

# **TR-350**

## **Ethernet Services using BGP MPLS Based Ethernet VPNs (EVPN)**

**Issue: 2**  
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bbf2016.691.01	TBD	TBD	Rao Cherukuri, BBF Distinguished Fellow Steven Blake, Ericsson	Correct [51] URL, R-81; fix editorial nits.
bbf2016.691.02	TBD	TBD	Rao Cherukuri, BBF Distinguished Fellow Steven Blake, Ericsson	Same as .01 with all changes accepted.
<a href="#">WT-350 ELine Modifications from bbf2016.691.02- Cherukuri-DF- bbf2016.691.doc</a>	TBD	TBD	Rao Cherukuri, BBF Distinguished Fellow Steven Blake, Ericsson	Same as .02 with changes for Bandwidth Policy and updated figures for Eline.
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<a href="#">WT-350 ELine final Modifications from bbf2016.691.02 -Cherukuri-DF- bbf2016.691.do cx</a>	TBD	TBD	Rao Cherukuri, BBF Distinguished Fellow	Proposed SB Candidate
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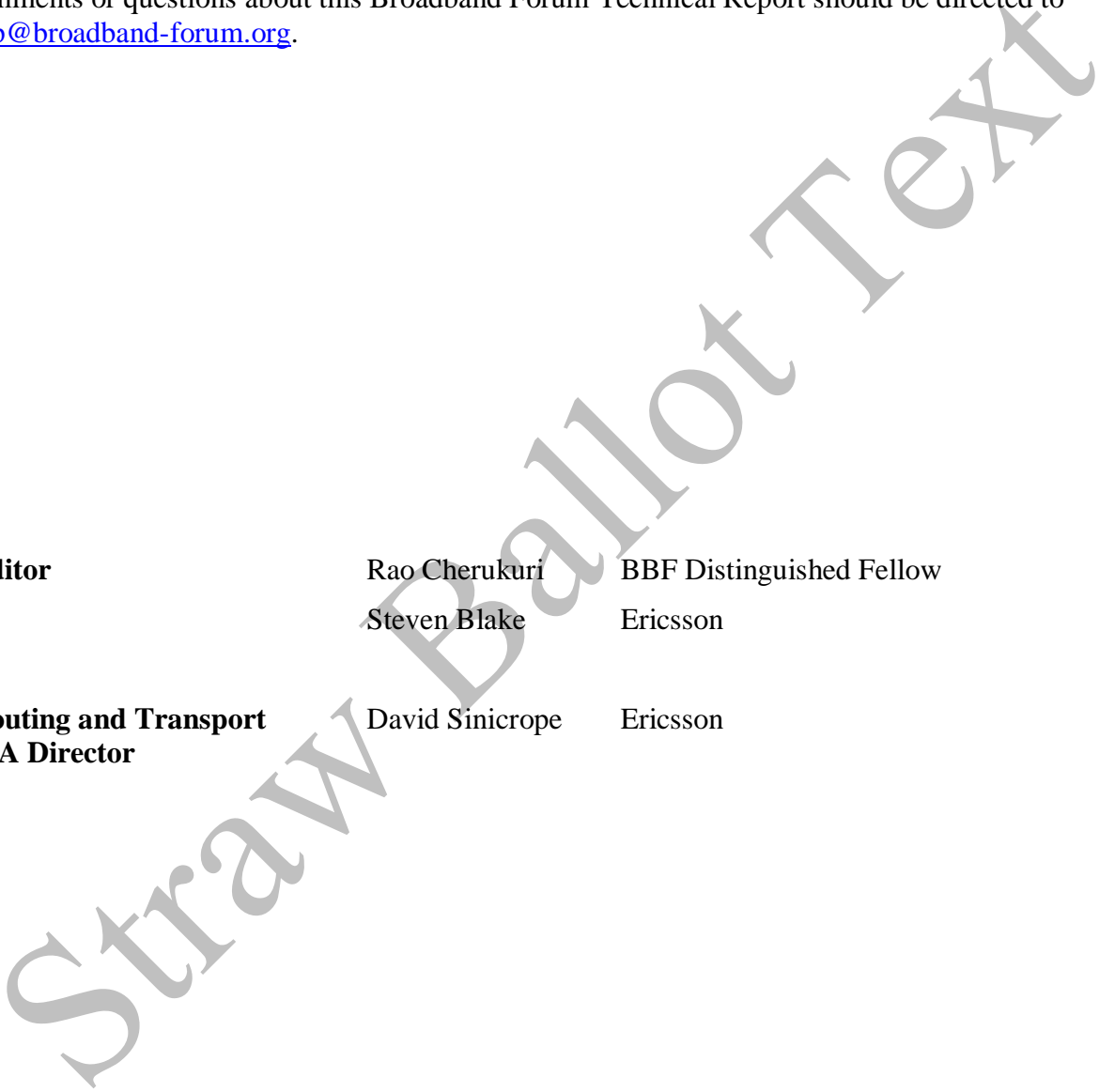
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36	TABLE OF CONTENTS	
37	<b>EXECUTIVE SUMMARY .....</b>	<b>10</b>
38	<b>1 PURPOSE AND SCOPE .....</b>	<b>11</b>
39	1.1 PURPOSE .....	11
40	1.2 SCOPE .....	11
41	<b>2 REFERENCES AND TERMINOLOGY .....</b>	<b>13</b>
42	2.1 CONVENTIONS .....	13
43	2.2 REFERENCES .....	13
44	2.3 DEFINITIONS .....	16
45	2.4 ABBREVIATIONS .....	17
46	<b>3 TECHNICAL REPORT IMPACT .....</b>	<b>19</b>
47	3.1 ENERGY EFFICIENCY .....	19
48	3.2 IPV6.....	19
49	3.3 SECURITY.....	19
50	3.4 PRIVACY .....	19
51	<b>4 CARRIER ETHERNET SERVICES.....</b>	<b>20</b>
52	4.1 CARRIER ETHERNET REQUIREMENTS .....	20
53	<b>5 LAYER 2 ETHERNET VPNS IN MPLS NETWORKS.....</b>	<b>21</b>
54	<b>6 REFERENCE ARCHITECTURE .....</b>	<b>22</b>
55	6.1 GENERAL REFERENCE ARCHITECTURE .....	22
56	6.2 MPLS FOR CARRIER ETHERNET IN BROADBAND ACCESS & AGGREGATION .....	23
57	6.2.1 <i>Multi-Service Broadband Access &amp; Aggregation</i> .....	23
58	6.2.2 <i>TR-178 Architectures</i> .....	23
59	<b>7 SIGNALING AND ROUTING.....</b>	<b>24</b>
60	7.1 LSP SIGNALING .....	24
61	7.1.1 <i>Multi-area LSP Signaling</i> .....	24
62	7.2 ROUTING.....	26
63	<b>8 OAM.....</b>	<b>27</b>
64	8.1 ETHERNET OAM.....	27
65	8.1.1 <i>Link OAM</i> .....	27
66	8.1.2 <i>ITU-T G.8013/Y.1731</i> .....	28
67	8.2 MEF SERVICE OAM.....	28
68	8.3 MPLS OAM.....	29
69	8.3.1 <i>LSP OAM</i> .....	29
70	8.3.2 <i>Convergence</i> .....	30
71	<b>9 QOS.....</b>	<b>32</b>
72	9.1 TUNNEL COS MAPPING AND MARKING.....	32
73	<b>10 PSN RESILIENCY .....</b>	<b>33</b>

