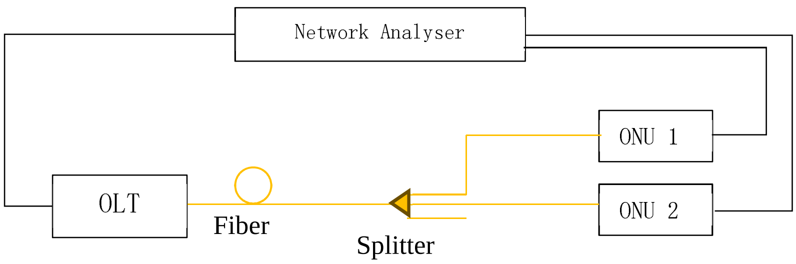

Figure 6: Service priority marking processing test configuration

5.5.1.3 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit according to the test configuration illustrated in Figure 6. If the ONU supports the function of modifying the service priority, disable the function on the ONU.

2) On the OLT, set the IEEE 802.1Q [2] priorities of upstream Ethernet streams from ONU 1 and ONU 2 to 3 and 5 respectively.

3) Use the network analyser to transmit Ethernet streams with the IEEE 802.1Q [2] priority 4 to the ONU 1 and ONU 2. Observe the data frames received by the upstream port of the OLT.

4) Enable the function of modifying the priority tag on the ONU and disable the function on the OLT. On the ONU 1, set the IEEE 802.1Q [2] priority of the upstream Ethernet flow to 3 and on the ONU 2 set the IEEE 802.1Q [2] priority of the upstream Ethernet flow to 5.

5) Repeat step 3.

5.5.1.4 Expected Results

In steps 3 and 5, on the uplink port of the OLT, the priority labels carried by the Ethernet frames from the ONU 1 and the ONU 2 shall be 3 and 5 respectively.

5.5.2 Priority Marked Replication

5.5.2.1 Test Purpose

To verify the capability of the OLT to copy the inner priority tag to the outer priority tag when processing the upstream service flow with dual VLAN tags.

5.5.2.2 Test Configuration

The test configuration is shown in Figure 5.

5.5.2.3 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit according to the test configuration illustrated in Figure 5.

2) Enable the VLAN stacking function on the OLT, configure the corresponding outer VLAN tag, and enable the priority-level tag duplication function. If the ONU supports this function, disable this function on the ONU.

3) Use the network analyser to transmit data frames with the IEEE 802.1Q [2] priority as 4 to the ONU user port. Observe the data frames received by the upstream port of the OLT.

5.5.2.4 Expected Results

In step 3, the received data frames at the OLT uplink port carry two VLAN tags and priority tags. The priority tags in the inner and outer layers shall be 4.

5.6 Quality of Services Functions -Service Flow Rate Limit

5.6.1 Flow Control Function

5.6.1.1 Test Purpose

To verify that the OLT's upstream Ethernet port and the ONU's user-side Ethernet port support IEEE 802.3 [7] flow control function (PAUSE frames) in full-duplex mode.

5.6.1.2 Test Configuration

The test configuration is shown in Figure 5.

5.6.1.3 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit according to the test configuration shown in Figure 5.
2) Enable PAUSE frame-based flow control on the OLT's upstream Ethernet port. Disable this function on the ONU.
3) Enable the port-based downstream rate limit function on the OLT to limit the maximum downstream rate of the Ethernet to 500 Mbps.
4) Use the network analyser to transmit a 1 Gbit/s data stream to the ONU via the OLT's upstream Ethernet port.
5) Use the network analyser to check whether the OLT receives the PAUSE frame from the upstream Ethernet port of the OLT.
6) Activate the PAUSE frame-based flow control on the ONU's Ethernet port. Disable this function on the OLT.
7) On the ONU, configure upstream rate limit for the user port by setting the maximum upstream rate to 50 % of the maximum rate supported by the user port.
8) Using the network analyser, transmit an upstream Ethernet data stream at the maximum rate supported by the ONU to the ONU user port.
9) Use the network analyser to check whether the ONU receives the PAUSE frame from the Ethernet port on the user's side.

5.6.1.4 Expected Results

The expected result shall be as follows:

- In step 5, the network analyser receives a PAUSE frame from the OLT's upstream Ethernet port.
- In step 9, the network analyser receives a PAUSE frame from the Ethernet port on the user's side ONU.

5.6.2 Downstream service flow rate limiting based on physical ports

5.6.2.1 Test Purpose

To test the capability of the OLT limiting the downstream service rate based on the ONU physical port.

5.6.2.2 Test Configuration

The test configuration is shown in Figure 7.

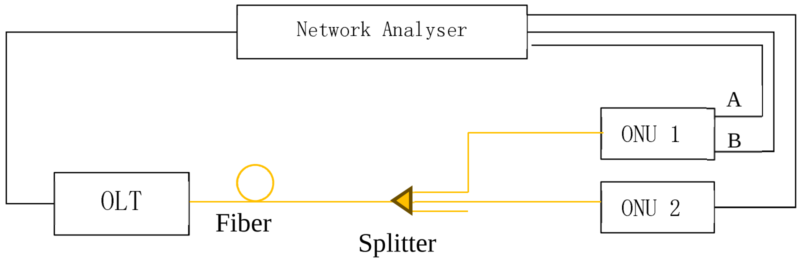

Figure 7: Service flow rate limit test configuration

5.6.2.3 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit according to the test configuration shown in Figure 7.

2) On the OLT, activate the function of flow rate limiting based on the physical port of the ONU, disable this function on the ONUs under test if the ONUs support this function.

3) Set the maximum downstream service rate of the Ethernet port A to 80 Mbps and the maximum downstream service rate of the Ethernet port B to 90 Mbps on the ONU 1. Set the maximum downstream service rate of the Ethernet port on the ONU 2 to 100 Mbps.

4) Use the network analyser to transmit downstream test data streams from the upstream port of the OLT to ports A, B of ONU 1, and to the ONU 2 with flow rate of 150 Mbps respectively.

5) Check the received rate of each Ethernet port on the ONU 1 and ONU 2.

5.6.2.4 Expected Results

The expected result shall be as follows:

- In step 5, ONU 1 receives downstream data traffic at 80 Mbps on Ethernet port A and 90 Mbps on port B, and the rate limit precision is within 5 % for each port.

- ONU 2 receives downstream data traffic at 100 Mbps on its port and the rate limit precision is within 5 %.

5.6.3 Downstream service flow rate limiting based on VLAN ID

5.6.3.1 Test Purpose

To test the capability of the OLT limiting the downstream service rate based on the VLAN ID.

5.6.3.2 Test Configuration

The test configuration is shown in Figure 7.

5.6.3.3 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit according to the test configuration shown in Figure 7.

2) Enable the VLAN ID-based rate limiting function on the OLT, disable this function on the ONUs under test if the ONUs support this function.

3) Set the maximum downstream service rate of VLAN 1, VLAN 2, and VLAN 3 to 80 Mbps, 90 Mbps, and 100 Mbps.

4) Map ONU 1's Ethernet port A to VLAN 1, port B to VLAN 2, and ONU 2's Ethernet port to VLAN 3.

5) Use the network analyser to transmit 150 Mbps downstream test data streams from the upstream port of the OLT to VLAN 1, VLAN 2, and VLAN 3 respectively.

6) Check the received rate of each Ethernet port on the ONU 1 and ONU 2.

5.6.3.4 Expected Results

The expected result shall be as follows:

- In step 6, the downstream data traffic received by the Ethernet port A of ONU 1 is 80 Mbps, and the downstream data traffic received by the Ethernet port B of ONU 1 is 90 Mbps, and the rate limit precision is within 5 % for each port.

- The downstream data traffic received by the Ethernet port of ONU 2 is 100 Mbps, and the rate limit precision is within 5 %.

5.6.4 Downstream service flow rate limiting based on Ethernet priority marking

5.6.4.1 Test Purpose

To test the capability of the OLT limiting the downstream service rate based on the Ethernet priority.

5.6.4.2 Test Configuration

The test configuration is shown in Figure 5.

5.6.4.3 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit according to the test configuration shown in Figure 5.

2) Enable the Ethernet priority-based rate limiting function on the OLT, disable this function on the ONU under test if the ONU supports this function. Set the maximum downstream rates for the following service flows based on their Ethernet priority tags:

   - Priority tag 5: 40 Mbps.

   - Priority tag 4: 30 Mbps.

   - Priority tag 3: 20 Mbps.

3) Use the network analyser to transmit three downstream test data streams at the rate of 50 Mbps respectively from the upstream port of the OLT to the user port of the ONU. The Ethernet priority of the three test data streams are set to 5, 4, 3 respectively.

4) Check the receiving rate of the Ethernet port on the ONU.

5.6.4.4 Expected Results

In step 4, in the downstream data stream received by the ONU's Ethernet port, traffic with Ethernet priority label 5 shall be 40 Mbps, while traffic with priority label 4 shall be 30 Mbps. The downstream traffic with the Ethernet priority marked as 3 is 20 Mbps, and the rate limit precision shall be within 5 % for each priority tag.

5.7 Service priority scheduling policy

5.7.1 Downlink strict priority scheduling policy

5.7.1.1 Test Purpose

To verify the capability of the OLT to schedule downstream services by using a strict priority scheduling policy.

5.7.1.2 Test Configuration

The test configuration is shown in Figure 5.

5.7.1.3 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit according to the test configuration shown in Figure 5.
2) On the OLT, enable strict priority scheduling for downstream traffic based on the IEEE 802.1Q [2] priority marking where priority values (e.g. 7) are always served before lower values (e.g. 0). If the ONU supports this function, disable it on the device.
3) On the OLT, configure a maximum downstream service rate limit of 100 Mbps on the ONU's Ethernet port.
4) Use the network analyser to transmit two downstream service streams at the rate of 100 Mbps to the OLT's upstream port. The two downstream service streams shall carry the IEEE 802.1Q [2] priorities 3 and 5 respectively.
5) Observe the service streams received by the ONU.

5.7.1.4 Expected Results

In step 5, the network analyser shall receive only the service flow with the priority of 5.

5.7.2 Downlink relative priority scheduling policy

5.7.2.1 Test Purpose

To verify the capability of the OLT scheduling downstream services by using a relative priority scheduling policy.

5.7.2.2 Test Configuration

The test configuration is shown in Figure 5.

