TECHNICAL REPORT

TR-292
Abstract Test Suite For MPLS OAM

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Notice

Issue History

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Executive Summary

TR-292 defines testing and validation procedures based on requirements for MPLS OAM in MPLS Mobile Backhaul Networks as specified in TR-221.

The test procedures are based on requirements as described in the following documents:

- Broadband Forum TR-221 "Technical Specifications for MPLS in Mobile Backhaul Networks",
- Broadband Forum TR-221C1 "Technical Specifications for MPLS in Mobile Backhaul Networks - Corrigendum 1",
- RFC 4379 "Detecting Multi-Protocol Label Switched (MPLS) Data Plane Failures",
- RFC 5085 "Pseudowire Virtual Circuit Connectivity Verification (VCCV): A Control Channel for Pseudowires",
- RFC 5880 "Bidirectional Forwarding Detection (BFD)",
- RFC 5884 "Bidirectional Forwarding Detection (BFD) for MPLS Label Switched Paths (LSPs)",
- RFC 5885 "Bidirectional Forwarding Detection (BFD) for the Pseudowire Virtual Circuit Connectivity Verification (VCCV)",
- RFC 6310 "Pseudowire (PW) Operations, Administration, and Maintenance (OAM) Message Mapping" and
- RFC 6474 "Packet Loss and Delay Measurement for MPLS Networks".

1 Purpose and Scope

1.1 Purpose

TR-292 describes the requirements and corresponding test procedures to be used when testing MPLS OAM for use in MPLS Mobile Backhaul Networks.

Vendors can refer to the requirements and test procedures defined in this specification in the development and commercial cycles of their products and carriers can use them to ensure that the network elements they deploy or add to their existing network will have the ability to deliver MPLS OAM based on TR-221.

1.2 Scope

An overview of the testing requirements that would comprise this Abstract Test Suite for MPLS OAM is provided as follows:

- OAM test for MPLS LSP, including LSP Ping and BFD profiles for LSP as listed in TR-221;
- OAM test for Pseudowire, including BFD with VCCV and LSP Ping with VCCV profiles as listed in TR-221; and
- Packet loss & delay measurement for LSP/PW.

2 References and Terminology

2.1 Conventions

In this Technical Report, several words are used to signify the requirements of the specification. These words are always capitalized. More information can be found be in RFC 2119 [1].

MUST, SHALL	This word, or the term "REQUIRED", means that the definition is an absolute requirement of the specification.
MUST NOT	This phrase means that the definition is an absolute prohibition of the specification.
SHOULD	This word, or the adjective "RECOMMENDED", means that there could exist valid reasons in particular circumstances to ignore this item, but the full implications need to be understood and carefully weighed before choosing a different course.
SHOULD NOT	This phrase, or the phrase "NOT RECOMMENDED" means that there could exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications need to be understood and the case carefully weighed before implementing any behavior described with this label.
MAY	This word, or the adjective "OPTIONAL", means that this item is one of an allowed set of alternatives. An implementation that does not include this option MUST be prepared to inter-operate with another implementation that does include the option.

2.2 References

The following references are of relevance to this Technical Report. At the time of publication, the editions indicated were valid. All references are subject to revision; users of this Technical Report are therefore encouraged to investigate the possibility of applying the most recent edition of the references listed below.
A list of currently valid Broadband Forum Technical Reports is published at www.broadband-forum.org.

Document		Title	Source	Year
[1]	RFC 2119	*Key words for use in RFCs to Indicate Requirement Levels*	IETF	1997
[2]	TR-221	*Technical Specifications for MPLS in Mobile Backhaul Networks*	Broadband Forum	2011
[3]	TR-221C1	*Technical Specifications for MPLS in*	Broadband Forum	2014

		Mobile Backhaul Networks - Corrigendum 1		
[4]	RFC 4378	*A Framework for Multi-Protocol Label Switching (MPLS) Operations and Management (OAM)*	IETF	2006
[5]	RFC 4379	*Detecting Multi-Protocol Label Switched (MPLS) Data Plane Failures*	IETF	2006
[6]	RFC 5085	*Pseudowire Virtual Circuit Connectivity Verification and Framework*	IETF	2007
[7]	RFC 5880	*Bidirectional Forwarding Detection (BFD)*	IETF	2010
[8]	RFC 5884	*Bidirectional Forwarding Detection (BFD) for MPLS Label Switched Paths (LSPs)*	IETF	2010
[9]	RFC 5885	*Bidirectional Forwarding Detection (BFD) for the Pseudowire Virtual Circuit Connectivity Verification (VCCV)*	IETF	2010
[10]	RFC 5994	*Application of Ethernet Pseudowires to MPLS Transport Networks*	IETF	2010
[11]	RFC 6310	*Pseudowire (PW) Operations, Administration, and Maintenance (OAM) Message Mapping*	IETF	2011
[12]	RFC 6374	*Packet Loss and Delay Measurement for MPLS Networks*	IETF	2011

2.3 Definitions

The following terminology is used throughout this Technical Report.

Customer Edge	A device where one end of a service originates and/or terminates. The CE is not aware that it is using an emulated service rather than a native service
Provider Edge	A device that provides pseudowire emulation of a native service to a CE
Pseudowire	A connection between two PEs carried over a PSN. The PE provides the adaptation between the CE and the PW
Ingress	The point where the native service such as Ethernet is encapsulated into a pseudowire PDU (ETH to PSN direction)
Egress	The point where the native service such as Ethernet is decapsulated from a pseudowire PDU (PSN to ETH direction)
DUT	Device Under Testing

Protocol Analyzer	A device which can emulate and analyze the specific network protocol

2.4 Abbreviations

This Technical Report uses the following abbreviations:

AC	Attachment Circuit
BFD	Bidirectional Forwarding Detection
CE	Customer Edge
DM	Delay Measurement
LM	Loss Measurement
LSP	Label Switched Path
OAM	Operations, Administration and Maintenance
PE	Provider Edge
PW	Pseudowire
WG	Working Group
TR	Technical Report

3 Technical Report Impact

3.1 Energy Efficiency

TR-292 has no impact on energy efficiency.

3.2 IPv6

TR-292 has no impact on IPv6.

3.3 Security

TR-292 has no impact on security.

3.4 Privacy

TR-292 has no impact on privacy.

4 Introduction

TR-292 describes the requirements and corresponding test procedures to be used when testing MPLS OAM in MPLS Mobile Backhaul Networks.
Vendors can refer to the requirements and test procedures defined in this specification in the development and commercial cycles of their products and carriers can use them to ensure that the network elements they deploy or add to their existing network will have the ability to deliver MPLS OAM based on TR-221 [2].

Note: The purpose of this TR is to validate the protocols and procedures of the referenced RFCs and standards. Where there is discrepancy between this document and the referenced RFCs and standards, the RFCs and standards take precedence.

5 Test Configuration

Although some test cases may require very specific test configurations, most of the MPLS OAM test cases defined in this document are expected to use the following test configurations.