74	10.1 FAILURE DETECTION .....	33
75	10.2 LSP RECOVERY .....	33
76	10.3 CONTROL PLANE RESILIENCY .....	34
77	<b>11 BGP MPLS-BASED ETHERNET VPN .....</b>	<b>35</b>
78	11.1 REFERENCE ARCHITECTURE AND OVERVIEW .....	35
79	11.2 EVPN SERVICE INTERFACES .....	36
80	11.2.1 VLAN-Based Service Interfaces .....	36
81	11.2.2 VLAN Bundle Service Interfaces .....	36
82	11.2.3 VLAN-Aware Bundle Service Interfaces .....	37
83	11.3 DATA PLANE .....	37
84	11.3.1 Underlying PSN transport .....	37
85	11.3.2 VPN encapsulation .....	37
86	11.3.3 VID Translation .....	37
87	11.3.4 Frame Ordering .....	37
88	11.4 CONTROL PLANE .....	37
89	11.5 MULTI-HOMING AND LOAD BALANCING .....	38
90	11.5.1 All-Active Redundancy Mode .....	38
91	11.5.2 Single-Active Redundancy Mode .....	38
92	11.6 FAST CONVERGENCE .....	39
93	<b>12 EVPN ENABLED MULTIPOINT TO MULTIPOINT ETHERNET VPN</b>	
94	<b>SERVICES (E-LAN) .....</b>	<b>40</b>
95	12.1 ETHERNET PRIVATE LAN (EP-LAN) .....	40
96	12.2 ETHERNET VIRTUAL PRIVATE LAN (EVP-LAN) .....	41
97	12.3 EVPN FOR ESTABLISHING EP-LAN AND EVP-LAN .....	41
98	12.3.1 Service Interfaces .....	42
99	12.3.2 Data plane .....	43
100	12.3.3 Tunnel signaling .....	43
101	12.3.4 Routing .....	43
102	12.3.5 Multi-Homing and Load balancing .....	43
103	12.3.6 OAM .....	44
104	12.3.7 Convergence .....	44
105	12.3.8 PSN Resiliency .....	44
106	12.3.9 Multicast and Broadcast .....	44
107	12.3.10 QoS .....	44
108	12.3.11 Security .....	44
109	12.4 SUPPORT OF SERVICE ATTRIBUTES FOR EP-LAN AND EVP-LAN .....	45
110	12.4.1 Bandwidth Profile .....	45
111	12.4.2 Bundling .....	45
112	12.4.3 CE-VLAN ID preservation for EVC .....	45
113	12.4.4 CE-VLAN CoS preservation for EVC .....	46
114	12.4.5 EVC Maximum Service Frame Size .....	46
115	12.4.6 Frame delivery .....	46
116	12.4.7 Layer 2 control protocols .....	47
117	12.4.8 EVC performance .....	47

118	<b>13</b>	<b>EVPN ENABLED POINT TO POINT ETHERNET VPN SERVICES (E-LINE)</b>	<b>49</b>
119	13.1	ETHERNET PRIVATE LINE (EPL)	49
120	13.2	ETHERNET VIRTUAL PRIVATE LINE (EVPL)	50
121	13.3	EVPN FOR ESTABLISHING EPL AND EVPL	51
122	13.3.1	<i>Service Interfaces</i>	51
123	13.3.2	<i>Operation</i>	52
124	13.3.3	<i>Data Plane</i>	52
125	13.3.4	<i>BGP extensions</i>	52
126	13.3.5	<i>Tunnel signaling</i>	53
127	13.3.6	<i>Routing</i>	53
128	13.3.7	<i>Multi-Homing and Load balancing</i>	53
129	13.3.8	<i>OAM</i>	53
130	13.3.9	<i>Convergence</i>	53
131	13.3.10	<i>PSN Resiliency</i>	53
132	13.3.11	<i>QoS</i>	53
133	13.3.12	<i>Security</i>	54
134	13.4	SUPPORT OF SERVICE ATTRIBUTES FOR EPL AND EVPL	54
135	13.4.1	<i>Bandwidth Profile</i>	54
136	13.4.2	<i>Bundling</i>	54
137	13.4.3	<i>CE-VLAN ID preservation for EVC</i>	55
138	13.4.4	<i>CE-VLAN CoS preservation for EVC</i>	55
139	13.4.5	<i>EVC Maximum Service Frame Size</i>	55
140	13.4.6	<i>Frame delivery</i>	56
141	13.4.7	<i>Layer 2 control protocols</i>	56
142	13.4.8	<i>EVC performance</i>	56
143	13.4.9	<i>Multiple Class of Service</i>	57
144	<b>14</b>	<b>EVPN ENABLED ROOTED-MULTIPOINT ETHERNET VPN SERVICES (E-TREE)</b>	<b>58</b>
145			
146	14.1	ETHERNET PRIVATE TREE (EP-TREE)	58
147	14.2	ETHERNET VIRTUAL PRIVATE TREE (EVP-TREE)	59
148	14.3	EVPN FOR ESTABLISHING EP-TREE AND EVP-TREE	60
149	14.3.1	<i>E-Tree support in EVPN</i>	61
150	14.3.2	<i>Service Interfaces</i>	61
151	14.3.3	<i>Data plane</i>	62
152	14.3.4	<i>Tunnel signaling</i>	62
153	14.3.5	<i>Routing</i>	62
154	14.3.6	<i>Multi-Homing and Load balancing</i>	62
155	14.3.7	<i>OAM</i>	62
156	14.3.8	<i>Convergence</i>	62
157	14.3.9	<i>PSN Resiliency</i>	62
158	14.3.10	<i>Multicast and Broadcast</i>	62
159	14.3.11	<i>QoS</i>	63
160	14.3.12	<i>Security</i>	63
161	14.4	SUPPORT OF SERVICE ATTRIBUTES FOR EP-TREE AND EVP-TREE	63
162	14.4.1	<i>Bandwidth Profile</i>	63

163	14.4.2	<i>Bundling</i> .....	64
164	14.4.3	<i>CE-VLAN ID preservation for EVC</i> .....	64
165	14.4.4	<i>CE-VLAN CoS preservation for EVC</i> .....	64
166	14.4.5	<i>EVC Maximum Service Frame Size</i> .....	64
167	14.4.6	<i>Frame delivery</i> .....	65
168	14.4.7	<i>Layer 2 control protocols</i> .....	65
169	14.4.8	<i>EVC performance</i> .....	65
170			
171			

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172 **List of Figures**

173		
174	Figure 1 Reference Architecture .....	22
175	Figure 2 Components of OAM .....	27
176	Figure 3 EVPN Architecture for Ethernet services using BGP MPLS.....	36
177	Figure 4 Ethernet Private LAN (EP-LAN) Service .....	40
178	Figure 5 Ethernet Virtual Private LAN (EVP-LAN) Service.....	41
179	Figure 6 Ethernet Private Line (EPL) Service .....	50
180	Figure 7 Ethernet Virtual Private Line (EVPL) Service.....	51
181	Figure 8 Ethernet Private Tree (EP-Tree) Service.....	59
182	Figure 9 Ethernet Virtual Private Tree (EVP-Tree) Service.....	60
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**185 Executive Summary**