5.7.2.3 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit according to the test configuration shown in Figure 5.
2) Activate the function of scheduling downstream service flows based on the IEEE 802.1Q [2] priority marking function. If the ONU supports this function, disable it on the device.
3) Set the percentage of the 8 queues to 10 %, 10 %, 10 %, 10 %, 10 %, 15 %, 15 % and 20 % respectively.
4) On the OLT, configure the maximum downstream service rate to the ONU's Ethernet port to 100 Mbps.
5) Use the network analyser to transmit 8 downstream service flows, each at 100 Mbps, to the OLT's upstream port. The traffic carries IEEE 802.1Q [2] priorities 0, 1, 2, 3, 4, 5, 6 and 7.

6) Observe the service flow received by the ONU.

5.7.2.4 Expected Results

In step 6, the network analyser receives packets from 8 flows marked with ascending priorities (0 - 7). The flows shall be allocated 10 %, 10 %, 10 %, 10 %, 10 %, 15 %, 15 % and 20 % of the total traffic respectively. The excess packets shall be discarded.

5.7.3 Uplink strict priority scheduling policy

5.7.3.1 Test Purpose

To verify the capability of the OLT to schedule upstream services by using the strict priority scheduling policy.

5.7.3.2 Test Configuration

The test configuration is shown in Figure 6.

5.7.3.3 Test Procedure

The test procedure shall be as follows:

1) Connect the devices according to the test configuration shown in Figure 6. Use the GE uplink port of the OLT to ensure that the upstream throughput of the ONU 1 and ONU 2 reaches 1 000 Mbps. Disable the upstream priority scheduling function of the ONU.

2) Enable the OLT to perform strict priority scheduling for upstream service flows based on the IEEE 802.1Q [2] priority.

3) Use the network analyser to transmit one upstream service flow to ONU 1. The rate is 1 000 Mbps and the carried IEEE 802.1Q [2] priority is 3. Use the network analyser to transmit one upstream service flow to ONU2. The rate is 1 000 Mbps and the carried IEEE 802.1Q [2] priority is 5. Observe the service flow received by the upstream port of the OLT.

5.7.3.4 Expected Results

In step 3, the network analyser receives only the service flow with the priority of 5.

5.7.4 Uplink relative priority scheduling policy

5.7.4.1 Test Purpose

To verify the capability of the OLT scheduling upstream services by using the relative priority scheduling policy.

5.7.4.2 Test Configuration

The test configuration is shown in Figure 6.

5.7.4.3 Test Procedure

The test procedure shall be as follows:

1) Connect the devices according to the test configuration shown in Figure 6. Use the GE uplink port of the OLT. Ensure that the upstream throughput of the two ONUs reaches 1 000 Mbps and disable the upstream priority scheduling function of the ONUs.

2) Enable the OLT to perform relative priority scheduling for upstream service flows based on the IEEE 802.1Q [2] priority, and set the weights of the eight queues to 10, 10, 10, 10, 10, 15, 15 and 20 respectively.

3) Use the network analyser to transmit four upstream service flows to ONU 1 at the rate of 250 Mbps. The carried IEEE 802.1Q [2] priorities marked as 0, 1, 2, and 3 respectively. Use the network analyser to transmit four upstream service flows to ONU 2. The rate of each service flow is 250 Mbps. The carried IEEE 802.1Q [2] priorities marked as 4, 5, 6 and 7 respectively.

4) Observe the service flow received by the upstream port of the OLT.

5.7.4.4 Expected Results

In step 4, the Network Analyser shall receive eight flows. The flows occupy 10 %, 10 %,10 %, 10 %, 10 % ,15 %, 15 % and 20 % of the total traffic in ascending order of priorities. The excess packets shall be discarded.

5.7.5 Uplink hybrid priority scheduling policy

5.7.5.1 Test Purpose

To verify the OLT's capability of scheduling upstream services by using the hybrid priority scheduling policy.

5.7.5.2 Test Configuration

The test configuration is shown in Figure 6.

5.7.5.3 Test Procedure

The test procedure shall be as follows:

1) Connect the devices according to the test configuration shown in Figure 6. Use one GE uplink port of the OLT. Ensure that the upstream throughput of the two ONUs reaches 1 000 Mbps. Disable the upstream priority scheduling function of the ONUs.

2) Enable the OLT to perform mixed priority scheduling for upstream service flows based on the IEEE 802.1Q [2] priority marking. Priority tags 1, 3 and 5 are relative priorities with weights 20, 30, and 50 respectively. Priority marking 7 is strict.

3) Use the network protocol analyser to transmit four upstream service flows at the rate of 250 Mbps to ONU 1 and ONU 2 respectively. The carried IEEE 802.1Q [2] priorities are 1, 3, 5 and 7 respectively.

4) Observe the service flows received by the upstream port of the OLT.

5.7.5.4 Expected Results

In step 4, all the traffic with IEEE 802.1Q [2] priority tag 7 shall be fully admitted by Network Analyser. For the remaining traffic with priority tags 1, 3 and 5 shall be allocated 20 %, 30 % and 50 % respectively. The excess traffic beyond these quotas shall be discarded.

5.8 Network slicing testing

5.8.1 Downlink service flow rate limiting

5.8.1.1 Test Purpose

To test the capability of the OLT slice to limit the downstream service rate based on the PON port.

5.8.1.2 Test Configuration

The test configuration is shown in Figure 8.

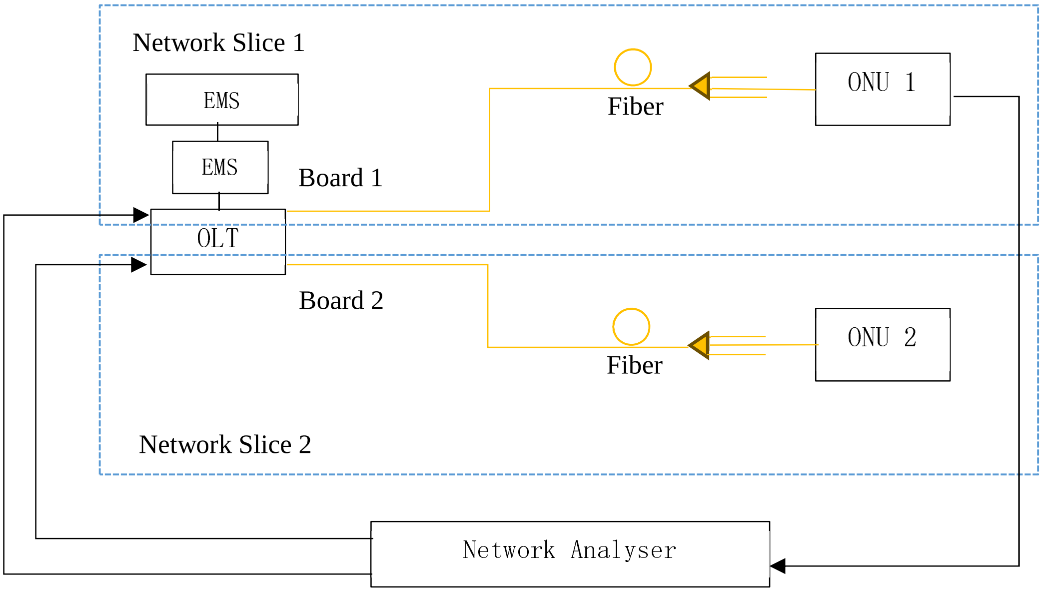

Figure 8: Configuring the Downlink Service Flow Rate Limit Function

5.8.1.3 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit as shown in Figure 8.

2) Log in to the EMS client:

   a) Open Network Slice Management interface on Network Slice Management page and select tested OLT.

   b) Add two network slices using following naming "Network Slice 1" and "Network Slice 2" in the network slice list accordingly.

   c) Set the network slice mode granularities of the two slices to board mode.

   d) Select a resource allocation template for each slice.

   e) Disable the rate limit function of the ONUs under test.

3) On Network Slice 1, activate the OLT PON port-based rate limit function and set the downstream service rate of the PON port to 8 Mbps.

4) Use network analyser to transmit 15 Mbps test data streams from the upstream port of the OLT in Network Slice 1 to the Ethernet port of the ONU 1.

5) Check the receiving rate of the Ethernet port on the ONU 1.

6) Repeat step 2 to step 5 using Network Slice 2 and ONU 2.

5.8.1.4 Expected Results

The expected result shall be as follows:

- In step 5, the data traffic received by the ONU1 Ethernet port is 8 Mbps, and the rate limit precision is within 5 %.

- In step 6, the data traffic received by the ONU2 Ethernet port is 8 Mbps, and the rate limit precision is within 5 %.

5.8.2 Downlink traffic rate limiting based on IEEE 802.1Q priority

5.8.2.1 Test Purpose

To test the capability of the OLT slice to limit the downstream service flow rate based on IEEE 802.1Q [2] priority.

5.8.2.2 Test Configuration

The test configuration is shown in Figure 8.

5.8.2.3 Test Procedure

The test procedure shall be as follows:

1) Connect the link as shown in Figure 8.
2) Log in to the EMS client:
   a) Open Network Slice Management view on Network Slice Management page and select tested OLT.
   b) Add two network slices using following naming "Network Slice 1" and "Network Slice 2" in the network slice list accordingly.
   c) Set the network slice mode granularity to board mode.
   d) Select a resource allocation template for each slice.
   e) Disable the IEEE 802.1Q [2] priority-based rate limiting function on ONU 1 and ONU 2.
3) Enable IEEE 802.1Q [2] priority-based downlink service rate limiting on Network Slice 1 and set the maximum downlink traffic rate to 8 Mbps for IEEE 802.1Q [2] priority 3 and 10 Mbps for IEEE 802.1Q [2] priority 5.
4) Use network analyser to transmit the service flow with priority 3 to the upstream port of the OLT in Network Slice 1 at the rate of 12 Mbps.
5) Record the traffic rate received by ONU 1.
6) Use network analyser to transmit the service flow with priority 5 to the upstream port of the OLT in Network Slice 1 at the rate of 12 Mbps.
7) Record the traffic rate received by ONU 1.
8) Repeat steps 3 - 7 for Network Slice 2 and ONU 2.

5.8.2.4 Expected Results

The expected result shall be as follows:

- In steps 4 and 6, the data traffic received by ONU 1 are 8 Mbps and 10 Mbps respectively, and the rate limit precision is within 5 %.
- In step 8, the data traffic received by ONU 2 are 8 Mbps and 10 Mbps respectively, and the rate limit precision is within 5 %.