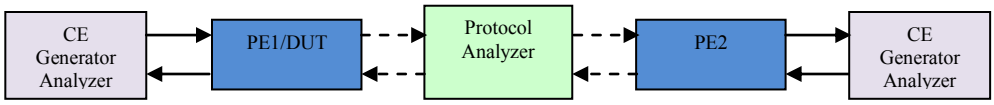

Figure 1

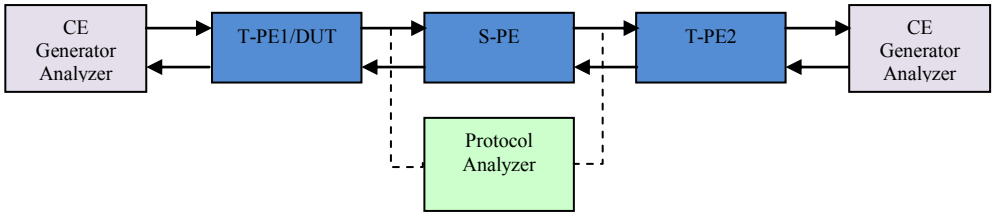

Figure 2

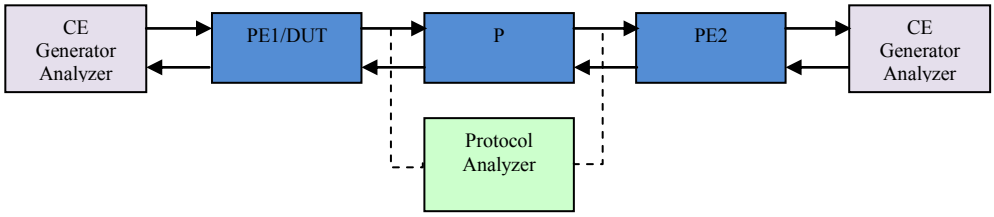

Figure 3

In each test configuration, the network elements other than DUT are assumed to be correctly implemented.

Notes: The CE Generator/Analyzer shall be capable of generating and receiving Customer Edge traffic (e.g., IP packets or Ethernet frames) transported over the LSP or PW under testing. Protocol Analyzer is required to support analysis of MPLS OAM.

6 Test Cases Summary

6.1 OAM for MPLS LSP

Number	Test Case Name	Test Status
1 (TR221-5.2.1-1)	LSP Ping for LDP LSP with reply mode 2 (Reply via an IPv4 UDP packet)	Mandatory if LDP is supported
2 (TR221-5.2.1-2)	LSP Ping for RSVP-TE LSP with reply mode 2 (Reply via an IPv4 UDP packet)	Mandatory if RSVP-TE is supported
3 (TR221-5.2.1-3)	LSP Traceroute for LDP LSP with reply mode 2 (Reply via an IPv4 UDP packet)	Mandatory if LDP is supported
4 (TR221-5.2.1-4)	LSP Traceroute for RSVP-TE LSP with reply mode 2 (Reply via an IPv4 UDP packet)	Mandatory if RSVP-TE is supported
5 (TR221-5.2.1-5)	BFD Session Initialization using LSP Ping	Mandatory
6 (TR221-5.2.1-6)	BFD Fault Detection	Mandatory

6.2 OAM for PW

6.2.1 OAM for SS-PW

Number	Test Case Name	Test Status
7 (TR221-5.2.3.1-1)	BFD with VCCV using PW-ACH	Mandatory
8 (TR221-5.2.3.1-2)	BFD with VCCV for Static PW (with IPv4 UDP headers)	Optional
9 (TR221-5.2.3.1-3)	BFD with VCCV using PW-ACH for LDP signaled PW (without IP/UDP headers)	Mandatory if LDP is supported
10 (TR221-5.2.3.1-4)	BFD with VCCV using PW-ACH for LDP signaled PW (with IPv4/UDP headers)	Optional
11 (TR221-5.2.3.1-5)	VCCV LSP Ping using PW-ACH	Mandatory

6.2.2 OAM for MS-PW

Number	Test Case Name	Test Status
12 (TR221-5.2.3.2-1)	MS-PW end to end Connectivity Verification using VCCV Ping (In-Band VCCV)	Optional
13 (TR221-5.2.3.2-2)	MS-PW partial Connectivity Verification using VCCV Ping (TTL Expiry VCCV)	Optional
14 (TR-221-5.2.3.2-3)	Including FEC 129 Sub-TLV in SP-PE TLV by an S-PE	Optional, applicable if FEC 129 is used in PW signaling

6.3 Packet Loss & Delay Measurement for LSP/PW

Number	Test Case Name	Test Status
15 (TR221-5.2.4-1)	Packet loss measurement for LSP/PW	Mandatory if loss measurement is supported
16 (TR221-5.2.4-2)	Delay measurement (two way) for LSP/PW	Mandatory if delay measurement is supported

7 Test Procedures

7.1 Test procedure 1 for LSP Ping

Test procedure 1

Use the CE Generator/Analyzer to generate services for encapsulation by the PEs, and use the Network Emulator/Analyzer to monitor the traffic between PE1 and PE2:

Part A:

Start LSP Ping on DUT using reply mode 2 (Reply via an IPv4 UDP packet) over the forward LSP.

Use the protocol analyzer to verify that the LSP Ping echo request packets are correctly formatted according to the test object.

Part B:

Start LSP Ping on PE2 using reply mode 2 (Reply via an IPv4 UDP packet) over the reverse LSP.

Use the protocol analyzer to verify that echo reply packets are triggered by DUT and correctly formatted according to the test object.

7.2 Test procedure 2 for LSP Traceroute

Test procedure 2

Use the CE Generator/Analyzer to generate services for encapsulation by the PEs, and use the Protocol Analyzer to monitor the traffic between PE1 and PE2:

Part A:

Start LSP Traceroute on DUT using reply mode 2 (Reply via an IPv4 UDP packet) over the forward LSP.

Use the Protocol Analyzer to verify that the LSP Traceroute echo request packets are correctly formatted according to the test object.

Part B:

Start LSP Traceroute on PE2 using reply mode 2 (Reply via an IPv4 UDP packet) over the reverse LSP.

Use the Protocol Analyzer to verify that echo reply packets are triggered by DUT and are correctly formatted according to the test object.

8 Test Case Template

Test Name	Name derived from reference document
Test Definition ID	A punctuated alphanumeric string assigned to each defined requirement and test procedure couple using the following convention: Up to 8 characters describing the source document followed by up to 10 characters describing the test requirement's section in the source document followed by the test case ID. Example: **RFC4379-3** where **"RFC4379"** refers to the source document RFC 4379, **"3"** refers to the test requirement's section 3
Reference document	Reference document name or number
Test Type	Functional, Conformance, Interoperability or Performance test
Test Status	Mandatory or Optional
Requirement Description	Brief description of the requirement that **MUST, MAY** or **SHOULD** be satisfied
Test Object	Succinct description of the test purpose
Test Configuration	Succinct description of the test bed configuration
Test Procedure	Succinct description of the test procedure
Units	Units can be time units, rates, counts in integers such as milliseconds, packets per second, numbers of valid packets, etc
Variables	Variables such as number of LSPs, etc
Results	Description of the textual, numerical and/or graphical format in which to display the test results. Results can be Pass or Fail
Remarks	Description of any particular observations that might affect the test result

9 Abstract Test Cases for MPLS OAM

9.1 OAM for MPLS LSP

Test Case 1: LSP Ping for LDP LSP with reply mode 2 (Reply via an IPv4 UDP packet)