186 Carrier Ethernet provides extensions to Ethernet, enabling telecommunications network providers  
187 to provide Ethernet services to customers and to utilize Ethernet technology in their networks.  
188

189 Carrier Ethernet services are being used in Broadband access networks, enterprise networks and  
190 backhaul networks. Providing Carrier Ethernet services using MPLS network infrastructure is  
191 generating revenue opportunities for global carriers, driven by customer demand for higher  
192 bandwidth connectivity. Though TR-224 describes the architecture for solutions to implement  
193 Carrier Ethernet services using an MPLS network, the VPLS based solution has a number of  
194 limitations when it comes to redundancy, multicast optimization and provisioning simplicity. It  
195 does not address requirements such as multi-homing with all-active forwarding, load balancing,  
196 policy-based control and control plane based MAC learning. Service interface requirements for  
197 data-center interconnects are also not addressed by TR-224.  
198

199 This document provides technical architecture and equipment requirements to implement the  
200 Carrier Ethernet services using BGP MPLS-based EVPNs in order to overcome the limitations of  
201 VPLS and address the additional requirements. By specifying a common technical architecture,  
202 common equipment requirements and common set of feature options, this document promotes  
203 multi-vendor interoperability.  
204  
205

## 206 1 Purpose and Scope

### 207 1.1 Purpose

208 Carrier Ethernet provides extensions to Ethernet enabling telecommunications network providers  
209 to provide Ethernet services to customers and to utilize Ethernet technology in their networks.  
210 Service providers are deploying Carrier Ethernet services around the globe, in large part, because  
211 Carrier Ethernet has compelling capabilities such as standardized service definitions as well as  
212 improved scalability, reliability, QoS, and manageability.  
213

214 Carrier Ethernet services are being used in Broadband access networks, enterprise networks and  
215 backhaul networks. The integration of Ethernet into MPLS network infrastructure is generating  
216 revenue opportunities for global carriers, driven by customer demand for higher bandwidth  
217 connectivity. This document provides a technical architecture and equipment requirements  
218 implementing the specified Ethernet services using BGP MPLS-based Ethernet VPNs (EVPNs) in  
219 IP/MPLS network.  
220

221 New Ethernet service applications require capabilities such as: multi-homing with all-active  
222 forwarding; load balancing; policy based control, and control plane MAC learning. TR-224 [4] and  
223 TR-178 [2] based solutions do not provide these features; solutions based on BGP MPLS EVPNs  
224 do.  
225

226 By specifying a common technical architecture, common equipment requirements and common set  
227 of feature options, this document promotes multi-vendor interoperability. This document may be  
228 used as a basis for conformance testing.

### 229 1.2 Scope

230 This document defines a reference architecture for Carrier Ethernet services using BGP MPLS-  
231 based Ethernet VPN mechanisms:  
232

- 233 • Ethernet multipoint to multipoint (E-LAN)
- 234 • Ethernet point to point (E-Line)
- 235 • Ethernet point to multipoint (E-Tree) including E-Tree\*
- 236 • Ethernet access to support wholesale access service
- 237 • Control, OAM, QoS, reliability and scalability for the MPLS network
- 238 • Support Ethernet service capabilities specified in RFC 7209 [37]  
239

240 This document specifies how to implement the Ethernet services layer. It does not specify the  
241 service layer itself. Ethernet Control and OAM protocols will be transparently transported, except  
242 for cases where Layer 2 control protocol processing is required per-service definition.  
243

244 This document includes the Carrier Ethernet E-LAN, E-Line, and E-Tree (including E-Tree\*)  
245 services types using BGP MPLS EVPNs.  
246

247

248 In order to support Carrier Ethernet services across multiple networks, the scope of this document  
249 includes the following:

- 250 • Attachment circuits (AC) providing a user-to-network interface complying with the MEF  
251 UNI are supported.
- 252 • Ethernet attachment circuits for multi-service broadband access and aggregation (i.e., TR-  
253 101/TR-178) are supported.
- 254 • Additional Ethernet service capabilities of BGP MPLS-based EVPNs (e.g. multi-homing  
255 with all-active forwarding, load balancing, policy based control, control based MAC  
256 learning, etc) are supported.
- 257 • Support for interworking with TR-224.
- 258 • To support Carrier Ethernet across multiple SP networks, the specification addresses multi  
259 autonomous systems which preserves end-to-end capabilities (e.g., OAM, QoS and  
260 protection etc).
- 261 • Cases where the UNI-N functions are or are not collocated with the PE are supported.

262

263 TR-350 provides technical architecture and equipment requirements implementing MEF Carrier  
264 Ethernet services with BGP MPLS EVPNs. EVPNs architecture and protocols are based on  
265 BGP/MPLS IP VPNs , which supports multiple domains. This capability is used to support  
266 connectivity between service endpoints (e.g. MEF UNIs) connected to different networks or  
267 operators.

268 TR-350 does not use architecture or connectivity models of Carrier Ethernet using MEF 26.1 [46].

269

## 270 2 References and Terminology

### 271 2.1 Conventions

272 In this Technical Report, several words are used to signify the requirements of the specification.  
 273 These words are always capitalized. More information can be found be in RFC 2119 [8].  
 274

<b>MUST</b>	This word, or the term “REQUIRED”, means that the definition is an absolute requirement of the specification.
<b>MUST NOT</b>	This phrase means that the definition is an absolute prohibition of the specification.
<b>SHOULD</b>	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.
<b>SHOULD NOT</b>	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.
<b>MAY</b>	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 <b>MUST</b> be prepared to inter-operate with another implementation that does include the option.

### 275 2.2 References

276 The following references are of relevance to this Technical Report. At the time of publication, the  
 277 editions indicated were valid. All references are subject to revision; users of this Technical Report  
 278 are therefore encouraged to investigate the possibility of applying the most recent edition of the  
 279 references listed below.