5.8.3 Downstream traffic shaping capability

5.8.3.1 Test Purpose

To test the capability of shaping the downstream burst traffic by the OLT slice.

5.8.3.2 Test Configuration

The test configuration is shown in Figure 9.

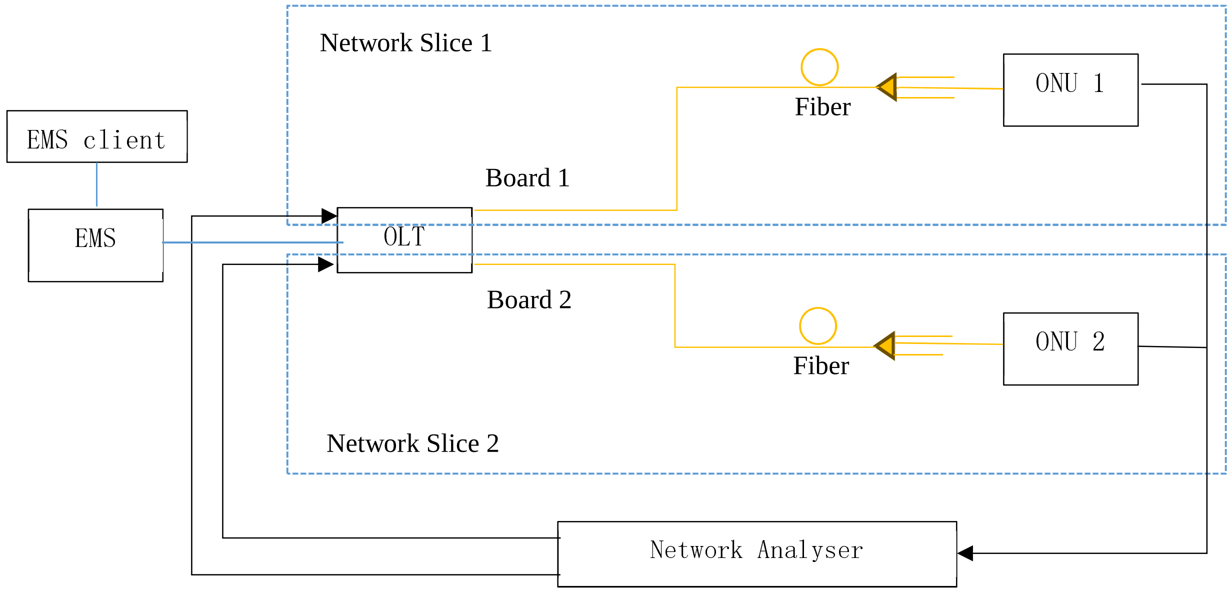

Figure 9: Uplink service priority scheduling policy

5.8.3.3 Test Procedure

The test procedure shall be as follows:

1) Connect the equipment as shown in Figure 9. Log in to the EMS client, open the Network Slice Management page, select the tested OLT, add two network slices named Network Slice 1 and Network Slice 2, set the network slice mode granularity to BOARD, select the resource allocation template, and click OK.

2) In network slice 1, an OLT uplink port is a 10GE port, and an ONU downlink port is a GE port. Set the downstream service bandwidth of the ONU to 1 000 Mbps.

3) Use the network analyser to transmit a single burst packet with a packet length of 1 024 bytes, a rate of 10 Gbps, and 1 000 burst packets to the upstream port of the OLT in network slice 1.

4) Use the network analyser to receive the downstream data stream.

5) If no packets are lost in step 4, increase the number of burst packets and repeat steps 3 and 4 until packet loss occurs.

6) Repeat step 2 to step 5 for the network slice 2.

5.8.3.4 Expected Results

The expected result shall be as follows:

- In step 5, record the number of packets last received, and further calculate the actual number of packets buffered for Network Slice 1.

- In step 6, record the number of packets last received, and further calculate the actual number of packets buffered for Network Slice 2.

5.8.4 Upstream IP service priority scheduling strategy

5.8.4.1 Test Purpose

To verify the OLT slice scheduling capability for upstream services using the hybrid priority scheduling policy.

5.8.4.2 Test Configuration

The test configuration is shown in Figure 10.

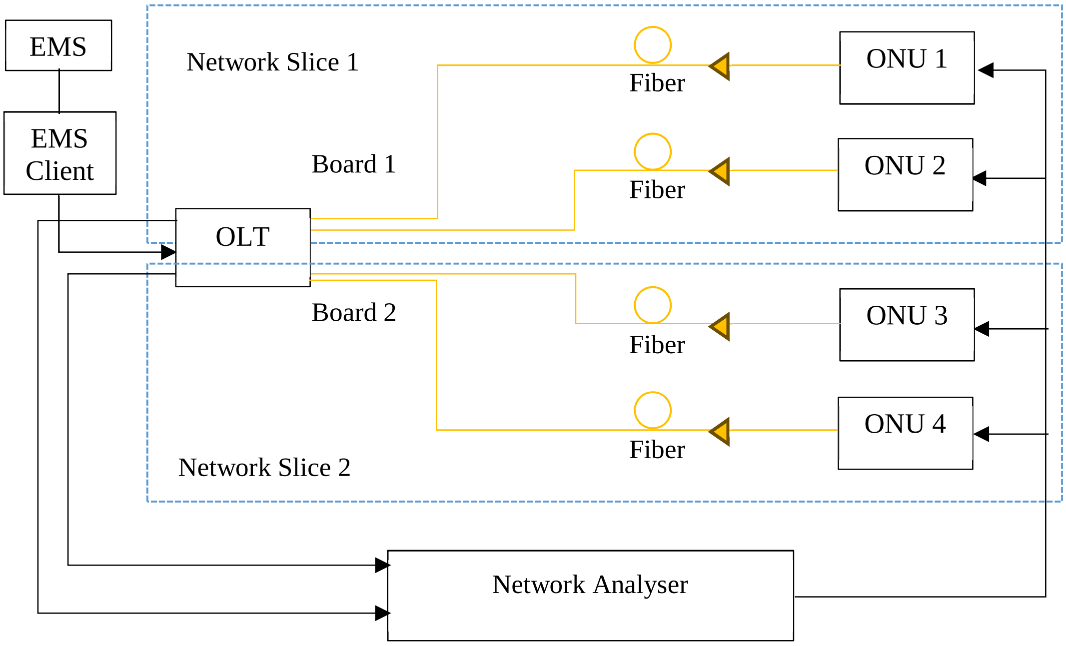

Figure 10: Uplink service priority scheduling policy

5.8.4.3 Test Procedure

The test procedure shall be as follows:

1) Connect the equipment as shown in Figure 10 and log in to the EMS client. On the Network Slice Management page, open the Network Slice Management view:

   a) Select the tested OLT. Add two network slices named Network Slice 1 and Network Slice 2.

   b) The network slice mode granularity set to BOARD.

   c) Select a resource allocation template and click OK. Do not configure any ONU-side service flow classification, marking, queuing, or scheduling functions.

2) Connect one GE port of the network analyser to the OLT uplink port of network slice 1 and connect the two ONUs on the two PON ports of network slice 1 to the other two GE ports of the network analyser.

3) Configure network slice 1 to perform hybrid priority scheduling for uplink service flows based on IEEE 802.1Q [2] priorities. IEEE 802.1Q [2] priorities 0 to 7 indicate the highest priorities in ascending order. 1, 3 and 5 are relative priorities, weights 20, 30, and 50, and 7 is absolute priority.

4) Use the network analyser to transmit two upstream service streams to ONU 1 and ONU 2. The rate of the service streams is 500 Mbps and the IEEE 802.1Q [2] priorities are 1, 3, 5 and 7 respectively. Observe the service flow received by the upstream port of the OLT in network slice 1.

5) Repeat steps 2, 3, 4 for the network slice 2.

5.8.4.4 Expected Results

The expected result shall be as follows:

- In step 4, all the flows with the IEEE 802.1Q [2] priority of 7 shall be received. The flows with the IEEE 802.1Q [2] priority of 1, 3 and 5 account for 20 %, 30 % and 50 % of the remaining traffic respectively. The excess traffic is discarded.

- In step 5, the results similar to step 4 shall be received.

5.8.5 Network slicing management view

5.8.5.1 Test Purpose

To verify the topology management function of a network slice.

5.8.5.2 Test Configuration

The test configuration is shown in Figure 11.

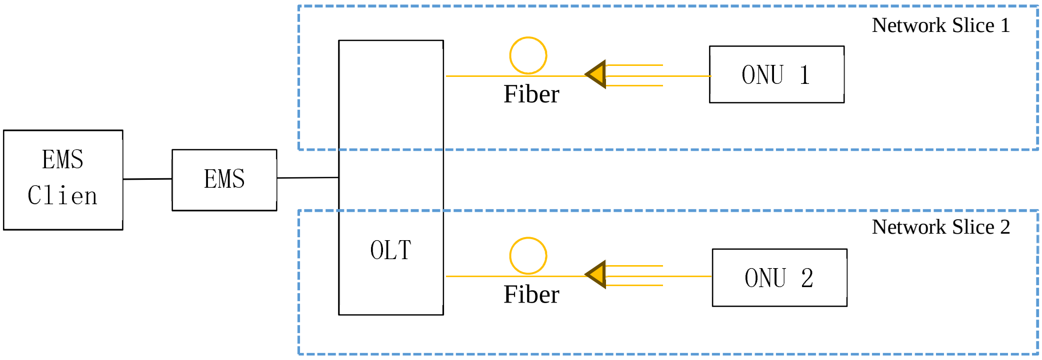

Figure 11: Network slicing management view test configuration

5.8.5.3 Test Procedure

The test procedure shall be as follows:

1) Connect the equipment as shown in Figure 11.
2) Log in to the EMS client and enter the OLT management view.
3) Check if the physical OLT management view is user-friendly (easy to understand, navigate and operate) and whether the information is displayed comprehensively.
4) Check if all network slices of the physical OLT are displayed on the management page.
5) Check if the management interface contains relevant resource information and if the information is comprehensive and user-friendly.
6) Check if the hierarchical relationship between physical devices and network slices are matched.
7) Randomly select a network slice and enter the slice management page.
8) Check if slice-related physical resources are graphically displayed on the management page.
9) Check if slice-related service resource information is displayed on the management page and whether the information is comprehensive and user-friendly.

5.8.5.4 Expected Results

The expected result shall be as follows:

- In step 3, the management interface has a graphical view, the common device information and functional modules are reasonable and user-friendly.
- In step 4, all network slices under the physical device are intuitively displayed in the management view.