Test Name	LSP Ping for LDP LSP with reply mode 2 (Reply via an IPv4 UDP packet)
Test Definition ID	TR221-5.2.1-1
Reference document	TR221 and RFC 4379
Test Type	Conformance
Test Status	Mandatory if LDP is supported per Section 5.1.1 of TR-221.
Requirement Description	According to R13 and R15 of TR221, when using LDP, LSP Ping MUST support replying via an IPv4 UDP packet as Reply Mode (code value 2) and LDP IPv4 prefix in its FEC Stack. Note: Each LSP Ping test case serves as a validation test for the specific function the test name shows, and also serves as a partial validation for R13 – general LSP Ping support. If this test case fails, either this specific function or the general LSP Ping is not correctly supported. A sequence of LSP Ping echo request packets can be sent by DUT with a label stack corresponding to the FEC Stack being tested. When an LSP Ping echo request packet is received, an echo reply packet MUST be sent by the DUT in response to the request. LSP Ping echo request packets include the following elements: a label stack; an IP header; a UDP header, and as the content of the UDP packet, an echo request message which carries a Target FEC stack of LDP IPv4 prefix. LSP Ping echo reply packets include the following elements: an IP header; a UDP header, and as the content of the UDP packet, an echo reply message which carries a Target FEC stack of LDP IPv4 prefix.
Test Object	**Part A: Verify that an LSP Ping echo request packets include the following fields:** 1. Label Stack: the label stack MUST include a top label value corresponding to the LSP, and the TTL MUST be set to 255. Refer to Section 2.1 of RFC 4379. 2. IP header: the source IP address MUST be a routable address of the sender; the destination IP address MUST be in the range 127/8; the IP TTL MUST be 1; and the IP header MUST contain a Router Alert IP option. Refer to Section 4.3 of RFC 4379. 3. UDP header: the UDP destination port MUST be set to 3503. Refer to Section 4.3 of RFC 4379. 4. Echo request message: Message Type value MUST be 1; TimeStamp Received MUST be zero; Reply mode MUST be 2 (Reply via an IPv4 UDP packet). Refer to Section 4.3 of RFC 4379. 5. Target FEC stack: the target FEC stack must include an LDP IPv4 prefix (it MUST be an LDP IPv4 prefix with sub-Type of 1 and Length of 5). Refer to Section 3.2 of RFC 4379.

	Part B: Verify that LSP Ping echo reply packets include the following fields: 1. IP header: the source IP address MUST be a routable address of the replier; the destination IP address MUST be equal to the source IP address of the echo request; the IP TTL MUST be 255; and the IP header MUST contain a Router Alert IP option. Refer to Section 4.5 of RFC 4379. 2. UDP header: the UDP source port MUST be set to 3503; the destination UDP port MUST be equal to the source UDP port of the echo request. Refer to Section 4.5 of RFC 4379. 3. Echo reply message: Message Type value MUST be 2; the Sender's Handle, Sequence Number, and TimeStamp Sent MUST be equal to those in the echo request. Refer to Section 4.5 of RFC 4379.
Test Configuration	Test configuration used per Figure 1 in Section 5, the DUT is PE1. PE1 and PE2 are both configured with an IPv4 address and IPv4 prefix. LSP Ping is configured to use LDP IPv4 prefix as its target FEC Stack on the DUT.
Test Procedure	1. Establish one unidirectional MPLS LSP for each direction using LDP between DUT and PE2; 2. Use Test procedure 1 per Section 7.1.
Units	LSP labels, echo request message, echo reply message, Target FEC sub TLV
Variables	Number of LSPs
Results	The test passes if all the verifications pass or else fails.
Remarks	

Test Case 2: LSP Ping for RSVP-TE LSP using reply mode 2 (Reply via an IPv4 UDP packet)

Test Name	LSP Ping for RSVP-TE LSP using reply mode 2 (Reply via an IPv4 UDP packet)
Test Definition ID	TR221-5.2.1-2
Reference document	TR221 and RFC 4379
Test Type	Conformance
Test Status	Mandatory if RSVP-TE is supported per Section 5.1.1 of TR-221.
Requirement Description	According to R13 and R15 of TR221, when using RSVP, LSP Ping MUST support replying via an IPv4 UDP packet as Reply Mode (code value 2) and carrying RSVP IPv4 LSP in its FEC Stack. Note: Each LSP Ping test case serves as a validation test for the specific function the test name shows, and also serves as a partial validation for R13 – general LSP Ping support. If this test case fails, either this specific function or the general LSP Ping is not correctly supported. A sequence of LSP Ping echo request packets can be sent by DUT with a label stack corresponding to the FEC Stack being tested. When an LSP Ping echo request packet is received, an echo reply packet MUST be sent by the DUT in response to the request. LSP Ping echo request packets include the following elements: a label stack; an IP header; a UDP header, and as the content of the UDP packet, an echo request message which carries a Target FEC stack of RSVP IPv4 LSP. LSP Ping echo reply packets include the following elements: an IP header; a UDP header, and as the content of the UDP packet, an echo reply message which carries a Target FEC stack of RSVP IPv4 LSP.
Test Object	**Part A: Verify that LSP Ping echo request packets include the fields specified in "Test Case 1: LSP Ping for LDP LSP with reply mode 2 (Reply via an IPv4 UDP packet)" except the following:** 5. Target FEC stack: the target FEC stack must include an RSVP IPv4 LSP (it MUST be an RSVP IPv4 LSP with sub-Type of 3 and Length of 20). Refer to Section 3.2 of RFC 4379. **Part B: Verify that LSP Ping echo reply packets include the fields specified in "Test Case 1: LSP Ping for LDP using reply mode 2 (Reply via an IPv4 UDP packet)".**
Test Configuration	Test configuration used per Figure 1 in Section 5, the DUT is PE1. PE1 and PE2 are both configured with an IPv4 address and IPv4 prefix. LSP Ping is configured to use RSVP-TE IPv4 LSP as its target FEC Stack on the DUT.
Test Procedure	1. Establish one unidirectional MPLS LSP for each direction using RSVP-TE between PE1 and PE2; 2. Use Test procedure 1 per Section 7.1.
Units	LSP labels, echo request message, echo reply message, Target FEC sub TLV
Variables	Number of LSPs
Results	The test passes if all the verifications pass or else fails
Remarks	

Test Case 3: LSP Traceroute for LDP LSP using reply mode 2 (Reply via an IPv4 UDP packet)

Test Name	LSP Traceroute for LDP using reply mode 2 (Reply via an IPv4 UDP packet)
Test Definition ID	TR221-5.2.1-3
Reference document	TR221 and RFC4379
Test Type	Conformance
Test Status	Mandatory if LDP is supported per Section 5.1.1 of TR-221.
Requirement Description	According to R14 and R15 of TR221, when using LDP, LSP Traceroute MUST support replying via an IPv4 UDP packet as Reply Mode (code value 2) and LDP IPv4 prefix in its FEC Stack. Note: Each LSP Traceroute test case serves as a validation test for the specific function the test name shows, and also serves as a partial validation for R14 - general LSP Traceroute support. If this test case fails, either this specific function or the general LSP Traceroute is not correctly supported. A sequence of LSP Traceroute echo request packets can be sent by DUT with a label stack corresponding to the FEC Stack being tested. When an LSP Traceroute echo request packet is received, an echo reply packet MUST be sent by the DUT in response to the request. LSP Traceroute echo request packets include the following elements: a label stack; an IP header; a UDP header, and as the content of the UDP packet, an echo request message which carries a Target FEC stack of LDP IPv4 prefix. LSP Traceroute echo reply packets include the following elements: an IP header; a UDP header, and as the content of the UDP packet, an echo reply message which carries a Target FEC stack of LDP IPv4 prefix.
Test Object	**Part A: Verify that LSP Traceroute echo request packets include the following fields:** 1. Label Stack: the label stack MUST include a top label value corresponding to the LSP, and the TTL MUST be set successively to 1, and then 2. Refer to Section 4.3 of RFC 4379. 2. IP header: the source IP address MUST be a routable address of the sender; the destination IP address MUST be in the range 127/8; the IP TTL MUST be 1; and the IP header MUST contain a Router Alert IP option. Refer to Section 4.3 of RFC 4379. 3. UDP header: the UDP destination port MUST be set to 3503. Refer to Section 4.3 of RFC 4379. 4. Echo request message: Message Type value MUST be 1; TimeStamp Received MUST be zero; Reply mode MUST be 2 (Reply via an IPv4 UDP packet). Refer to Section 4.3 of RFC 4379. 5. Target FEC stack: the target FEC stack must include an LDP prefix (it MUST be an LDP IPv4 prefix with sub-Type of 1 and Length of 5). Refer to Section 3.2.1 of RFC 4379. **Part B: Verify that LSP Traceroute echo reply packets include the following fields:** 1. IP header: the source IP address MUST be a routable address of the replier; the destination IP address MUST be equal to the source IP address of the echo request; the IP TTL MUST be 255; and the IP header MUST contain a Router Alert IP option. Refer to Section 4.5 of