280 A list of currently valid Broadband Forum Technical Reports is published at  
 281 [www.broadband-forum.org](http://www.broadband-forum.org).  
 282

Document	Title	Source	Year
[1] <a href="#">TR-101</a>	<i>Migration to Ethernet-Based Broadband Aggregation</i>	BBF	2011
[2] <a href="#">TR-178</a>	<i>Multi-service Broadband Network Architecture and Nodal Requirements</i>	BBF	2014
[3] <a href="#">TR-221</a>	<i>Technical Specifications for MPLS in Mobile Backhaul Networks</i>	BBF	2011

[4]	<a href="#">TR-224</a>	<i>Technical Specification for MPLS in Carrier Ethernet Networks</i>	BBF	2014
[5]	<a href="#">IEEE 802.3</a>	<i>IEEE Standard Ethernet</i>	IEEE	2012
[6]	<a href="#">IEEE 802.1Q</a>	<i>IEEE Standard for Local and metropolitan area networks--Media Access Control (MAC) Bridges and Virtual Bridged Local Area Networks</i>	IEEE	2011
[7]	<a href="#">RFC 1195</a>	<i>Use of OSI IS-IS for Routing in TCP/IP and Dual Environments</i>	IETF	1990
[8]	<a href="#">RFC 2119</a>	<i>Key words for use in RFCs to Indicate Requirement Levels</i>	IETF	1997
[9]	<a href="#">RFC 2328</a>	<i>OSPF Version 2</i>	IETF	1998
[10]	<a href="#">RFC 3209</a>	<i>RSVP-TE: Extensions to RSVP for LSP Tunnels</i>	IETF	2001
[11]	<a href="#">RFC 3270</a>	<i>Multi-Protocol Label Switching (MPLS) Support of Differentiated Services</i>	IETF	2002
[12]	<a href="#">RFC 3473</a>	<i>Generalized Multi-Protocol Label Switching (GMPLS) Signaling Resource Reservation Protocol-Traffic Engineering (RSVP-TE) Extensions</i>	IETF	2003
[13]	<a href="#">RFC 3478</a>	<i>Graceful Restart Mechanism for Label Distribution Protocol</i>	IETF	2003
[14]	<a href="#">RFC 3564</a>	<i>Requirements for Support of Differentiated Services-aware MPLS Traffic Engineering</i>	IETF	2003
[15]	<a href="#">RFC 3623</a>	<i>Graceful OSPF Restart</i>	IETF	2003
[16]	<a href="#">RFC 3630</a>	<i>Traffic Engineering (TE) Extensions to OSPF Version 2</i>	IETF	2003
[17]	<a href="#">RFC 5306</a>	<i>Restart Signaling for Intermediate System to Intermediate System (IS-IS)</i>	IETF	2004
[18]	<a href="#">RFC 4090</a>	<i>Fast Reroute Extensions to RSVP-TE for LSP Tunnels</i>	IETF	2005
[19]	<a href="#">RFC 4124</a>	<i>Protocol Extensions for Support of Diffserv-aware MPLS Traffic Engineering</i>	IETF	2005
[20]	<a href="#">RFC 4206</a>	<i>Label Switched Paths (LSP) Hierarchy with Generalized Multi-Protocol Label Switching (GMPLS) Traffic Engineering (TE)</i>	IETF	2005
[21]	<a href="#">RFC 4364</a>	<i>BGP/MPLS IP Virtual Private Networks (VPNs)</i>	IETF	2006

- [22] [RFC 4379](#) *Detecting Multi-Protocol Label Switched (MPLS) Data Plane Failures* IETF 2006
- [23] [RFC 4761](#) *Virtual Private LAN Service (VPLS) Using BGP for Auto-Discovery and Signaling* IETF 2007
- [24] [RFC 4762](#) *Virtual Private LAN Service (VPLS) Using BGP for Auto-Discovery and Signaling* IETF 2007
- [25] [RFC 5036](#) *LDP Specification* IETF 2007
- [26] [RFC 5150](#) *Label Switched Path Stitching with Generalized Multiprotocol Label Switching Traffic Engineering (GMPLS TE)* IETF 2008
- [27] [RFC 5151](#) *Inter-Domain MPLS and GMPLS Traffic Engineering -- Resource Reservation Protocol-Traffic Engineering (RSVP-TE) Extensions* IETF 2008
- [28] [RFC 5283](#) *LDP Extension for Inter-Area Label Switched Paths (LSPs)* IETF 2008
- [29] [RFC 5286](#) *Basic Specification for IP Fast Reroute: Loop-Free Alternates* IETF 2008
- [30] [RFC 5305](#) *IS-IS Extensions for Traffic Engineering* IETF 2008
- [31] [RFC 5586](#) *MPLS Generic Associated Channel* IETF 2009
- [32] [RFC 5880](#) *Bidirectional Forwarding Detection (BFD)* IETF 2010
- [33] [RFC 5881](#) *Bidirectional Forwarding Detection (BFD) for IPv4 and IPv6 (Single Hop)* IETF 2010
- [34] [RFC 5884](#) *Bidirectional Forwarding Detection (BFD) for MPLS Label Switched Paths (LSPs)* IETF 2010
- [35] [RFC 6424](#) *Mechanism for Performing Label Switched Path Ping (LSP Ping) over MPLS Tunnels* IETF 2011
- [36] [RFC 6790](#) *The Use of Entropy Labels in MPLS Forwarding* IETF 2012
- [37] [RFC 7209](#) *Requirements for Ethernet VPN (EVPN)* IETF 2014
- [38] [RFC 7387](#) *Framework for Ethernet Tree (E-Tree) Service over a Multiprotocol Label Switching (MPLS) Network* IETF 2014
- [39] [RFC 7432](#) *BGP MPLS Based Ethernet VPN* IETF 2015
- [40] [G.8013/Y.1731](#) *OAM functions and mechanisms for Ethernet based networks* ITU-T 2013
- [41] [MEF 6.1](#) *Ethernet Services Definitions - Phase 2* MEF 2008

[42]	<a href="#">MEF 10.2</a>	<i>Ethernet Services Attributes - Phase 2</i>	MEF	2009
[43]	<a href="#">MEF 30</a>	<i>Service OAM Fault Management Implementation Agreement</i>	MEF	2011
[44]	<a href="#">MEF 22.1</a>	<i>Mobile Backhaul Phase 2 Implementation Agreement</i>	MEF	2012
[45]	<a href="#">MEF 23.1</a>	<i>Carrier Ethernet Class of Service – Phase 2</i>	MEF	2012
[46]	<a href="#">MEF 26.1</a>	<i>External Network Network Interface (ENNI) – Phase 2</i>	MEF	2012
[47]	<a href="#">MEF 35</a>	<i>Service OAM Performance Monitoring Implementation Agreement</i>	MEF	2012
[48]	<a href="#">MEF 6.1.1</a>	<i>Layer 2 Control Protocol Handling Amendment to MEF 6.1</i>	MEF	2012
[49]	<a href="#">MEF 10.3</a>	<i>Ethernet Services Attributes - Phase 3</i>	MEF	2013
[50]	<a href="#">MEF 6.2</a>	<i>EVC Ethernet Services Definitions - Phase 3</i>	MEF	2014
[51]	<a href="#">MEF 45</a>	<i>Multi-CEN L2CP</i>	MEF	2014
[52]	<a href="#">draft-ietf-bess-evpn-etree</a>	<i>E-TREE Support in EVPN &amp; PBB-EVPN</i>	IETF	2017
[53]	<a href="#">draft-ietf-bess-evpn-vpws</a>	<i>Virtual Private Wire Support in EVPN</i>	IETF	2017

## 283 2.3 Definitions

284 The following terminology is used throughout this Technical Report.

285	<b>AGN</b>	An aggregation node (AGN) is a node which aggregates several access nodes (ANs).
	<b>AN</b>	An access node is a node which processes customer frames or packets at Layer 2 or above. This includes but is not limited to DSLAMs or OLTs (in case of (G)PON deployments).
	<b>E-Line</b>	A service connecting two customer Ethernet ports over a WAN.
	<b>E-LAN</b>	A multipoint service connecting a set of customer endpoints, giving the appearance to the customer of a bridged Ethernet network connecting the sites.
	<b>E-Tree</b>	A rooted multipoint Ethernet Virtual Connection. The E-Tree service type can support one or multiple Root UNIs (see Section 9.3/MEF 6.2 [50])



**E-Tree\*** Partially implementing MEF multipoint service connecting only one root and a set of leaves, but preventing inter-leaf communication. See details in TR-221.