- In step 5, the management interface intuitively displays the port or board resource occupied by the related network slice, and displays in detail information such as the related resource allocated by the network slice, global resource, allocated resource, and remaining resource.
- In step 6, the management view intuitively displays the hierarchy between the physical OLT and the network slice.
- In step 8, after the network slice management interface is displayed, the physical resources of the slice are displayed in a graphical view, and only the resources occupied by the slice are viewed by the relevant ports or boards.
- In step 9, the management interface provides the service resource information, including the resources owned by the slice, used resources, and remaining resources, and the interface is user-friendly.

5.8.6 Network slice maintenance and management mode

5.8.6.1 Test Purpose

To verify maintenance and management functions for network slices.

5.8.6.2 Test Configuration

The test configuration is shown in Figure 12.

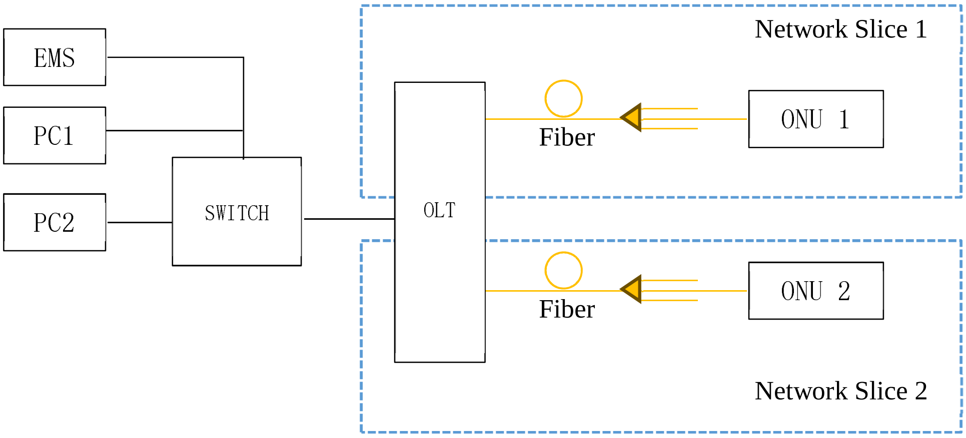

Figure 12: Network slice creation test configuration

5.8.6.3 Test Procedure

The test procedure shall be as follows:

1) Connect the equipment as shown in Figure 12. Log in into the EMS client, open the network slice management interface, and create network slice 1 and network slice 2. The granularity of the network slice 1 set to PORT, and the granularity of network slice 2 set to BOARD.

2) Set different management IP addresses for different slices, set the management IP address of the network slice 1 to A, and the management IP address of network slice 2 to B.

3) Set the IP address of PC1 within the same subnet as IP A, set the IP address of PC2 within the same subnet as IP B.

4) After step 3, network slice 1 is visited and managed by PC1 via IP A, network slice 2 is visited and managed by PC2 via IP B.

5) After step 3, network slice 1 is visited and managed by PC2 via IP B, network slice 2 is visited and managed by PC1 via IP A.

6) Set the IP address of PC1 within a different subnet to IP A, set the IP address of PC2 a different subnet to IP B.

7) After step 6, network slice 1 is visited and managed by PC1 via IP A, network slice 2 is visited and managed by PC2 via IP B.

8) PC1 logs in to the physical OLT via management IP address as the administrator account, and assigns account 1 and password 1 to slice 1, account 2 and password 2 to slice 2.

9) PC1 logs in to the network slice 1 by using the account 1 and password 1 of the network slice 1, performs service configuration of VLAN 1 000 for the network slice 1, and saves the configuration.

10) PC2 logs in to the network slice 2 by using the account 2 and the password 2 of the network slice 2, performs service configuration of the VLAN 2 000 on the network slice 2, and saves the configuration.

11) PC1 logs in to the network slice 2 by using the account 1 and the password 1 of the network slice 1, and PC2 logs in to the network slice 1 by using the account 2 and the password 2 of the network slice 2.

12) Change the management IP addresses of network slice 1 and network slice 2 to the same management IP address in step 3. Repeat steps 4 through 7 to verify that the OLT slice supports the same management IP address.

5.8.6.4 Expected Results

The expected result shall be as follows:

- In step 4, the user can successfully access the target server.
- In steps 5 and 7, a message is displayed indicating that the user cannot access the server.
- In steps 9 and 10, the user can access and configure services successfully.
- In step 11, a message is displayed indicating that the user cannot access the server.
- In step 12, the test results are the same as the expected results in steps 4 through 7 when network slice 1 and network slice 2 are configured with different management IP addresses.

5.8.7 Network slice user management permission

5.8.7.1 Test Purpose

To verify the user permission function of the network slice.

5.8.7.2 Test Configuration

The test configuration is shown in Figure 12.

5.8.7.3 Test Procedure

The test procedure shall be as follows:

1) Connect the equipment as shown in Figure 12. Log in to the EMS client, open the network slice management view, and create network slice 1 and network slice 2. The granularity of network slice 1 is PORT, and the granularity of network slice 2 is BOARD.

2) On the User Management page, create user group A, grant the management permission to the user group A, set the management domain to network slice 1, and create a user USER1 in the user group.

3) On the User Management page, create user group B and grant the management permission to the user group B. Set the management domain to network slice 2, and create a user USER2 in the user group B.

4) Log in to the management page as USER1 in PC1 and view the devices that are operated.

5) Log in to the management page as USER2 in PC2 and view the devices that are operated.

6) From PC2, log in to the management page as USER1 and view the devices that are operated.

7) From PC1, log in to the management page as USER2 and view the devices that are operated.

8) Create multiple user management accounts for network slice 1 and network slice 2 to verify whether accounts with different levels and different management and operation rights can be assigned to each network slice. (For example, high-level users have READ and WRITE permissions and low-level users have READ-ONLY permissions), and check whether the created user permission can be used normally and whether the user permission matches the configured permission.

9) On the OLT User Rights Management page, observe the created and allocated account information, verify whether all accounts are displayed in a user-friendly and classified manner, and whether the account and slice are subordinated.

5.8.7.4 Expected Results

The expected result shall be as follows:

- In step 4, only physical resources and attributes of network slice 1 can be viewed after logging in to the management interface.
- In step 5, only the physical resources and attributes of network slice 2 are displayed after the login to the management page.
- In step 6, after logging in as USER1 from PC2, only physical resources and attributes of network slice 1 can be viewed. Access to network slice 2 is not permitted.
- In step 7, after logging in as USER2 from PC1, only physical resources and attributes of network slice 2 can be viewed. Access to network slice 1 is not permitted.
- In step 8, multiple management accounts can be created for each slice, and accounts of different levels and different management permissions can be created for each slice. All permissions are displayed and selected as required.
- In step 9, all created management accounts can be displayed, and the dependency relationships between accounts and slices can be properly and friendly.

5.8.8 Deleting and modifying network slices

5.8.8.1 Test Purpose

To test the function of deleting and modifying an OLT network slice.

5.8.8.2 Test Configuration

The test configuration is shown in Figure 13.

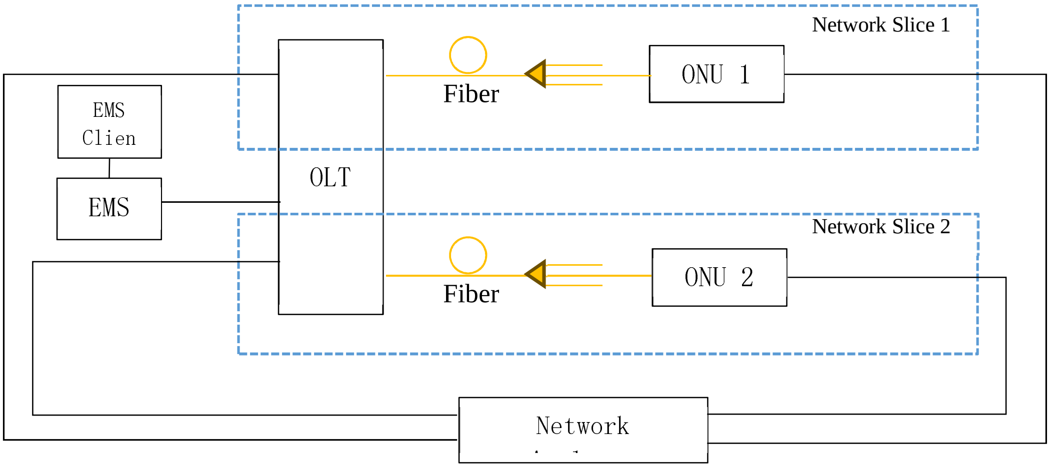

Figure 13: Network Slicing network configuration

5.8.8.3 Test Procedure

The test procedure shall be as follows:

1) Connect the equipment according as shown in Figure 13.

2) Log in to the EMS client and set-up the configuration for 2 network slices:

   a) Open the network slice management view on the network slice management page and select the tested OLT.

   b) Configure network slice 1 to PORT mode and network slice 2 to BOARD mode.

3) Configure resource profile and service profile in the network slice:

   a) Add one ONU per each network slice.

   b) Use data network analyser to verify ONU services are online.

4) Save the configuration data of network slices 1 and 2 and observe if configuration data is saved.

5) Delete network slice 1 via the Network Slice Management page and observe the operation and execution statuses.

6) Verify if the user configuration was saved before the network slice 1 was deleted.

7) Check if the global resource template was changed.

8) Verify the user configuration modification function for network slice 2.

9) Modify ONU configuration in network slice 2.

EXAMPLE: Add a VLAN value and a priority tag.

10) Observe whether services on ONU 2 are functioning normally: adjust meter configuration based on ONU configuration setup in step 9 and confirm service recovery.

11) Verify the user migration function under the network slice.

12) Add an ONU from network slice 2 to network slice 1.

13) Check whether the ONU from the network slice 2 is migrated to network slice 1.

5.8.8.4 Expected Results

The expected result shall be as follows:

- In step 4, the network slice data configuration is successfully saved.
- In step 5, the Network Management System displays a user-friendly message when the deletion operation is performed.
- In step 6, the previously saved data configuration still exists after the ONU is deleted.
- In step 7, the resources occupied by slice 1 are automatically released and displayed on the Total Resource Statistics page after slice 1 is deleted.
- In step 8, the configuration of network slice 2 is successfully modified.
- In step 9, after the ONU service configuration in network slice 2 is modified, the data flow is interrupted. Services are automatically recovered after the meter data configuration is modified.
- In step 13, during the user migration process, user-friendly operational prompts are provided such as batch operations and warning prompts.