	RFC 4379. 2. UDP header: the UDP source port MUST be set to 3503; the destination UDP port MUST be equal to the source UDP port of the echo request. Refer to Section 4.5 of RFC 4379. 3. Echo reply message: Message Type value MUST be 2; the Sender's Handle, Sequence Number, and TimeStamp Sent MUST be equal to those in the echo request. Refer to Section 4.5 of RFC 4379.
Test Configuration	Test configuration used per Figure 3 in Section 5, the DUT is PE1. PE1 and PE2 are both configured with an IPv4 address and IPv4 prefix. LSP Traceroute is configured to use LDP IPv4 prefix as its target FEC Stack on the DUT.
Test Procedure	1. Establish one unidirectional MPLS LSP for each direction using LDP between DUT and PE2; 2. Use Test procedure 2 per Section 7.2.
Units	LSP labels, echo request message, echo reply message, Target FEC sub TLV
Variables	Number of LSPs
Results	The test passes if all the verifications pass or else fails.
Remarks	

Test Case 4: LSP Traceroute for RSVP-TE LSP using reply mode 2 (Reply via an IPv4 UDP packet)

Test Name	LSP traceroute for RSVP-TE using reply mode 2 (Reply via an IPv4 UDP packet)
Test Definition ID	TR221-5.2.1-4
Reference document	TR221 and RFC4379
Test Type	Conformance
Test Status	Mandatory if RSVP-TE is supported per Section 5.1.1 of TR-221.
Requirement Description	According to R14 and R15 of TR221, when using RSVP-TE, LSP Traceroute MUST support replying via an IPv4 UDP packet as Reply Mode (code value 2) and carrying RSVP IPv4 LSP in its FEC Stack. Note: Each LSP Traceroute test case serves as a validation test for the specific function the test name shows, and also serves as a partial validation for R14 – general LSP Traceroute support. If this test case fails, either this specific function or the general LSP Traceroute is not correctly supported. A sequence of LSP Traceroute echo request packets can be sent by DUT with a label stack corresponding to the FEC Stack being tested. When an LSP Traceroute echo request packet is received, an echo reply packet MUST be sent by the DUT in response to the request. LSP Traceroute echo request packets include the following elements: a label stack; an IP header; a UDP header, and as the content of the UDP packet, an echo request message which carries a Target FEC stack of RSVP IPv4 LSP. LSP Traceroute echo reply packets include the following elements: an IP header; a UDP header, and as the content of the UDP packet, an echo reply message which carries a Target FEC stack of RSVP IPv4 LSP.
Test Object	**Part A: Verify that LSP Traceroute echo request packets include the fields specified in "Test Case 3: LSP Traceroute for LDP LSP using reply mode 2 (Reply via an IPv4 UDP packet)" except the following:** 5. Target FEC stack: the target FEC stack must include an RSVP IPv4 LSP (it MUST be an RSVP IPv4 LSP with sub-Type of 3 and Length of 20). Refer to Section 3.2.3 of RFC 4379. **Part B: Verify that LSP Traceroute echo reply packets include the fields specified in "Test Case 3: LSP Traceroute for LDP using reply mode 2 (Reply via an IPv4 UDP packet)".**
Test Configuration	Test configuration used per Figure 3 in Section 5, the DUT is PE1. PE1 and PE2 are both configured with an IPv4 address and IPv4 prefix. LSP Traceroute is configured to use RSVP IPv4 LSP as its target FEC Stack on the DUT.
Test Procedure	1. Establish one unidirectional MPLS LSP for each direction using RSVP-TE between PE1 and PE2; 2. Use Test procedure 2 per Section 7.2.
Units	LSP labels, echo request message, echo reply message, Target FEC sub TLV
Variables	Number of LSPs

Results	The test passes if all the verifications pass or else fails
Remarks	

Test Case 5: BFD Session Initialization using LSP Ping

Test Name	BFD Session Initialization using LSP Ping
Test Definition ID	TR221-5.2.1-5
Reference document	TR221, RFC 5884
Test Type	Conformance
Test Status	Mandatory
Requirement Description	LSP Ping can bootstrap the BFD session correctly as per RFC 5884 (According to [R12] of TR221, BFD for MPLS LSPs MUST be supported per RFC 5884).
Test Object	**Part A: Verify that the BFD Discriminator TLV in the bootstrapping LSP Ping message includes the following elements:** LSP Ping TLV type value MUST be 15; The 4-byte value field MUST be the local discriminator of the DUT. Refer to Section 6 of RFC 5884. **Part B: Verify that local BFD learns remote discriminator from the BFD Discriminator TLV correctly:** My Discriminator MUST be equal to the local discriminator of the originator LSR. Refer to Section 6 of RFC 5884. Your Discriminator MUST be equal to zero or the local discriminator of the target LSR. Refer to Section 6 of RFC 5884.
Test Configuration	Test configuration used per Figure 1 in Section 5, the DUT is PE1.
Test Procedure	1. Establish one unidirectional MPLS LSP for each direction between PE1 and PE2. 2. Use the CE Generator/Analyzer to generate services for encapsulation by the PEs. Use the Protocol Analyzer to monitor traffic between PE1 and PE2. 3. Establish LSP Ping session between DUT and PE2, then establish BFD session between DUT and PE2 in BFD asynchronous mode (refer to Sec.6 of RFC 5884), then Part A: Use the protocol analyzer to verify that LSP Ping echo request from DUT includes a BFD discriminator TLV, and the TLV is correctly formatted according to Test Object Part A. Part B: Use the protocol analyzer to verify that Your Discriminator in the subsequent BFD packets sent by DUT is the same as the value of BFD discriminator TLV in LSP Ping echo reply sent from PE2.
Units	LSP Ping echo request, LSP Ping echo reply, BFD Discriminator TLV
Variables	Number of LSPs
Results	The test passes if all the verifications pass or else fails.
Remarks	