Note: Ethernet Tree (E-Tree) service type is specified in Section 6.3/MEF 6.1 [41]. The Appendix in TR-221 modifies the E-Tree service type which is used in different services. The modified E-Tree\* service type is used in both Ethernet Private Tree service and Ethernet Virtual Private Tree Service specified in Section 14 .

## 286 2.4 Abbreviations

287 This Technical Report uses the following abbreviations:  
288

AC	Attachment Circuit
AGN	Aggregation Node
AN	Access Node
BFD	Bidirectional Forwarding Detection
BGP	Border Gateway Protocol
BNG	Broadband Network Gateway
CE	Customer Edge
CoS	Class of Service
CV	Connectivity Verification
EPL	Ethernet Private Line
EP-LAN	Ethernet Private-LAN
EVC	Ethernet Virtual Connection
EVPL	Ethernet Virtual Private Line
EVP-LAN	Ethernet Virtual Private – LAN
FD	Frame Delay
FRR	Fast Re-route
FLR	Frame Loss Ratio
H-VPLS	Hierarchal Virtual Private LAN Service
IETF	Internet Engineering Task Force
IP	Internet Protocol
ITU-T	International Telecommunication Union Telecommunication Standardization Sector
L2VPN	Layer 2 Virtual Private Network
LAN	Local Area Network
LER	Label Edge Router
LFA	Loop Free Alternate
LSP	Label Switched Path

LSR	Label Switch Router
MAC	Medium Access Control
MEF	Metro Ethernet Forum
MPLS	Multi Protocol Label Switching
OAM	Operations, Administration and Management
OAMPDU	OAM Protocol Data Unit
P	Provider
PE	Provider Edge
PSN	Packet Switched Network
PW	Pseudowire
QoS	Quality of Service
RFC	Request for Comments
RSVP-TE	Resource ReSerVation Protocol with Traffic Engineering extensions
SLA	Service Level Agreement
TE	Traffic Engineering
T-LDP	Targeted Label Distribution Protocol
TLV	Type/Length/Value
TR	Technical Report
UNI	User to Network Interface
UDP	User Datagram Protocol
VPLS	Virtual Private LAN Service
VPN	Virtual Private Network
VPWS	Virtual Private Wire Service
WG	Working Group

289

290

## 291 **3 Technical Report Impact**

### 292 **3.1 Energy Efficiency**

293 TR-350 has no impact on energy efficiency.

### 294 **3.2 IPv6**

295 Carrier Ethernet services operate at Layer 2 and therefore the network is agnostic to IPv6 user  
296 traffic. The IPv6 header DSCP field is assumed to be mapped to the Ethernet P bits by the service  
297 user.

298  
299 IPv6 addressing may appear in its respective places in control, OAM, and management protocols,  
300 e.g., node ids, FECs, and loopback addresses, etc.

301  
302 TR-350 has no direct impact on IPv6.

### 303 **3.3 Security**

304 Security requirements are specified for each service in respective sections.

### 305 **3.4 Privacy**

306 Any issues regarding privacy are not affected by TR-350.

307  
308

## 309 4 Carrier Ethernet services

310 Ethernet is now being used as both a transport technology and a service delivery architecture. The  
311 MEF Carrier Ethernet specifies Ethernet service type, service attributes, QoS and SLA. The  
312 service type includes point-to-point (E-Line), point-to-multipoint (E-Tree), multipoint-to-  
313 multipoint (E-LAN), and E-Access. The service definition includes both port-based and VLAN-  
314 based service identification.

315  
316 TR-224 refers to MEF 6.1 and MEF 10.2. TR-350 uses the backward compatible subset of the  
317 revised specifications MEF 6.2 [50] and MEF 10.3 [49] to achieve the equivalent function. This  
318 makes TR-350 compatible with TR-224.

319  
320 The MEF also defined Carrier Ethernet as a ubiquitous, standardized, carrier-class service and  
321 network defined by attributes that distinguish Carrier Ethernet from familiar LAN-based Ethernet.

### 322 4.1 Carrier Ethernet Requirements

323 Service providers worldwide are migrating their existing networks to deliver Carrier Ethernet  
324 services to enterprises, businesses & residential end-users. The attributes are as follows:

- 325
- 326 1. Standardized Services
    - 327 • Support E-Line, E-LAN and E-Tree service types as defined by MEF
    - 328 • No changes to customer LAN equipment or networks and accommodates existing
    - 329 network connectivity such as, time-sensitive, TDM traffic and signaling
    - 330 • Wide choice and granularity of bandwidth and quality of service options
  - 331 2. Security
  - 332 3. Scalability
    - 333 • The ability to support millions of Ethernet Virtual Connection (EVC) services for
    - 334 enterprise and residential users
    - 335 • Scalability of bandwidth from 1 Mbps to 10 Gbps and beyond, in granular
    - 336 increments
  - 337 4. Reliability
    - 338 • The ability for the network to detect & recover from faults quickly
    - 339 • Fast network convergence
  - 340 5. Quality of Service
    - 341 • Service Level Agreements (SLAs) that deliver end-to-end performance
    - 342 • Traffic profile enforcement per-EVC
    - 343 • Hierarchical queuing
  - 344 6. Service Management
    - 345 • Minimize network touch points in provisioning
    - 346 • Standards-based OAM to support SLA
- 347  
348

## 349 **5 Layer 2 Ethernet VPNs in MPLS Networks**

350 MPLS has for a long time been defined as a convergence technology, one that will allow service  
351 providers to bring together their disparate networks and leverage features like traffic engineering,  
352 hierarchal QoS, and service interworking.

353  
354 Provider Provisioned Virtual Private Networks (PPVPN) now dominates the IP-VPN services  
355 market and is projected for significant growth. Many service providers have provided Ethernet  
356 VPN services using Virtual Private LAN Services (VPLS) as an alternative that allows enterprises  
357 to manage their own routing.

358  
359 TR-224 uses VPLS to support Ethernet LAN services in IP/MPLS networks. A VPLS PE  
360 emulates an Ethernet bridge (IEEE 802.1Q [6]) and performs MAC learning in the data plane.  
361 New applications using Ethernet services require capabilities such as: multi-homing with all-active  
362 forwarding, load balancing, policy based control, and control plane MAC learning. To support  
363 these capabilities IETF developed BGP MPLS-based Ethernet VPNs (EVPNs). TR-224 based  
364 solutions do not provide these features.