5.8.9 Network slice alarm management

5.8.9.1 Test Purpose

To verify the alarm management function of a network slice.

5.8.9.2 Test Configuration

The test configuration is shown in Figure 11.

5.8.9.3 Test Procedure

The test procedure shall be as follows:

1) Connect the equipment as shown in Figure 11. Log in to the EMS client, open the Network Slice Management interface, and create network slice 1 and network slice 2. The granularity of network slice 1 is on port mode, and the granularity of network slice 2 is on board mode.
2) Add ONUs to network slices 1 and 2 respectively.
3) Log in to the physical OLT from PC1, network slice 1 from PC2, and network slice 2 from PC3. PC1 has the management permission, and PC2 and PC3 have the user permission on network slice 1 and network slice 2 respectively. After login, the alarm management page is displayed.
4) Performing operations such as disconnecting and connecting optical fibers and powering off the devices of the network slice 1, the network slice 2.
5) Log in to network slice 1, go to the alarm configuration management interface page, and check whether the alarms are displayed and following configurations can be performed on this slice and whether other network slices are affected.
6) Log in to network slice 2, go to the alarm configuration management interface page, and check whether the alarms are displayed and following configurations can be performed and whether the alarm affects other network slices.
7) Log in to the physical OLT, access the alarm management interface page, and check whether all alarms are recorded and displayed. Check whether operations such as masking and setting alarm severities can be performed on different slices.

5.8.9.4 Expected Results

The expected result shall be as follows:

- In step 5, only the alarms related to network slice 1 can be viewed and related operations can be performed on the alarms, and other network slices are not affected.
- In step 6, only the alarms related to network slice 2 can be viewed and related operations can be performed on the alarms, and other network slices are not affected.
- In step 7, all alarms are displayed. The network slices to which the alarms belong can be identified and related operations can be performed on the alarms.

5.9 Security functions testing

5.9.1 Limiting the number of MAC addresses stored by an ONU

5.9.1.1 Test Purpose

To verify that the ONU supports a configurable limit of the number of MAC addresses and is capable of limiting the MAC addresses of user devices connected to its ports.

5.9.1.2 Test Configuration

The test configuration is illustrated in Figure 14.

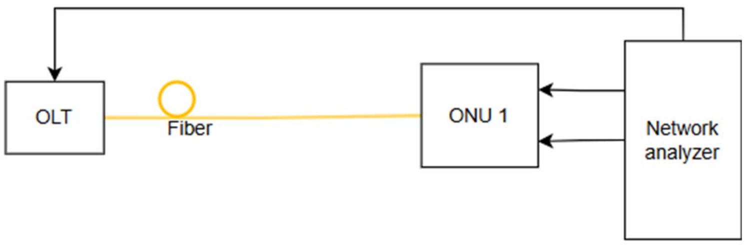

Figure 14: OLT/ONU test configuration for limiting MAC addresses

5.9.1.3 Test Procedure

The test procedure shall be as follows:

1) Connect the OLT, ONU and Network analyser according to the test configuration illustrated in Figure 14.
2) Configure the maximum number of MAC addresses that the ONU user port can store to X, ensuring that X does not exceed the ONU maximum MAC address buffer capacity. (X is not greater than the maximum MAC address buffer depth of the ONU.)
3) Use the network analyser to transmit M (M < X) packets, each with a unique source MAC address, to the ONU user port. Monitor the packet reception status on the OLT upstream port.
4) Use the network analyser to transmit N (N > X) packets, each with a unique source MAC address, to the ONU user port. Monitor the packet reception status on the OLT upstream port.

5.9.1.4 Expected Result

The expected result shall be as follows:

- In step 3, M packets are received from the upstream port of the OLT.
- In step 4, only X packets are received from the upstream port of the OLT.

5.9.2 MAC address anti-spoofing

5.9.2.1 Test Purpose

To verify that the OLT detects user MAC address spoofing and process the spoofing according to the security policy. For example, discard the frames with duplicate MAC addresses and protected MAC addresses.

5.9.2.2 Test Configuration

The test configuration is shown in Figure 15.

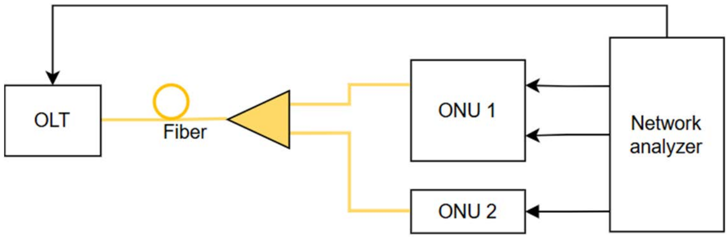

Figure 15: OLT/ONUs test configuration for MAC address anti-spoofing

5.9.2.3 Test Procedure

The test procedure shall be as follows:

1) Connect OLT, ONU and Network analyser illustrated in Figure 15.
2) Configure the OLT via the NMS to discard frames with duplicate MAC addresses. Add the user ports of ONU 1 and ONU 2 to the same VLAN, and ensure the MAC address table expiration time on the PON device is sufficient to allow the test to complete.
3) Use the network analyser to transmit several upstream test frames with source MAC address A to the user port of ONU 1.
4) Use the network analyser to transmit several upstream test frames with source MAC address B to the user port of ONU 2.
5) Use the network analyser to transmit several upstream test frames with source MAC address A to the user port of ONU 2.
6) Configure the protected MAC address C on the OLT.
7) Use the network analyser to transmit upstream test frames with source MAC address C to the user port of ONU 2.

5.9.2.4 Expected Result

The expected result shall be as follows:

- In steps 3 and 4, the network analyser receives the upstream test frames from ONU 1 and ONU 2.
- In steps 5 and 7, the network analyser does not receive the upstream test frames from ONU 2.

5.9.3 OLT MAC address table depth

5.9.3.1 Test Purpose

To test the buffering capability of the OLT MAC address table.

5.9.3.2 Test Configuration

The test configuration is shown in Figure 16.

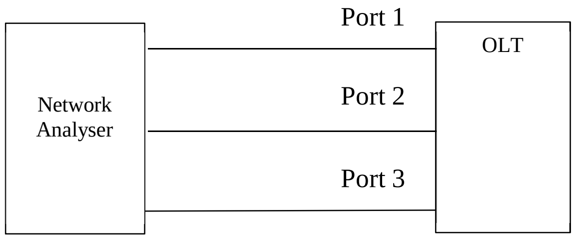

Figure 16: Test setup of OLT MAC address table depth test

5.9.3.3 Test Procedure

The test procedure shall be as follows:

1) Connect the network analyser and OLT as illustrated in Figure 16.

2) Add uplink ports 1, 2, and 3 of the OLT to the same VLAN.

3) Use the network analyser to transmit N frames (N is greater than the estimated depth of the OLT address table) to port 1 at the rate of 1 000 frames per second. The source MAC addresses are different. The destination MAC address is fixed to MAC address of the port 2.

4) Use the network analyser to transmit N frames to port 2 at the rate of 1 000 frames per second. The destination MAC addresses of the frames correspond to the source MAC addresses used in step 3.

5) Check the receiving results of ports 1 and 3.

5.9.3.4 Expected Result

The expected result shall be as follows:

- In step 5, when N exceeds the OLT's MAC address table depth, port 3 receives M frames from port 2.
- The final value of N-M represents the OLT MAC address table depth.

5.9.4 OLT frame filtering

5.9.4.1 Test Purpose

To verify that the OLT filters upstream and downstream Ethernet data frames according to the Ethernet encapsulation protocol, source MAC address, destination MAC address, source IP address, destination IP address, TCP port number, and UDP port number.

To test the function of filtering DHCP OFFER, ACK, NAK frames, IP multicast data streams, and IGMP query frames from users.

5.9.4.2 Test Configuration

The test configuration is shown in Figure 17.

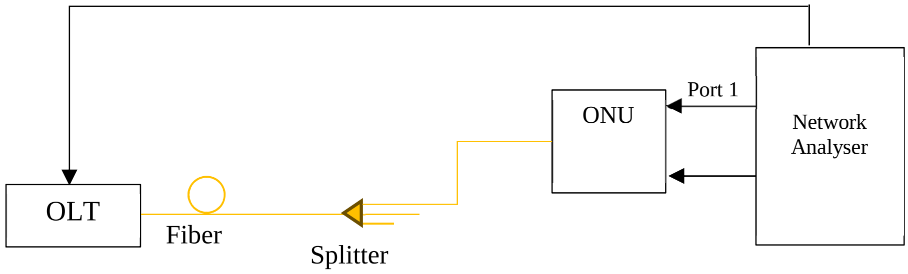

Figure 17: OLT frame filtering

5.9.4.3 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit according to the test configuration shown in Figure 17.
2) Disable the frame filtering function of the ONU and enable the frame filtering function of the OLT.
3) Configure the OLT to filter the IPoE encapsulated frames.
4) Use the network analyser to transmit IPoE-encapsulated frames and IEEE 802.1X [3] encapsulated frames to the OLT.
5) Configure the OLT to filter IEEE 802.1X [3] encapsulated frames.
6) Use the network analyser to transmit IPoE-encapsulated frames and IEEE 802.1X [3] encapsulated frames to the OLT.
7) Configure the OLT to filter the flow with the source IP address 172.24.10.X.
8) Use the network analyser to send two flows with the source IP addresses 172.24.10.X and 172.24.10.Y (X ≠ Y) to the OLT.
9) Configure the OLT to filter the flow with the destination IP address 172.24.10.X.
10) Use the network analyser to send two flows with the destination IP addresses 172.24.10.X and 172.24.10.Y to the OLT (X ≠ Y).
11) Configure the OLT to filter the TCP/UDP source port number X.
12) Use the network analyser to send two TCP/UDP source ports X and Y (X ≠ Y) to the OLT.
13) Configure the OLT to filter the flow with the TCP/UDP destination port number X.
14) Use the network analyser to send TCP/UDP flows with destination port numbers X and Y (X ≠ Y) to the OLT.
15) Configure the OLT to filter the flow with the source MAC address 00-00-11-11-11-X.
16) Use the network analyser to transmit the flow with the source MAC addresses 00-00-11-11-11-X and 00-00-11-11-11-Y (X ≠ Y) to the OLT. The destination MAC address is the source MAC address of port 1 on the network analyser.
17) Configure the OLT to filter the flows whose destination MAC address is the source MAC address of port 1 on the network analyser.
18) Use the network analyser to send the flow whose destination MAC address is the source MAC address of port 1 on the network analyser to the OLT.
19) Configure the OLT to filter out the UDP flows from the user port whose destination address is the multicast address.
20) Use the network analyser to transmit UDP flows to the ONU. The destination IP address is 239.x.y.z. (The values of x, y, and z are any values ranging from 1 to 254.)