Test Case 6: BFD Fault Detection

Test Name	BFD Fault Detection
Test Definition ID	TR221-5.2.1-6
Reference document	TR221, RFC 5880, RFC 5884
Test Type	Conformance
Test Status	Mandatory
Requirement Description	BFD can detect a data plane failure in the forwarding path of an MPLS LSP (According to [R12] of TR221, BFD for MPLS LSPs MUST be supported per RFC 5884).
Test Object	**Verify that a BFD packet includes the following fields:** 1. Label Stack: the label stack MUST include a top label value corresponding to the LSP. Refer to Section 7 of RFC 5884. 2. IP header: The IP TTL or hop limit MUST be set to 1; the source IP address MUST be a routable address of the replier. Refer to Section 7 of RFC 5884. 3. UDP header: the UDP destination port MUST be 3784 or 4784. Refer to Section 7 of RFC 5884. 4. BFD message is encapsulated in the UDP payload. Refer to Section 7 of RFC 5884. **Verify that Dynamic BFD for LSP can detect fault correctly.**
Test Configuration	Test configuration used per Figure 1 in Section 5, the DUT is PE1.
Test Procedure	1. Establish two unidirectional LSPs from PE1 to PE2 and from PE2 to PE1 respectively. 2. Use the CE Generator/Analyzer to generate services for encapsulation by the PEs. Use the Protocol Analyzer to monitor traffic between PE1 and PE2. 3. Establish BFD session between DUT and PE2 in BFD asynchronous mode, the state of BFD session is UP, refer to Section 6 of RFC 5884. 4. Use the protocol analyzer to verify that BFD packets from DUT are formatted correctly according to the test object. 5. Use the Protocol Analyzer to simulate a failure condition by blocking user traffic from PE2 to PE1 including BFD packets. 6. Verify that after failure condition above has been introduced, and after 5 times of BFD cycle have passed, the state of BFD session on DUT migrates from UP to DOWN. 7. Remove the failure condition and ensure the BFD session comes back up after the failure.
Units	BFD
Variables	Number of LSPs, BFD cycle, Type of LSP and its FEC (LDP/RSVP-TE)
Results	The test passes if all the verifications pass or else fails.
Remarks	

9.2 OAM for PW

9.2.1 OAM for SS-PW

Test Case 7: BFD with VCCV using PW-ACH

Test Name	BFD with VCCV using PW-ACH
Test Definition ID	TR-221-5.2.3.1-1
Reference document	TR-221, RFC5880, RFC5085, RFC5885, RFC5994
Test Type	Conformance
Test Status	Mandatory
Requirement Description	According to R17 and R18 of TR221, For VCCV control channel type1, VCCV Profile1: BFD without IP/UDP Headers MUST be supported and when the PW is established using static provisioning, BFD status signaling using diagnostic codes per the VCCV profile1 SHOULD be used. The connection verification method used by VCCV is BFD with diagnostics as defined in [RFC5885] (CV TYPE: 0x10/0x20). [RFC5085] specifies that the first nibble is set to 0x1 to indicate a channel associated with a pseudowire(PW-ACH) in which the Version and the Reserved fields are set to 0, and the Channel Type is set to 0x7 to indicate that the payload carried is BFD without IP/UDP headers.
Test Object	**Verify that a BFD for VCCV packet using PW-ACH includes the following fields:** 1. Label Stack: Label stack include two labels, the top label value corresponding to an LSP and the bottom label value corresponding to a PW. Refer to Section 3 of RFC 5885. 2. Generic Control Word: The first nibble is set to 0001b to indicate a channel associated with a pseudowire. The Version and the Reserved fields are set to 0, and the Channel Type is set to 0x7. 3. BFD message using diagnostic codes follows the Control Word directly. **Verify that BFD for VCCV without IP/UDP head for static PW can operate correctly.**
Test Configuration	Test configuration used per Figure1 in Section 5, the DUT is PE1.
Test Procedure	1. Establish one unidirectional LSP for each direction between PE1 and PE2, and establish at least one static PW over this LSP. 2. Use the CE Generator/Analyzer to generate Ethernet services for encapsulation by the PEs. Use the Protocol Analyzer to monitor traffic between DUT and PE2. 3. Configure BFD session for VCCV between DUT and PE2, verify that CV type is correct and verify that BFD session is established successfully. 4. Use the protocol analyzer to verify that BFD packets from DUT are formatted correctly according to the test object. 5. Use the Protocol Analyzer to simulate a failure condition by blocking user traffic from PE2

	to DUT including BFD packets. 6. Verify that in the above failure condition, after 5 times of BFD cycle, the state of BFD session on DUT migrates from UP to DOWN.
Units	LSP label, PW label, Target FEC sub TLV
Variables	Number of LSPs, BFD cycle, Type of CV (0x10 for Fault Detection Only or 0x20 for Fault Detection and Status Signaling)
Results	The test passes if all the verifications pass or else fails.
Remarks	

Test Case 8: BFD with VCCV for static PW (with IPv4 UDP headers)

Test Name	BFD with VCCV for static PW (with IPv4 UDP headers)
Test Definition ID	TR221-5.2.3.1-2
Reference document	TR221, RFC5880, RFC5085, RFC5885, RFC5994
Test Type	Conformance
Test Status	Optional
Requirement Description	According to R17 and R18 of TR221, BFD is one of the connection verification method used by VCCV. When the PW is established using static provisioning, BFD status signaling using diagnostic codes per the VCCV profile supported SHOULD be used for fault notification.
Test Object	**Verify that a BFD for VCCV packet includes the following fields:** 1. Label Stack: Label stack include two labels, the top label value corresponding to an LSP and the bottom label value corresponding to a PW. Refer to Section 3 of RFC 5885. 2. Generic Control Word: The first nibble is set to 0001b to indicate a channel associated with a pseudowire. The Version and the Reserved fields are set to 0, and the Channel Type is set to 0x0021 for IPv4 payloads. Refer to Section 3 of RFC 5885. 3. The IP header: The source IP address MUST be an address of the sender; the destination IP address is a (randomly chosen) IPv4 address from the range 127/8. Refer to Section 3 of RFC 5885. 4. UDP header: The UDP destination port MUST be 3784 and source port MUST be within the range 49152 through 65535. Refer to Section 3 of RFC 5885. 5. BFD message is encapsulated in the UDP payload. Refer to Section 4 of RFC 5880. Where CV type MUST be either 0x04 or 0x08, both stand for IP/UDP encapsulation. **Verify that BFD for VCCV with IPv4 UDP header for static PW can operate correctly.**
Test Configuration	Test configuration used per Figure1 in Section 5, the DUT is PE1.

Test Procedure	1. Establish one unidirectional LSP for each direction between PE1 and PE2,and establish at least one static PW over this LSP. 2. Use the CE Generator/Analyzer to generate Ethernet services for encapsulation by the PEs. Use the Protocol Analyzer to monitor traffic between DUT and PE2. 3. Configure BFD session for VCCV between DUT and PE2, verify that the CV type is correct and BFD session is established successfully. 4. Use the protocol analyzer to verify that BFD packets from DUT are formatted correctly according to the test object. 5. Use the Protocol Analyzer to simulate a failure condition by blocking user traffic from PE2 to DUT including BFD packets. 6. Verify that in the above failure condition, after 5 times of BFD cycle, the state of BFD session on DUT migrates from UP to DOWN, and the PW failure is reported correctly.
Units	LSP label, PW label, Target FEC sub TLV
Variables	Number of PWs, BFD cycle, Type of CV (0x04 for Fault Detection Only or 0x08 for Fault Detection and Status Signaling)
Results	The test passes if all the verifications pass or else fails.
Remarks	

Test Case 9: BFD with VCCV using PW-ACH for LDP signaled PW (without IP/UDP headers)