365  
366 When an Ethernet multipoint service is provided using EVPN, control-plane-based remote MAC  
367 learning is used over the MPLS core (PE to PE) network. MAC learning between PE and CE is  
368 done in the data plane. EVPN is designed to handle multi-homing, and per-flow load balancing.  
369 The EVPN technology uses MP-BGP over an MPLS network. The technology is similar to BGP  
370 MPLS-based IP VPNs (RFC 4364). Using MP-BGP to distribute the reachability of MAC  
371 addresses over a MPLS network brings the same operational control and scale of L3VPN to  
372 L2VPN.

373  
374 The EVPN solution provides a common base for all Ethernet service types including E-LAN, E-  
375 Line, E-Tree (including E-Tree\* from TR-221), E-Access and enables these services to be created  
376 such that they can span across domains. In addition to the common base above, BGP MPLS-based  
377 EVPNs also provide solutions for the requirements in RFC 7209 [37] including:

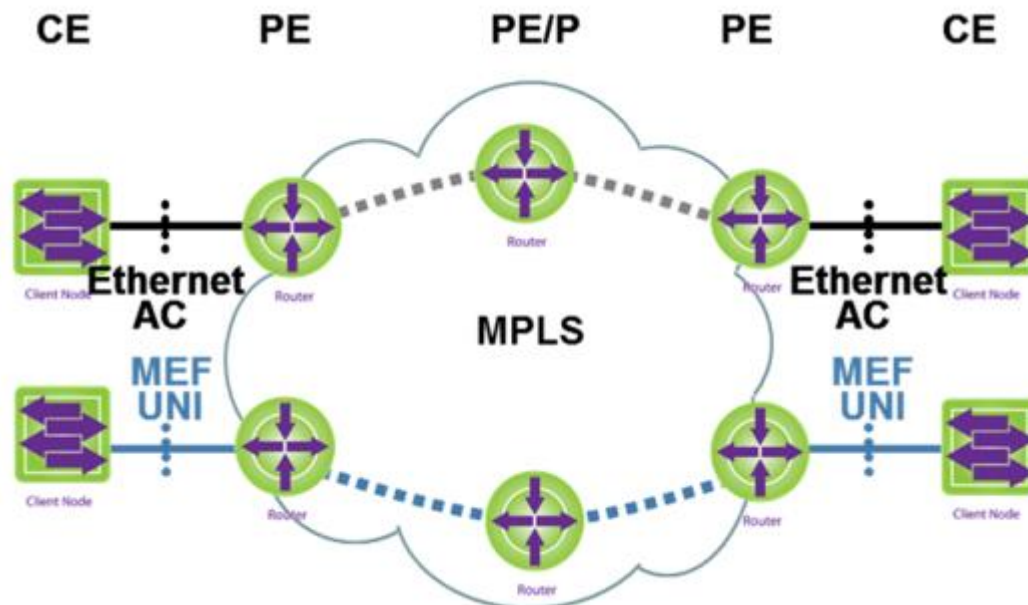
- 378 • Multi-homing: with all active forwarding and load balancing from CE to CE. VPLS can  
379 only support multi-homing with single active mode.
- 380 • Flow based load balancing and multipath
- 381 • Multicast optimization: must be able to support P2MP MPLS LSPs and MP2MP MPLS  
382 LSPs. VPLS only supports P2MP MPLS LSPs.
- 383 • Fast convergence to minimize downtime and packet loss.
- 384 • Support MAC mobility to support cloud services.

385  
386

## 387 6 Reference Architecture

### 388 6.1 General Reference Architecture

389 Figure 1 provides a generic overview of how Carrier Ethernet Services can be deployed using a  
 390 BGP MPLS-based EVPN infrastructure, including basic reference points and their functional roles.  
 391 Depending on the application, non-MEF-defined Ethernet Attachment Circuits and Attachment  
 392 Circuits providing User-to-Network interfaces complying with Metro Ethernet Forum definitions  
 393 (MEF UNI) are supported. Multi-domain connectivity and external handoff are also supported.  
 394



395  
 396 **Figure 1 Reference Architecture**  
 397

398 Defined as business interfaces supporting the service handoff between different parties (between  
 399 user and provider or between providers, respectively), UNI has two functions:

- 400
- 401 1. provide reference points for network demarcation
  - 402 2. provide associated functionality
- 403

404 For deploying Metro Ethernet Forum-compliant Ethernet Services over MPLS, PE nodes need to  
 405 support the corresponding MEF UNI functionality at Attachment Circuit interfaces.

406  
 407  
 408  
 409  
 410  
 411  
 412

## 413 **6.2 MPLS for Carrier Ethernet in Broadband Access & Aggregation**

### 414 **6.2.1 Multi-Service Broadband Access & Aggregation**

415 For Multi-Service Broadband access and aggregation architecture see Section 6.2.1/TR-224 [4].

### 416 **6.2.2 TR-178 Architectures**

417 There are two reference architectures that are being used to represent TR-178 networks: 1) MPLS-  
418 enabled access and 2) TR-101. For architectural details of MPLS-enabled access nodes and TR-  
419 101 see Section 6.2.2/TR-224 [4].

420

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## 421 **7 Signaling and Routing**

422 This section specifies the signaling protocol used to establish the underlying MPLS tunnel. Traffic  
423 engineered PSN tunnels must be used when specific path (e.g. for protection purpose), QoS or  
424 bandwidth constraints are required.

### 425 **7.1 LSP Signaling**

426 One of the following provisioning and signaling procedures are used for LSPs.

- 427
- 428 [R-1] PE and P routers supporting MPLS TE and non-TE LSPs MUST support one or  
429 both of the following methods:
- 430 • Static provisioning
  - 431 • Dynamic signaling
- 432
- 433 [R-2] Both of the following methods MUST be supported by PE and P routers for  
434 dynamically signaled PSN tunnel LSPs:
- 435 • LDP is used to set up, maintain and release LSP tunnels per RFC 5036 [25].
  - 436 • RSVP-TE is used to set up, maintain and release LSPs for traffic engineered tunnels per  
437 RFC 3209 [10] and RFC 5151 [27]. When traffic engineering is needed on the LSP,  
438 RSVP-TE MUST be used.
- 439
- 440 [R-3] When co-routed bidirectional LSPs are required, GMPLS-RSVP-TE as per RFC  
441 3473 [12] MAY be supported by PE and P routers.

#### 442 **7.1.1 Multi-area LSP Signaling**

443 Several operators have multi-area networks for scalability. Link state Interior Gateway Protocols  
444 (IGPs) such as OSPF (RFC 2328 [9]) and IS-IS (RFC 1195 [7]) allow dividing networks into areas  
445 or levels so as to increase routing scalability within a routing domain.

446

447 Further some operators' L2VPN networks span different geographical areas. To support these  
448 networks, it is necessary to support inter-area and inter-AS (Autonomous System) Multiprotocol  
449 Label Switching (MPLS) LSPs.

450

451 An "MPLS Domain" is considered to be any collection of network elements implementing MPLS  
452 within a common realm of address space or path computation responsibility. Examples of such  
453 domains include Autonomous Systems, Interior Gateway Protocol (IGP) routing areas, and  
454 GMPLS overlay networks.

455

456 Signaling extensions for inter-area LSPs (that is, LSPs that traverse at least two IGP areas) are  
457 required to ensure MPLS connectivity between PEs located in distinct IGP areas.