21) Configure the OLT to filter upstream DHCP Offer/ACK/NAK data frames.

22) Use the network analyser to transmit upstream DHCP Offer/ACK/NAK packets to the port of the ONU.

23) Use the network analyser to transmit the flow with the source MAC address being the MAC address in Table 1 and the destination MAC address being the source MAC address of port 1 of the network analyser to the OLT one by one.

Table 1: Predefined and Reserved MAC Addresses

MAC address	action	Default Behaviour	Reference standard
01-80-C2-00-00-00	Bridge Group Address (BPDUs)	Block	IEEE 802.1Q [2], Table 7-9
01-80-C2-00-00-01	PAUSE	Block	IEEE 802.1Q [2], Table 7-9
01-80-C2-00-00-02	Slow protocol (LACP, EFM OAMPDUs)	Block	IEEE 802.3 [7], Table 57A-1
01-80-C2-00-00-03	EAP over LANs	Block	IEEE 802.1Q [2], Table 8-1
01-80-C2-00-00-04 - 01-80-C2-00-00-0F	Retained	Block	IEEE 802.1Q [2], Table 7-9
01-80-C2-00-00-10	Bridge management address for all LANs	Block	IEEE 802.1Q [2], Table 7-10
01-80-C2-00-00-20	GMRP	Block	IEEE 802.1Q [2], Table 12-1
01-80-C2-00-00-21	GVRP	Block	IEEE 802.1Q [2], Table 10-1
01-80-C2-00-00--C2-00-0022-01-80-2F	Reserve the GARP application address	Block	IEEE 802.1Q [2], Table 12-1

5.9.4.4 Expected Results

The expected result shall be as follows:

- In step 4, the network analyser receives only the IEEE 802.1X [3] encapsulated frames.
- In step 6, the network analyser receives only the IPoE-encapsulated frames.
- In step 8, the network analyser does not receive the flow with the source IP address 172.24.10.X.
- In step 10, the network analyser does not receive the flow with the destination IP address 172.24.10.X.
- In step 12, the network analyser does not receive the TCP/UDP flow whose source port number is X.
- In step 14, the network analyser does not receive the TCP/UDP flow with the destination port number X.
- In step 16, the network analyser does not receive the flow with the source MAC address 00-00-11-11-11-X.
- In step 18, the network analyser does not receive the flow whose destination MAC address is port 1 of the network analyser.
- In step 20, the network analyser does not receive any UDP flow whose destination IP address is the multicast address.
- In step 22, the network analyser does not receive the upstream DHCP Offer/ACK/NAK test frames.
- In step 23, the network analyser does not receive the flow whose source MAC address is the MAC address listed in Table 1.

5.9.5 ONU frame filtering

5.9.5.1 Test Purpose

To verify that the ONU filters upstream and downstream Ethernet data frames according to the Ethernet encapsulation protocol, source MAC address, destination MAC address, source IP address, destination IP address, TCP port number, and UDP port number.

To verify that the ONU filters DHCP OFFER/ACK/NAK frames, IP multicast data streams, and IGMP query frames from users.

5.9.5.2 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit according to the test configuration diagram Figure 17.

2) Disable the frame filtering function of the OLT and enable the frame filtering function of the ONU.

3) For other test procedures, see clause 5.8.4. Change the configuration of the OLT to the configuration of the ONU.

5.9.5.3 Expected Results

Same as for OLT specified in clause 5.8.4.4.

5.10 Edge computing testing

5.10.1 Test Purpose

To verify that the industrial PON equipment supports edge computing capabilities.

5.10.2 Test Configuration

The test configuration is shown in Figure 18.

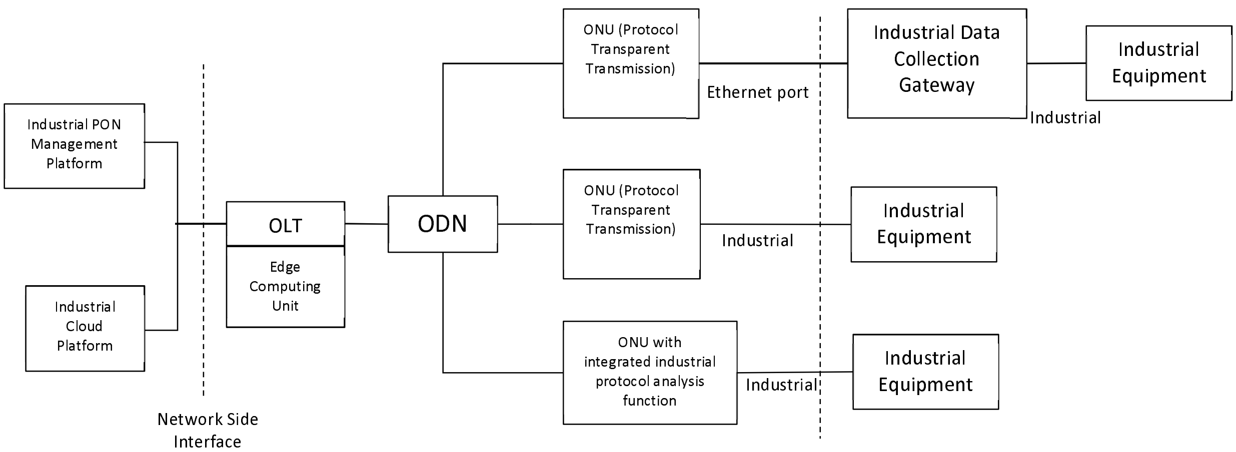

Figure 18: Edge Computing Unit Functional Test Configuration

5.10.3 Test Procedure

The test procedure shall be as follows:

1) Connect the test configuration as shown in Figure 18. The downstream dedicated industrial data acquisition gateway is connected to the ONU UNI via an Ethernet interface.

2) Configure an industrial data acquisition gateway to connect with industrial equipment, enabling industrial data collection functions.

3) The industrial data acquisition gateway connects to the ONU device of the industrial PON, transmitting data to the industrial cloud platform via the industrial PON network.

4) Verify the information reported by industrial equipment on the industrial cloud platform.

5) Send certain controlling commands from the industrial cloud platform to the industrial equipment.

6) Connect the test configuration as shown in Figure 18. The ONU shall connect to the industrial devices with a compatible industrial-grade physical interface.

7) The industrial PON system encapsulates and forwards the data packets reported by the industrial equipment without modifying the industrial protocol types or data content within these packets, ensuring their direct transmission to the industrial cloud platform.

8) From the industrial cloud platform, the information transmitted by the industrial equipment is monitored, and control commands are issued to the equipment as needed.

9) Configure the industrial equipment to generate data, and send data information to the industrial cloud platform via the industrial ONU using industrial protocol A.

10) When the industrial ONU is an industrial PON device using an open platform, configure the ONU to enable protocol parsing functionality, set up to convert Protocol A into OPC UA protocol, and report data in the common format of the OPC UA protocol. No configuration is required when the ONU uses a customized platform.

11) The industrial cloud platform acts as an OPC UA Client to receive and display data reported by industrial devices.

12) When the industrial ONU is an industrial PON device using an open platform, configure the ONU to enable protocol parsing and use the MQTT protocol to report data, repeating step 3. No configuration is required when the ONU uses a customized platform.

13) Configure the ONU to convert Protocol A into other common data format protocols supported by the network.

14) Deploy an industrial application locally on the OLT edge computing units using a storage medium.

15) Check locally whether the application has been successfully deployed.

16) Access and execute industrial applications through industrial terminals to establish normal service processes.

17) Configure application upgrades on OLT edge computing units by industrial equipment and monitor the operational status of the applications.

18) Terminate the industrial application on OLT edge computing units by industrial equipment and repeat the process in step 3.

19) Delete the industrial application on OLT edge computing units by industrial equipment and check the status of the application.

5.10.4 Expected Results

The expected result shall be as follows:

- In step 4, the industrial cloud platform successfully receives the information reported by industrial equipment.
- In step 5, the industrial cloud platform successfully sends control commands to the industrial equipment.
- In step 8, the industrial cloud platform successfully receives the information reported by the industrial equipment and issues control commands to it.
- In step 10, the industrial ONU is successfully configured and reports data types as OPC UA.
- In step 11, the data reported by the industrial equipment is correctly displayed on the industrial cloud platform.
- In step 12, the industrial ONU is successfully configured to report data in the MQTT format, and the data reported by the industrial equipment is correctly displayed on the industrial cloud platform.
- In step 13, the ONU successfully converts protocol A into other common data format protocols supported by the network.

- In step 15, the application is successfully created within the industrial PON equipment and is locally queried to confirm successful deployment.
- In step 16, the deployed application capabilities is successfully executed on the industrial PON equipment.
- In step 17, the application is successfully upgraded, operates normally, and executes application deployment capabilities.
- In step 18, the application functionality is terminated, and the service process established in step 2 is not accessed via the industrial terminal.
- In step 19, the application on the industrial PON equipment is successfully deleted.

6 Performance testing for industrial PON

6.1 PON and Ethernet related performance testing

6.1.1 PON port throughput

6.1.1.1 Test Purpose

Test the throughput of a PON port on industrial PON equipment.

6.1.1.2 Test Configuration

The test configuration is shown in Figure 19.

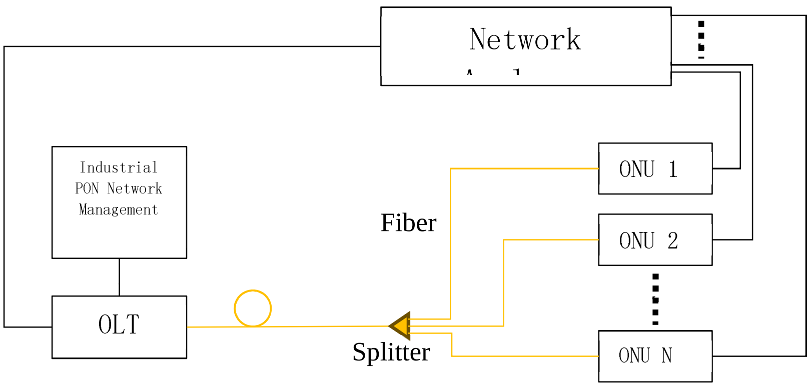

Figure 19: PON Port Throughput Test Configuration

6.1.1.3 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit according to the test configuration shown in Figure 19. The number of ONUs is chosen to ensure that the sum of the upstream and downstream throughput of N ONUs exceeds the throughput of a single OLT PON interface.