Test Name	BFD with VCCV using PW-ACH for LDP signaled PW (without IP/UDP headers)
Test Definition ID	TR221-5.2.3.1-3
Reference document	TR221, RFC5880, RFC5085, RFC5885, RFC5994, RFC6310
Test Type	Conformance
Test Status	Mandatory if LDP is supported
Requirement Description	According to R17 and R19 of TR221, when LDP is supported for PW establishment, for VCCV control channel type 1, VCCV Profile1: BFD without IP/UDP Headers MUST be supported, and fault notification MUST be supported per RFC6310 by PE routers. The connection verification method used by VCCV is BFD with diagnostics as defined in [RFC5885] (CV TYPE: 0x10). [RFC5085] specifies that the first nibble is set to 0x1 to indicate a channel associated with a pseudowire (PW-ACH) in which the Version and the Reserved fields are set to 0, and the Channel Type is set to 0x7 to indicate that the payload carried is BFD without IP/UDP headers.
Test Object	**Verify that a BFD for VCCV packet includes the following fields:** 1. Label Stack: Label stack include two labels, the top label value corresponding to an LSP and the bottom label value corresponding to a PW. Refer to Section 3 of RFC 5885. 2. Generic Control Word: The first nibble is set to 0001b to indicate a channel associated with a pseudowire. The Version and the Reserved fields are set to 0, and the Channel Type is set to 0x0007. Refer to Section 3 of RFC 5885. 3. BFD message using diagnostic codes follows the Control Word directly. Refer to Section 3 of RFC 5885. **Verify that BFD for VCCV for LDP** signaled **PW can operate correctly.**
Test Configuration	Test configuration used per Figure1 in Section 5, the DUT is PE1.
Test Procedure	1. Establish one unidirectional LSP for each direction between PE1 and PE2, and establish at least one PW using LDP over this LSP. 2. Use the CE Generator/Analyzer to generate Ethernet services for encapsulation by the PEs. Use the Protocol Analyzer to monitor traffic between DUT and PE2. 3. Configure BFD session for VCCV between DUT and PE2, verify that the CV type is 0x10 and BFD session is established successfully. 4. Use the protocol analyzer to verify that BFD packets from DUT are formatted correctly according to the test object. 5. Use the Protocol Analyzer to simulate a failure condition by blocking user traffic from PE2 to DUT including BFD packets. 6. Verify that in the above failure condition, after 5 times of BFD cycle, the state of BFD session on DUT migrates from UP to DOWN.
Units	LSP label, PW label, Target FEC sub TLV
Variables	Number of PWs, BFD cycle, Type of CV
Results	The test passes if all the verifications pass or else fails.
Remarks	

Test Case 10: BFD with VCCV for LDP signaled PW (with IPv4/UDP headers)

Test Name	BFD with VCCV using PW-ACH for LDP signaled PW (with IPv4/UDP headers)
Test Definition ID	TR221-5.2.3.1-4
Reference document	TR221, RFC5880, RFC5085, RFC5885, RFC5994
Test Type	Conformance
Test Status	Optional
Requirement Description	According to R17 and R19 of TR221, BFD is one of the connection verification method used by VCCV. When LDP is supported for PW establishment, BFD status signaling using diagnostic codes per the VCCV profile 2 SHOULD be used for fault notification.
Test Object	**Verify that a BFD for VCCV packet includes the following fields:** 1. Label Stack: Label stack include two labels, the top label value corresponding to an LSP and the bottom label value corresponding to a PW. Refer to Section 3 of RFC 5885. 2. Generic Control Word: The first nibble is set to 0001b to indicate a channel associated with a pseudowire. The Version and the Reserved fields are set to 0, and the Channel Type is set to 0x0021 for IPv4 payloads. Refer to Section 3 of RFC 5885. 3. The IP header: The source IP address MUST be an address of the sender; the destination IP address is a (randomly chosen) IPv4 address from the range 127/8. Refer to Section 3 of RFC 5885. 4. UDP header: The UDP destination port MUST be 3784 and source port MUST be within the range 49152 through 65535. Refer to Section 3 of RFC 5885. 5. BFD message is encapsulated in the UDP payload. Refer to Section 4 of RFC 5880. Where CV type MUST be 0x04, which stands for IP/UDP encapsulation for PW Fault Detection only. **Verify that BFD for VCCV with IPv4 UDP header for LDP based PW can operate correctly.**
Test Configuration	Test configuration used per Figure1 in Section 5, the DUT is PE1.
Test Procedure	1. Establish one unidirectional LSP for each direction between PE1 and PE2, and establish at least one PW using LDP over this LSP. 2. Use the CE Generator/Analyzer to generate Ethernet services for encapsulation by the PEs. Use the Protocol Analyzer to monitor traffic between DUT and PE2. 3. Configure BFD session for VCCV between DUT and PE2, verify that the CV type is 0x04 and BFD session is established successfully. 4. Use the protocol analyzer to verify that BFD packets from DUT are formatted correctly according to the test object. 5. Use the Protocol Analyzer to simulate a failure condition by blocking user traffic from PE2 to DUT including BFD packets. 6. Verify that in the above failure condition, after 5 times of BFD cycle, the state of BFD session on DUT migrates from UP to DOWN.
Units	LSP label, PW label, Target FEC sub TLV

Variables	Number of PWs, BFD cycle, Type of CV
Results	The test passes if all the verifications pass or else fails.
Remarks	

Test Case 11: VCCV LSP Ping using PW-ACH

Test Name	VCCV LSP Ping using PW-ACH
Test Definition ID	TR-221-5.2.3.1-5
Reference document	TR-221
Test Type	Conformance
Test Status	Mandatory
Requirement Description	According to R16 and R20 of TR221, VCCV Control Channel (CC) Type1, also known as "PWE3 Control Word with 0001b as first nibble", MUST be supported. MPLS LSP Ping (CV type 0x02) SHOULD be supported per RFC 5085. When the control channel for the PW is chosen as "PWE3 Control Word with 0001b as first nibble" (use the PW Associated Channel Header), VCCV LSP Ping packets are sent over the PW together with in-band data traffic. VCCV messages with CC Type1 and CV type (0x02) include the following elements: a label stack; a generic Control Word; an LP Ping header; Target FEC stack.
Test Object	**Part A: Verify that VCCV LSP Ping echo request packets include the following fields:** 1. Label Stack: the label stack MUST include a top label value corresponding to an LSP, and the TTL MUST be set to 255, and a bottom label value corresponding to a PW. Refer to Section 2.1 of RFC 4379. 2. PW Associated Channel Header：the first nibble is set to 0001b to indicate a channel associated with a pseudowire. The Version and the Reserved fields are set to 0, and the Channel Type is set to 0x0021 for IPv4 payloads. 3. IP header and UDP header are set in accordance with the corresponding fields in LSP Ping test case 1. 4. Target FEC stack: containing the sub-TLV of sub-Type 10 for "FEC 128 Pseudowire", or 11 for the "FEC 129 Pseudowire". **Part B: Verify that VCCV LSP ping using PW-ACH operates correctly in verifying connectivity of the PW and the data plane used to transport the data path for the PW and that VCCV LSP Ping echo reply packets include the following fields:** 1. Label Stack: the label stack MUST include a top label value corresponding to an LSP, and the TTL MUST be set to 255, and a bottom label value corresponding to a PW. Refer to Section 2.1 of RFC 4379. 2. PW Associated Channel Header: the first nibble is set to 0001b to indicate a channel associated with a PW. The Version and the Reserved fields are set to 0, and the Channel Type is set to 0x0021 for IPv4 payloads.