458  
459  
460



461

462 **7.1.1.1 Multi-area RSVP-TE Signaling**

463 Inter-domain TE LSPs can be supported by one of three options as specified in RFC 5151 [27] and  
464 given below:

- 465 • contiguous LSPs
- 466 • nested LSPs
- 467 • stitched LSPs.

468 Note: While the specifications below cover both MPLS Traffic Engineering (TE)  
469 and GMPLS, the intent is to use the TE coverage.

470 **Contiguous**

471 A contiguous TE LSP is a single TE LSP that is set up across multiple  
472 domains using RSVP-TE signaling procedures described in Section 7.1.

473

474 **Nested**

475 One or more TE LSPs may be nested within another TE LSP as described in  
476 RFC 4206 [20]. This technique can be used to nest one or more inter-  
477 domain TE LSPs into an intra-domain hierarchical LSP (H-LSP). The label  
478 stacking construct is used to achieve nesting in packet networks.

479

480 To improve scalability, it may be useful to aggregate LSPs by creating a  
481 hierarchy of such LSPs.

482

483 [R-4] PE routers SHOULD support establishment of RSVP-TE LSPs using  
484 LSP hierarchy as per RFC 4206 [20].

485

486 **Stitched**

487 LSP stitching signaling procedures are described in RFC 5150 [26]. This  
488 technique can be used to stitch together shorter LSPs (LSP segments) to  
489 create a single, longer LSP. The LSP segments of an inter-domain LSP may  
490 be intra-domain LSPs or inter-domain LSPs.

491

492 The process of stitching LSP segments results in a single, end-to-end  
493 contiguous LSP in the data plane. But in the control plane, each segment is  
494 signaled as a separate LSP (with distinct RSVP sessions) and the end-to-end  
495 LSP is signaled as yet another LSP with its own RSVP session. Thus, the  
496 control plane operation for LSP stitching is very similar to that for nesting.

497

498 [R-5] PE routers SHOULD support establishment of RSVP-TE LSPs using  
499 LSP stitching as per RFC 5150 [26].

### 500 7.1.1.2 Multi-area LDP Signaling

501 RFC 5283 [28] facilitates the establishment of Label Switched Paths (LSPs) that would span  
502 multiple IGP areas in a given Autonomous System (AS).

503

504 [R-6] PE routers SHOULD support establishment of inter-area LSPs using  
505 LDP as per RFC 5283 [28].

## 506 7.2 Routing

507 [R-7] One or both of the following methods MUST be supported by PE and P routers:  
508 • Static routing  
509 • Dynamic routing

510

511 [R-8] Both of the following methods MUST be supported by PE and P routers to  
512 exchange routing information to facilitate dynamic LSP signaling:

- 513 • OSPF (RFC 2328 [9])
- 514 • IS-IS (RFC 1195 [7])

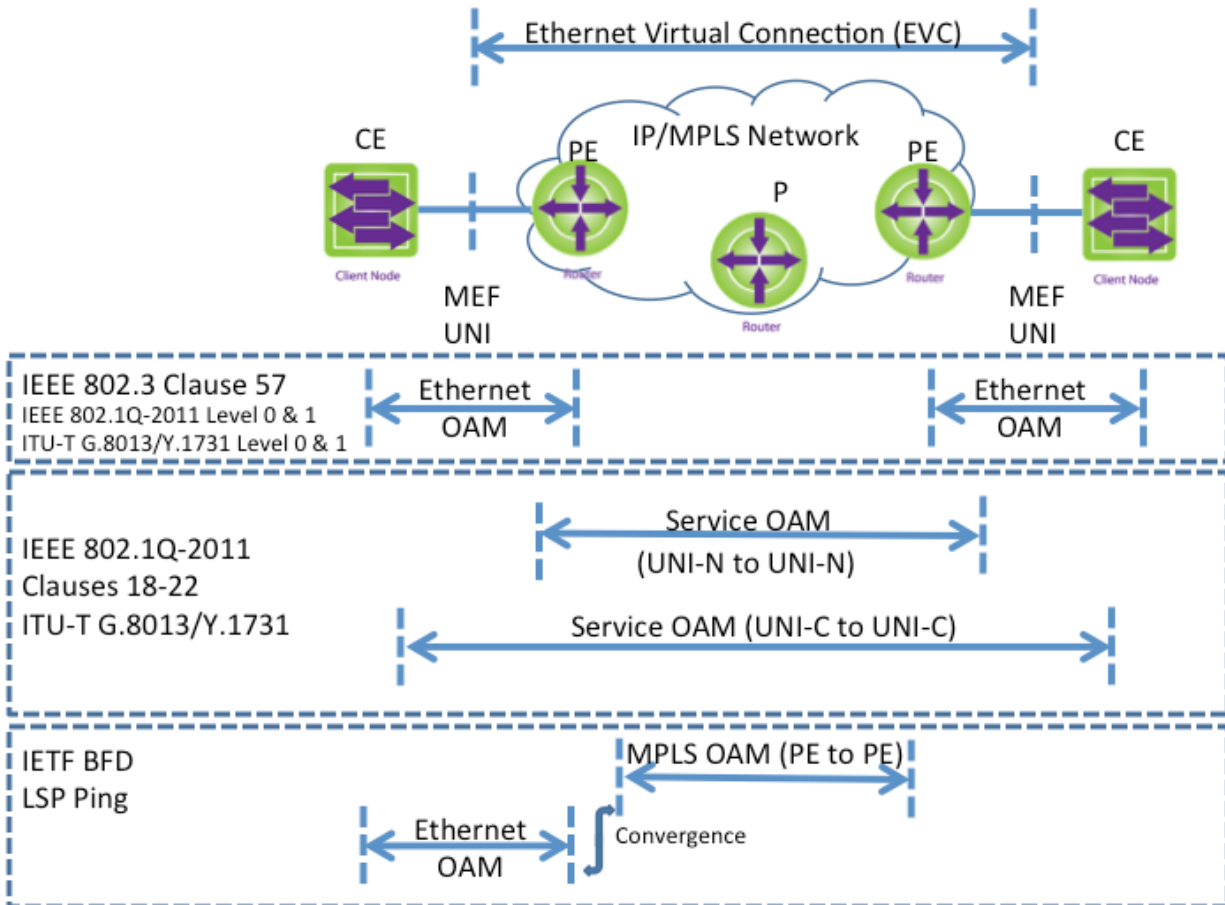
515

516 [R-9] Traffic engineering extensions of OSPF and IS-IS are used to exchange traffic  
517 attributes for RSVP-TE tunnels. If TE is supported, both of the following methods MUST  
518 be supported by PE and P routers:

- 519 • OSPF-TE (RFC 3630 [16])
- 520 • IS-IS-TE (RFC 5305 [30])

521 **8 OAM**

522 OAM in Carrier Ethernet networks was developed to provide fault management and performance  
 523 monitoring tools for network links and end-to-end EVCs. Figure 2 below shows the components  
 524 of OAM when the MEF services are provided using EVPN.  
 525



526  
 527  
 528  
 529

**Figure 2 Components of OAM**

530 **8.1 Ethernet OAM**

531 The OAM functions for the UNI should use the Ethernet OAM as defined in Link OAM (Clause  
 532 57/IEEE 802.3 [5]) and/or ITU-T G.8013/Y.1731 [40].