2) Configure each ONU to use the maximum data bandwidth, for GPON system, the FEC is disabled for both directions, for XG-PON and XGS-PON system, the FEC is disabled for upstream and enabled for downstream, for 50G-PON system the FEC is enabled for both directions.

3) Send N downstream streams with VLAN tags from the network analyser to the OLT, corresponding to N ONUs, where the total bandwidth of the N streams exceeds the downstream bandwidth of the PON port.

4) Test the traffic received by each ONU user port when the downstream packet lengths are 68, 132, 260, 516, 1 028, 1 284, and 1 522 bytes, respectively, with a test duration of 20 seconds.

5) Send upstream traffic with VLAN tags from the network analyser to N ONU devices, where the total traffic exceeds the upstream bandwidth of the PON port.

6) Test the traffic received by the OLT uplink port for upstream packet lengths of 68, 132, 260, 516, 1 028, 1 284, and 1 522 bytes, with a test duration of 20 seconds.

NOTE: Testing instruments generally use a binary method for throughput testing, with the main principle as follows: the testing instrument first sends packets at 100 % of the traffic. If no packet loss is detected, the test is complete, and the throughput is the line speed. If packet loss is detected, the instrument then tests with ((100 % + 0) / 2) of the traffic. If no packet loss is found, it tests again with ((50 % + 100 %) / 2) of the traffic, and so on. Through this binary method, the maximum throughput of the device is ultimately determined.

6.1.1.4 Expected Results

In steps 4 and 6, record the test results from the network analyser has successfully run the throughput test via binary method. The throughput test results shall be as shown in Table 2.

Table 2: Typical throughput test results for different PON systems

	GPON	XG-PON	XGS-PON	Asymmetric 50G-PON	Symmetric 50G-PON
Downstream (L2)	≥ 800 Mbps	≥ 8 000 Mbps	≥ 8 000 Mbps	≥ 36 Gbps	≥ 36 Gbps
Upstream (L2)	≥ 800 Mbps	≥ 1 800 Mbps	≥ 8 000 Mbps	≥ 18 Gbps	≥ 36 Gbps

6.1.2 VxLAN Tunnel Capacity Test

6.1.2.1 Test Purpose

To test the VxLAN tunnel capacity of the OLT device is no fewer than 4 096 VxLAN tunnels.

6.1.2.2 Test Configuration

The test configuration is shown in Figure 20.

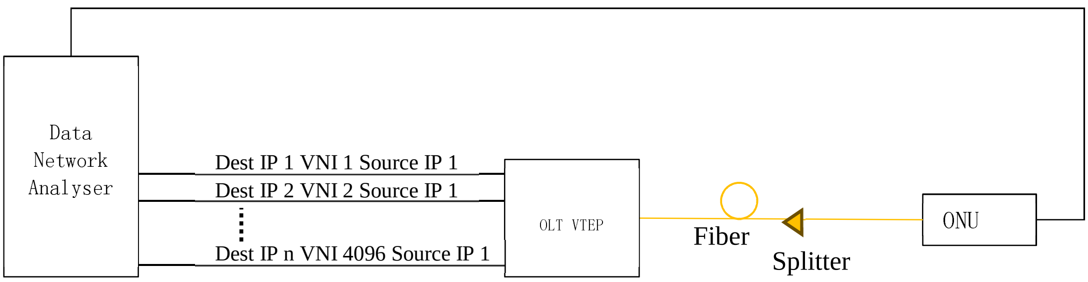

Figure 20: VxLAN Tunnel Capacity Configuration

6.1.2.3 Test Procedure

The test procedure shall be as follows:

1) Configure the test connection according to Figure 20.

2) Create VxLAN tunnels Tunnel 1…4 096, with the same Source IP address, VNI ranging from 1…4 096, and different Dest IP addresses.

3) When the number of tunnels reaches the maximum capacity of the device, the data network analyser sends a test traffic flow containing n tunnel capacities to verify whether the service is functioning properly.

4) Capture and analyse packets at the upstream port and user side to verify whether they meet the VxLAN packet encapsulation requirements.

6.1.2.4 Expected Results

The expected result shall be as follows:

- In step 2, the service is forwarded normally.
- In step 4, the message format complies with the VxLAN encapsulation and decapsulation format requirements specified in IETF RFC 7348 [4]. The OLT shall support no fewer than 4 096 VxLAN tunnels.

6.1.3 VxLAN ID (VNI) Capacity Test

6.1.3.1 Test Purpose

To test the VxLAN ID (VNI) capacity and configuration range of the OLT.

6.1.3.2 Test Configuration

The test configuration is shown in Figure 21.

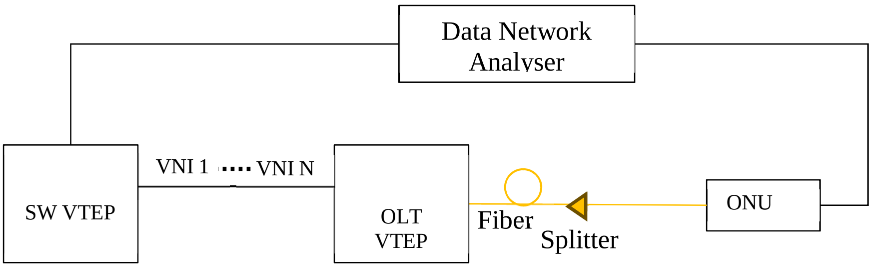

Figure 21: VxLAN ID Capacity Test Configuration

6.1.3.3 Test Procedure

The test procedure shall be as follows:

1) Configure the test connection according to Figure 21.

2) Create tunnel A, with VNI configured arbitrarily between 0 and 16 777 215.

3) Check and verify the configurable range of VNI.

4) Configure multiple VNI values simultaneously until the maximum configuration range of the device is met.

5) Capture and analyse packets at the upstream port and user side to verify whether they meet the VxLAN packet encapsulation requirements.

6.1.3.4 Expected Results

The expected result shall be as follows:

- In step 3, the VNI ID configuration range is 0 to 16 777 215.
- In step 4, the OLT supports at least 4 096 VNIs, preferably up to 8 192 VNIs configured simultaneously.
- In step 5, the message format complies with the VxLAN encapsulation requirements specified in IETF RFC 7348 [4].

6.1.4 OLT VxLAN MAC Address Capacity

6.1.4.1 Test Purpose

To test the maximum capacity of MAC addresses in OLT VxLAN tunnels.

6.1.4.2 Test Configuration

The test configuration is shown in Figure 22.

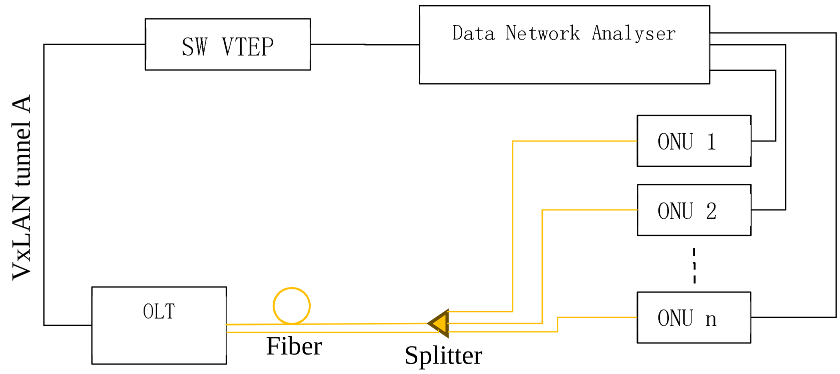

Figure 22: Test configuration for testing the maximum capacity of MAC addresses in OLT VxLAN tunnels

6.1.4.3 Test Procedure

The test procedure shall be as follows:

Single PON Port Capacity:

1) Configure the test configuration according to Figure 22.

2) Create VxLAN tunnel A, with the ONU configured in Transparent Transmission mode.

3) Using data network analyser send an upstream data traffic through the ONU, configuring the MAC addresses of the data traffic to increment by a step size of 1, with a total of 500 MAC addresses.

4) Verify whether the service is functioning normally by mirroring and analysing packets on the OLT uplink port to determine if packets meet the VxLAN encapsulation requirements.

5) Using data network analyser send an upstream data traffic through the ONU, configuring the MAC addresses of the data traffic to increment by a step size of 1, and modifying the number of MAC addresses to the maximum supported capacity of the device.

6) Verify whether the service is functioning normally by mirroring and analysing packets on the OLT uplink port to verify if packets meet the VxLAN encapsulation requirements.

Device Capacity:

7) Configure following settings: PON Port 1 - ONU 1, PON Port 2 - ONU 2, …, PON Port N - ONU n.

8) Create VxLAN tunnels for each ONU.

9) Using data network analyser send an upstream data traffic through all ONUs user port each generating traffic with unique MAC address ranges.

10) Verify whether the service is functioning normally by mirroring and analysing packets on the OLT uplink port to determine if the packets meet the VxLAN encapsulation requirements.

11) Scale all ONUs simultaneously to their maximum supported MAC capacity.

12) At full system load, verify all performance metrics and encapsulation requirements by mirroring and analysing packets on the OLT uplink port

Device is referring to a physical device such as ONU, OLT or data network analyser.

Port is referring to a physical or logical interface on a device where connection is made and where the data flow is used.

6.1.4.4 Expected Results

The expected result shall be as follows:

In steps 4 and 10:

- The service is functioning normally.
- The message MAC address matches the configuration address of the data network analyser.
- The message format complies with the VxLAN message encapsulation format requirements specified in IETF RFC 7348 [4].
- The supported number of VxLAN MAC entries is no less than OLT PON 4 096 per port.

In steps 6 and 12:

- The service is functioning normally.
- The message MAC address matches the configuration address of the data network analyser.
- The message format complies with the VxLAN message encapsulation format requirements specified in IETF RFC 7348 [4].
- The supported number of VxLAN MAC entries is no less than 16 384 per device.