	3. IP header and UDP header are set in accordance with the corresponding fields in LSP Ping test case 1. 4. Target FEC stack format: containing the sub-TLV of sub-Type 10 for "FEC 128 Pseudowire", or 11 for the "FEC 129 Pseudowire".
Test Configuration	Test configuration used per Figure 1 in Section 5, the DUT is PE1.
Test Procedure	1. Establish one unidirectional LSP for each direction between PE1 and PE2, and establish at least one PW over this LSP. The PW is configured to support CC type 1 (PWE3 Control Word with 0001b as first nibble) and CV type 0x02 (LSP Ping); 2. Use the CE Generator/Analyzer to generate services for encapsulation by the PEs and use the Protocol Analyzer to monitor traffic between DUT and PE2: **Part A:** Start VCCV LSP ping on DUT on control channel that is associated with the established PW. Use the protocol analyzer to verify that the VCCV message (including LSP Ping echo request) is correctly formatted according to Test Object Part A. **Part B:** Start VCCV LSP ping on DUT on control channel that is associated with the established PW. Verify that a VCCV message (including LSP Ping echo request) reaches DUT and triggers a VCCV message (including LSP Ping echo reply) from DUT and use the protocol analyzer to verify that the VCCV message (including LSP Ping echo reply) is correctly formatted according to Test Object Part B.
Units	LSP label, PW label, Target FEC sub TLV
Variables	PW type (FEC 128 or 129), PW type (the PW could be statically configured or established by LDP signaling).
Results	The test passes if all the verifications pass or else fails.
Remarks	

9.2.2 OAM for MS-PW

Test Case 12: MS-PW E2E Connectivity Verification using VCCV Ping (In-Band VCCV)

Test Name	MS-PW end to end Connectivity Verification using VCCV Ping (In-Band VCCV)
Test Definition ID	TR-221-5.2.3.2-1
Reference document	TR-221, RFC4379, RFC5085, RFC6073
Test Type	Conformance
Test Status	Optional
Requirement Description	According to R22 of TR221, if MS-PW is supported, End-to-end MS-PW connectivity verification SHOULD be supported using VCCV connectivity verification (Ping). This operation enables the connectivity of the MS-PW to be tested from source T-PE to destination T-PE. In order to do this, the sending T-PE must include the FEC used in the last segment of the MS-PW to the destination T-PE in the VCCV-Ping echo request. Upon receiving a VCCV-Ping echo request, the destination T-PE responds to the echo request with an echo reply with a return code of 3 (Egress Router).
Test Object	**Part A: Verify that VCCV LSP Ping echo request packets include the following fields:** 1. Label Stack: the label stack MUST include a top label value corresponding to an LSP, the TTL MUST be set to 255, and a bottom label value corresponding to a PW, the TTL can be set to any value that is sufficient for the packet to reach the destination T-PE. 2. PW Associated Channel Header: the first nibble is set to 0001b to indicate a channel associated with a pseudowire. The Version and the Reserved fields are set to 0, and the Channel Type is set to 0x0021 for IPv4 payloads. 3. IP header and UDP header are set in accordance with the corresponding fields in LSP Ping test case 1. 4. Target FEC stack: it MAY include the FEC (sub-Type 10 for "FEC 128 Pseudowire", or 11 for the "FEC 129 Pseudowire") used in the last segment of the MS-PW to the destination T-PE. **Part B: Verify that VCCV LSP Ping echo reply packets include the following fields:** 1. Label Stack: the label stack MUST include a top label value corresponding to an LSP, the TTL MUST be set to 255, and a bottom label value corresponding to a PW, the TTL can be set to any value that is sufficient for the packet to reach the destination T-PE. 2. PW Associated Channel Header: the first nibble is set to 0001b to indicate a channel associated with a PW. The Version and the Reserved fields are set to 0, and the Channel Type is set to 0x0021 for IPv4 payloads. 3. IP header and UDP header are set in accordance with the corresponding fields in LSP Ping test case 1. 4. Target FEC stack format: it MAY include the FEC (sub-Type 10 for "FEC 128 Pseudowire", or 11 for the "FEC 129 Pseudowire") used in the last segment of the MS-PW to the destination T-PE.

	5. The return code of echo reply packet is 3 (Egress Router).
Test Configuration	Test configuration used per Figure2 in Section 5, the DUT is T-PE1.
Test Procedure	1. Establish two unidirectional LSPs for each direction between T-PE1 and S-PE and between S-PE and T-PE2. Set up an MS-PW consisting of PW segment 1 between T-PE1 and S-PE and PW segment 2 between T-PE2 and S-PE. The PW segments are configured to enable VCCV with CC type 1 (PWE3 Control Word with 0001b as first nibble) and CV type (0x02, LSP Ping); S-PE is configured to connect PW segment 1 to PW segment 2. 2. Use the CE Generator/Analyzer to generate services for encapsulation by the T-PEs and use the Protocol Analyzer to monitor traffics between T-PE1 and S-PE and between S-PE and T-PE2: Part A: Start VCCV LSP ping on T-PE1 on control channel that is associated with the established MS-PW. Use the protocol analyzer to verify that the VCCV message (including LSP Ping echo request) is correctly formatted according to Test Object Part A. Part B: Start VCCV LSP ping on T-PE2 on control channel that is associated with the established MS-PW. Verify that a VCCV message (including LSP Ping echo reply) is replied by the DUT, and use the protocol analyzer to verify that the VCCV message is correctly formatted according to Test Object Part B.
Units	LSP labels, echo request message, echo reply message, Target FEC sub TLV, PW labels
Variables	Number of S-PEs
Results	The test passes if all the verifications pass or else fails.
Remarks	

Test Case 13: MS-PW partial Connectivity Verification using VCCV Ping (TTL Expiry VCCV)

Test Name	MS-PW partial Connectivity Verification using VCCV Ping (TTL Expiry VCCV)
Test Definition ID	TR-221-5.2.3.2-2
Reference document	TR-221, RFC4379, RFC5085, RFC6073
Test Type	Conformance
Test Status	Optional
Requirement Description	According to R23 of TR221, if MS-PW is supported, partial MS-PW connectivity verification SHOULD be supported using VCCV connectivity verification (Ping). This operation verifies the connectivity of a segment of an MS-PW to be tested between the source T-PE and an S-PE. The FEC used on the last segment to be tested must be included in the VCCV-Ping echo request message.
Test Object	**Part A: Verify that VCCV LSP Ping echo request packets include the following fields:** 1. Label Stack: the label stack MUST include a top label value corresponding to an LSP, the TTL MUST be set to 255, and a bottom label value corresponding to a PW, the TTL should be set to the exact value to allow the packet to reach the destination S-PE. 2. IP header and UDP header are set in accordance with the corresponding fields in LSP Ping test case 1. 3. Target FEC stack: it MUST include the FEC (sub-Type 10 for "FEC 128 Pseudowire", or 11 for the "FEC 129 Pseudowire") used in the last segment of the MS-PW. **Part B: Verify that VCCV LSP Ping echo reply packets include the following fields:** 1. Label Stack: the label stack MUST include a top label value corresponding to an LSP, the TTL MUST be set to 255, and a bottom label value corresponding to a PW, the TTL should be set to the exact value to allow the packet to reach the destination S-PE. 2. IP header and UDP header are set in accordance with the corresponding fields in LSP Ping test case 1. 3. Target FEC stack format: it MUST contain the FEC (sub-Type 10 for "FEC 128 Pseudowire", or 11 for the "FEC 129 Pseudowire") used in the last segment of the MS-PW.
Test Configuration	Test configuration used per Figure2 in Section 5, the DUT is T-PE1.
Test Procedure	1. Establish two unidirectional LSPs for each direction between T-PE1 and S-PE and between S-PE and T-PE2. Set up an MS-PW consisting of PW segment 1 between T-PE1 and S-PE and PW segment 2 between T-PE2 and S-PE. The PW segments are configured to enable VCCV with CC type 3 (TTL Expiry VCCV) and CV type 0x02 (LSP Ping); S-PE is configured to connect PW segment 1 to PW segment 2. 2. Use the CE Generator/Analyzer to generate services for encapsulation by the T-PEs and use the Protocol Analyzer to monitor the packet flow between T-PE1 and S-PE: Part A: Start VCCV LSP ping on T-PE1 on control channel that is associated with the established MS-PW, PW label TTL is set to 1 to force the VCCV packet to be processed at S-PE. Use the protocol analyzer to verify that the VCCV message (including LSP Ping echo

	request) is correctly formatted according to Test Object Part A. Part B: Start VCCV LSP ping on S-PE on control channel that is associated with the established MS-PW, PW label TTL is set to 1 to force the VCCV packet to be processed at T-PE1. Use the protocol analyzer to verify that a VCCV message (including LSP Ping echo reply) is replied by T-PE1, and the message is correctly formatted according to Test Object Part B.
Units	LSP labels, echo request message, echo reply message, Target FEC sub TLV, PW labels
Variables	
Results	The test passes if all the verifications pass or else fails.
Remarks	

Test Case 14: Including FEC 129 Sub-TLV in SP-PE TLV by an S-PE

Test Name	Including FEC 129 Sub-TLV in SP-PE TLV by an S-PE
Test Definition ID	TR-221-5.2.3.2-3
Reference document	TR-221C1, RFC4379, RFC5085, RFC6073
Test Type	Conformance
Test Status	Optional, applicable if FEC 129 is used in PW signaling
Requirement Description	According to [R-25a] of TR-221C1, the S-PE MUST support including the FEC 129 of the last PW segment in the Pseudowire Switching Point PE sub-TLV as per the FEC 129 encoding in Section 7.4.1/RFC6073 when LDP FEC 129 is used to signal the PW. According to [R-25b] of TR-221C1, the S-PE MUST support including FEC 129 in the Target FEC stack TLV in the VCCV echo reply message as per the FEC 129 encoding in Section 3.2.10/RFC 4379.
Test Object	**Part A: Verify that MS-PW LDP mapping message includes the following fields:** 1. SP-PE TLV: the "U" bit MUST be set for backward compatibility and Sub-TLV Type MUST be encoded as 0x096D. 2. FEC sub-TLV of last PW segment traversed: Type is encoded as 0x05. The FEC element of the last PW segment traversed MUST be in accordance with the FEC 129 encoding in Section 7.4.1/RFC6073. **Part B: Verify that VCCV LSP Ping (PW-ACH) operates correctly using the FEC obtained by processing the FEC 129 sub-TLV of the optional SP-PE TLV.**
Test Configuration	Test configuration used per Figure2 in Section 5, the DUT is S-PE.
Test Procedure	1. Establish two unidirectional LSPs for each direction between T-PE1 and S-PE and between S-PE and T-PE2. Set up an MS-PW consisting of PW segment 1 between T-PE1 and S-PE and PW segment 2 between T-PE2 and S-PE using the generalized FEC 129. The PW segments are configured to enable VCCV with CC type 1 (PWE3 Control Word with 0001b as first nibble) and CV type 0x02 (LSP Ping); S-PE is configured to connect PW segment 1 to PW segment 2. 2. Use the CE Generator/Analyzer to generate services for encapsulation by the T-PEs and use the Protocol Analyzer to monitor traffics between T-PE1 and S-PE and between S-PE and T-PE2: Part A: Initiate MS-PW setup via dynamic LDP control plane using the generalized FEC 129. Use the protocol analyzer to verify that the SP-PE TLV included into the LDP mapping message by S-PE is correctly formatted according to Test Object Part A. Part B: Start VCCV LSP ping on T-PE1 on control channel that is associated with the established MS-PW. Use the protocol analyzer to verify that the FEC stack in VCCV message is consistent with FEC 129 according to Test Object Part B.
Units	SP-PE TLV, FEC 129 sub TLV

Variables	
Results	The test passes if all the verifications pass or else fails.
Remarks	

9.3 Packet Loss & Delay Measurement for LSP/PW

Test Case 15: Packet loss measurement for LSP/PW

Test Name	Packet loss measurement for LSP/PW
Test Definition ID	TR221-5.2.4-1
Reference document	TR221 and RFC 6374
Test Type	Performance Monitoring and Measurement
Test Status	Mandatory if loss measurement is supported
Requirement Description	According to R28 of TR221, PE and P routers SHOULD support packet loss measurement per RFC 6374.
Test Object	1. PE and P should properly give the accurate result of LM.
Test Configuration	Test configuration used per Figure1 in Section 5, the DUT is PE1.
Test Procedure	1. Establish at least one MPLS LSP/PW tunnel between PE1 and PE2. 2. Use the CE Generator/Analyzer to generate services for encapsulation by the PEs, and use the Protocol Analyzer to monitor the traffic between PE1 and PE2. The Network Analyzer should be configured to work in pass through mode. 3. Start LM measurement on PE1 and PE2. The packet loss should be 0. 4. Verify the LM query message and response message are correctly formatted. 5. Use the Protocol Analyzer to insert a packet loss rate. To reduce the probability of losing a single measurement probe, the measurement probe should be sent multiple times. 6. Compare the LM result executed on PEs with packet loss rate inserted into the traffic and packet loss rate monitored by CE Generator/Analyzer to estimate the accuracy of LM.
Units	LSP labels, LM query message, response message
Variables	Packet loss rate
Results	Pass or fail
Remarks	

Test Case 16: Delay measurement for LSP/PW

Test Name	Delay measurement (two way) for LSP/PW
Test Definition ID	TR221-5.2.4-2
Reference document	TR221 and RFC 6374
Test Type	Performance Monitoring and Measurement
Test Status	Mandatory if delay measurement is supported
Requirement Description	According to R28 of TR221, PE and P routers SHOULD support Delay measurement per RFC 6374.
Test Object	1. PE and P should properly give the accurate result of DM.
Test Configuration	Test configuration used per Figure1 in Section 5, the DUT is PE1.
Test Procedure	1. Establish at least one MPLS LSP/PW tunnel between PE1 and PE2. 2. Use the CE Generator/Analyzer to generate services for encapsulation by the PEs, and use the Protocol Analyzer to monitor the traffic between PE1 and PE2. The Network Analyzer should be configured to work in pass through mode. 3. Start DM measurement on PE1 and PE2. 4. Verify the DM query message and response message are correctly formatted. 5. Use the Protocol Analyzer to insert delay into traffic, labeled as T. 6. Start DM measurement on PE1 and PE2. The delay results are labeled as T1and T2 respectively. 7. Use the Protocol Analyzer to insert another delay into traffic, labeled as T'. 8. Start DM measurement on PE1 and PE2. The delay results are labeled as T1'and T2' respectively. 9. Compare the (T' -T) with (T1'-T1) and (T2' –T2) to estimate the consistency of DM.
Units	LSP labels, DM query message, response message
Variables	Time delay
Results	Pass or fail
Remarks	

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