6.2 Deterministic performance testing

6.2.1 Transmission Determinism Testing (north-to-south)

6.2.1.1 Test Purpose

To test the end-to-end transmission deterministic delay and jitter capability of industrial PON equipment.

6.2.1.2 Test Configuration

The test configuration is shown in Figure 19.

6.2.1.3 Test Procedure

The test procedure shall be as follows:

a) Connect the circuit according to the test configuration shown in Figure 19; the number of ONUs, N, shall be sufficient to ensure that after deterministic transmission is adopted, the sum of the upstream and downstream throughput of the N ONUs reaches at least 50 % of the PON port throughput.

b) Configure the bandwidth mode for each ONU to deterministic transmission mode.

c) Using a network analyser, measure the average, minimum, and maximum upstream and downstream link latency and jitter with lengths of 64, 128, 256, 512, 1 024, 1 280, and 1 518 bytes, at a traffic rate equivalent to 50 % of the PON port's throughput.

6.2.1.4 Expected Results

For expected results, see clause 8.3 of ETSI GS F5G 022 [1].

6.3 Environmental adaption testing

6.3.1 Low-temperature testing

6.3.1.1 Test Purpose

To test the low-temperature environmental adaptability of industrial PON equipment.

6.3.1.2 Test Procedure

The testing steps are as follows:

1) Place the device under test in the testing environment at room temperature, connect the power supply, and ensure the system operates in a normal and stable state.

2) Begin cooling down, with a cooling rate not exceeding 0,7 °C/min.

3) When the temperature reaches the maximum required operating temperature for the type of equipment, stop cooling (no condensation). After the temperature stabilizes, maintain it for 2 hours and spot-check whether the following tests meet the requirements:

    a) PON Interface Test (any two sub-items are selected for testing, see clause 5.1).

    b) Throughput test (see clause 6.1.1).

4) The power supply to the DUT is cut off, allowing the tested equipment to naturally return to room temperature conditions, and then the tested equipment is removed from the low-temperature test environment.

6.3.1.3 Expected Results

The test results shall comply with the specifications in Table 3.

Table 3: Industrial PON Environmental Temperature Adaptability Requirements

Equipment Type	Operating Temperature °C		Storage and transportation temperature °C	
	Low temperature	High temperature	Low temperature	High temperature
I	-10	+60	To be determined	To be determined
II	-20	+70	To be determined	To be determined
III	-25	+75	-55	+85
IV	-40	+85	-55	+95
NOTE: The actual operating temperature of ONU equipment is influenced not only by the ambient environmental temperature but also by factors such as thermal radiation from surrounding devices. Therefore, the upper limit of the actual operating temperature is generally higher than the maximum temperature that the natural environment can reach.				

6.3.2 High-temperature testing

6.3.2.1 Test Purpose

To test the high-temperature environmental adaptability of industrial PON equipment.

6.3.2.2 Test Procedure

The testing steps are as follows:

1) Place the device under test in the testing environment at room temperature, connect the power supply, and ensure the system operates in a normal and stable state.

2) Begin heating at a rate not exceeding 0,7 °C/min.

3) When the temperature reaches the maximum required operating temperature for the type of equipment, stop heating. After the temperature stabilizes, maintain it for 2 hours and spot-check whether the following tests meet the requirements:

   a) PON Interface Test (any two sub-items are selected for testing, see clause 5.1).

   b) Throughput test (see clause 6.1.1).

4) The power supply to the DUT is cut off, allowing the tested equipment to naturally return to room temperature conditions, and then the tested equipment is removed from the high -temperature test environment.

6.3.2.3 Expected Results

The test results shall comply with the specifications in Table 3.

6.3.3 High Humidity Testing

6.3.3.1 Test Purpose

To test the ONU equipment functioning in high-humidity environments.

6.3.3.2 Test Procedure

The testing steps are as follows:

1) Place the device under test in a humid environment at room temperature, then connect it to the power supply and link it to the testing instrument.

2) Start humidifying the room and control the temperature at 25 °C.

3) Once the humidity reaches its limit, stop humidification. After the humidity has stabilized, maintain the conditions for 2 hours, and then verify that the following indicators meet the required specifications:

   a) PON Interface Test (any two sub-items are selected for testing, see clause 5.1).

   b) Throughput test (see clause 6.1.1).

4) Turn off the power and keep the testing equipment until the environment recovers naturally to normal humidity conditions and then remove it from the high-humidity test environment.

6.3.3.3 Expected Results

Industrial PON equipment should operate as specified under the relative humidity conditions specified in Table 4 for industrial environments.

Table 4: Relative Humidity Conditions

Lower relative humidity	High relative humidity
4 %	95 %

7 Management and Provisioning testing for industrial PON

7.1 Human Machine Interface and Basic Functions

7.1.1 Test Purpose

To test the graphical interface of the system management.

7.1.2 Test Configuration

The test configuration is shown in Figure 23.

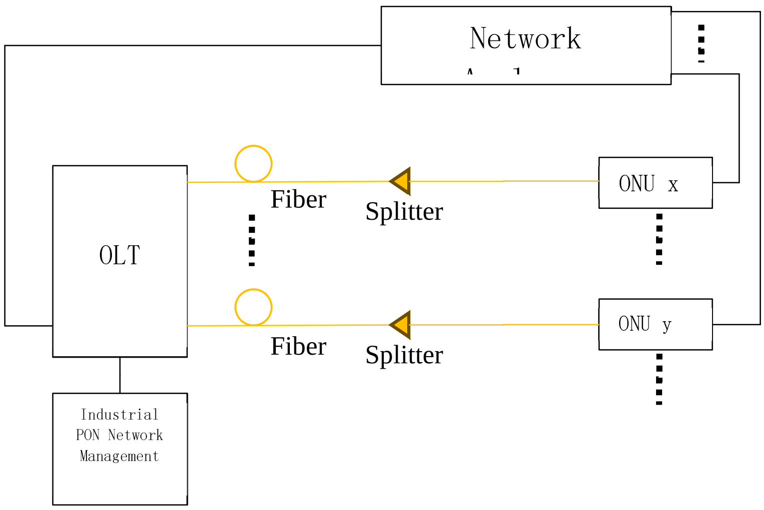

Figure 23: Network Management Test Configuration

7.1.3 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit according to test configuration shown in Figure 23, and log in to the network management system.

2) On the HMI, check whether the system has the hardware view function for devices and hardware boards.

3) When performing critical operations (such as system restarts or port closures), check whether a confirmation prompt appears.

4) Click the help menu or button to view the corresponding help information.

7.1.4 Expected Results

The expected result shall be as follows:

- In step 2, the hardware information shall be shown on the HMI correctly.
- In step 3, the confirmation prompt appears on the HMI correctly.
- In step 4, the help information display on the HMI correctly.

7.2 Configuration Management

7.2.1 Test Purpose

To test the configuration management function of the system.

7.2.2 Test Configuration

The test configuration is shown in Figure 23.

7.2.3 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit according to the test configuration shown in Figure 23, and log in to the network management system.

2) Configure related OLT line cards, let all ONUs be registered and in normal working mode.

3) Configure the parameters for the OLT uplink port and ONU user interface.

4) Configure QoS and SLA parameters for uplink and downlink traffic flows.

5) Configure VLAN, filtering rules, multicast, and other Ethernet function parameters for ONU user ports.

6) Configure system functions such as encryption and fiber protection switching parameters.

7) Check the status of each line card and port under test.

7.2.4 Expected Results

The network management system shall supports configuring and viewing various parameters from step 1 to step 7, and after configuration, the system is operating in the corresponding state. All configuration operations shall be saved to log files and shall support to be retrieved if needed.

7.3 Performance Management

7.3.1 Test Purpose

To test the performance management functions of the network management system.

7.3.2 Test Configuration

The test configuration is shown in Figure 23.

7.3.3 Test Procedure

The test procedure shall be as follows:

1) Connect the test environment according to the test configuration shown in Figure 23, and initiate the performance management function through the network management console.

2) Select the PON equipment type and specify the performance statistics parameters to be collected (including PON interface performance parameters, network-side and user-side service interface performance parameters, etc.).

3) Set the relevant attributes of the collection task, including start time, duration, polling interval, etc., and submit the performance collection task to begin data collection.

4) Query the historical records through the network management system and export the query results and statistical data to an external file.

7.3.4 Expected Results

The expected result shall be as follows:

- The network management system supports the 15-minute and 24-hour statistical reports for the current day and the previous day.
- The network management system supports obtaining the system bandwidth usage and retrieve ONU performance monitoring data through OMCI.
- The network management system supports collecting statistics on multicast performance parameters.
- The network management system supports querying of all historical records and save the query and statistical results to an external file.

7.4 Fault and alarm management

7.4.1 Test Purpose

To test the fault and alarm management of the network management system.

7.4.2 Test Configuration

The test configuration is shown in Figure 23.

7.4.3 Test Procedure

The test procedure shall be as follows:

1) Connect the circuit according to the test configuration shown in Figure 23, and initiate the fault and alarm management functions through the network management console.
2) Manually induce equipment failure to check the status of equipment indicator lights and the fault management process of the network management system.
3) Select the alarm that requires confirmation and confirm the alarm.
4) Repeat steps 2 and 3 to create multiple different types of alarms.
5) Sort the alarm information according to the set order (such as fault severity, cause of the fault, time period, etc.).
6) Select different filtering options based on various levels, time periods, and alarm causes.
7) After the system generates an alarm, immediately power off and then power on the system.
8) Select an alarm message and perform a delete operation on it.

7.4.4 Expected Results

The expected result shall be as follows:

- The network management system and equipment correctly execute responses to various faults and perform board-level fault localization. The network administrator correctly executes operations on various types of alarm information.
- After restart the system, the alarm history is shown correctly.

7.5 Security management

7.5.1 Test Purpose

To test the security management functions of the network management system.

7.5.2 Test Configuration

The test configuration is shown in Figure 23.

7.5.3 Test Procedure

The test procedure shall be are as follows:

1) Connect the circuit according to the test configuration shown in Figure 23, and add users of different levels such as administrators and operators through the network management console.

2) Log in to the network management console using different user levels.

3) Perform operations such as configuration queries and modifications.

4) Perform user addition, deletion, and query operations through the network management console.

5) View and query all logs (including username, operation time, and operation type) through the network management system.

7.5.4 Expected Results

The network management system shall support to deny access to unauthorized users and those with incorrect passwords, and prevent users from performing actions beyond their authority.

History

Version	Date	Status
V1.1.1	April 2026	Publication