533 **8.1.1 Link OAM**

534 The PE supports Ethernet Link OAM, when the user is directly connected to the network  
 535 demarcation point (i.e., at the MEF UNI in Figure 2). Link OAM provides OAM functions for

536 network access segments (UNI-C to UNI-N). Link OAM provides for Ethernet Link Fault  
537 Detection, Monitoring and Loopback for access links.

538  
539 [R-10] The PE MUST support link OAM Active mode as per Clause 57.2.9.1/IEEE 802.3  
540 [5].

541  
542 [R-11] The PE MUST support initiating OAM Discovery process as per Subclause  
543 57.3.2.1/IEEE 802.3 [5].

544  
545 [R-12] The PE MUST support sending informational OAM Protocol Data Units  
546 (OAMPDU) as per Subclause 57.2.10/IEEE 802.3 [5].

547  
548 [R-13] The PE MUST support sending Event Notification OAMPDUs as per Subclause  
549 57.2.10/IEEE 802.3 [5].

550  
551 [R-14] The PE MUST support sending loopback control OAMPDUs as per Subclause  
552 5.2.11/IEEE 802.3 [5].

553  
554 [R-15] The PE MAY support sending Organization specific OAMPDU per Subclause  
555 57/IEEE 802.3 [5].

556  
557 [R-16] The PE MAY support sending Variable Request OAMPDUs as per Subclause  
558 57.4.3.3/IEEE 802.3 [5].

## 559 8.1.2 ITU-T G.8013/Y.1731

560 The OAM functions defined in ITU-T G.8013/Y.1731 can be used for OAM of the UNI between  
561 the CE and the PE.

562  
563 [R-17] The PE MUST support sending and receiving OAM frames at level 0 (as  
564 recommended in G.8013/Y.1731 [40]).

## 565 8.2 MEF Service OAM

566 The Carrier Ethernet Services are provided between one User Network Interface (UNI) and one or  
567 more UNIs. A network operator must be able to manage the services using Service OAM  
568 (SOAM). The network operator's service OAM is originated at the PE's UNI-N.

569  
570 [R-18] The PE MUST support SOAM at the EVC SOAM level 4 as described in MEF 30  
571 [43].

572  
573 [R-19] OAM frames, sent at SOAM levels 5, 6, or 7, as described in MEF 30, are sent as  
574 user data and MUST be carried transparently.

575  
576 [R-20] The PE MAY support sending and receiving SOAM frames across the UNI at the  
577 UNI SOAM level 1, as described in MEF 30 [43].

578 See Section 12.4.8 for information on performance monitoring.

### 579 **8.3 MPLS OAM**

580 This section describes techniques to perform OAM for the underlying MPLS tunnels used to  
581 support Ethernet services. OAM is an important and fundamental functionality in an MPLS  
582 network. OAM contributes to the reduction of operational complexity, by allowing for efficient  
583 and automatic detection, localization, handling and diagnosis of defects. OAM functions, in  
584 general, are used for fault-management, performance monitoring, and protection-switching  
585 applications.

#### 586 **8.3.1 LSP OAM**

587 This section describes techniques to perform OAM for the underlying MPLS LSPs used in an  
588 EVPN application.

589

590 LSP-Ping and Bidirectional Forwarding Detection (BFD) RFC 5880 [32] are OAM mechanisms  
591 for MPLS LSPs RFC 5884 [34]. Further it is desirable that the OAM traffic is sent in-band in an  
592 LSP. The following OAM mechanisms are supported:

593

594 [R-21] The PE MAY support GAL and G-ACh per LSP, as per RFC 5586 [31].

##### 595 **8.3.1.1 BFD for MPLS LSPs**

596 BFD monitors the integrity of the LSP for any loss of continuity defect. In particular, it can be  
597 used to detect a data plane failure in the forwarding path of an MPLS LSP.

598

599 [R-22] PE and P routers MUST support BFD for MPLS LSPs as per RFC  
600 5884 [34].

##### 601 **8.3.1.2 Detecting MPLS Data Plane Failures**

602 LSP Ping is used to perform on-demand Connectivity Verification (CV) and Route Tracing  
603 functions. It provides two modes: "ping" mode and "traceroute" mode.

604 In "ping" mode (basic connectivity check), the packet should reach the end of the path, at which  
605 point it is sent to the control plane of the egress LSR, which then verifies whether it is indeed an  
606 egress for the FEC.

607

608 [R-23] PE and P routers MUST support "ping" mode as per RFC 4379 [22].

609

610 RFC 6424 [35] enhances the mechanism for performing Label Switched Path Ping (LSP Ping)  
611 over MPLS Tunnels and when LSP stitching [RFC5150] is in use.

612

613 [R-24] PE and P routers MUST support enhanced MPLS ping and traceroute as per RFC  
614 6424 [35].

615

616 In "traceroute" mode (fault isolation), the packet is sent to the control plane of each transit LSR,  
 617 which performs various checks that it is indeed a transit LSR for this path; this LSR also returns  
 618 further information that helps check the control plane against the data plane.

619  
 620 [R-25] PE and P routers SHOULD support "traceroute" mode as per RFC 4379 [22].

621  
 622 The LSP Ping Reply modes as defined in Section 3/RFC 4379 [22] apply as shown in  
 623 Table 1.

624  
 625

Reply Mode	Echo request	Echo Reply
Reply via an IPv4/IPv6 UDP packet (code value 2)	MUST	MUST
Reply via application level control channel (code value 4)	MAY	MAY

626

627 **Table 1 LSP Ping Reply Modes**

628

629 The following subsections of Section 3.2/RFC 4379 [22] concerning Target FEC Stack apply as  
 630 follows:

631

632 [R-26] When LDP is supported - LDP IPv4 prefix as defined in Section 3.2.1/RFC 4379  
 633 [22] MUST be supported.

634

635 [R-27] When RSVP is supported - RSVP IPv4 LSP as defined in Section 3.2.3/RFC 4379  
 636 [22] MUST be supported.

637

638 [R-28] When BGP is supported – BGP-labeled IPv4 prefix as defined in Section  
 639 3.2.11/RFC 4379 [22] MUST be supported.

640

641 [R-29] When LDP is supported - LDP IPv6 prefix as defined in Section 3.2.2/RFC 4379  
 642 [22] SHOULD be supported.

643

644 [R-30] When RSVP is supported - RSVP IPv6 LSP as defined in Section 3.2.4/RFC 4379  
 645 [22] SHOULD be supported.

646

647 [R-31] When BGP is supported – BGP-labeled IPv6 prefix as defined in Section  
 648 3.2.12/RFC 4379 [22] SHOULD be supported.

### 649 **8.3.2 Convergence**

650 This section specifies the requirements for the recovery mechanisms from PE to CE network (AC  
 651 link) failures. The recovery procedures are described in Section 17/RFC 7432 [39].

652

653 [R-32] The PE routers MUST support recovery from PE to CE network failures (AC link  
 654 failures) as per Section 17.3/RFC 7432 [39].

655

656 [R-33] The PE routers MUST support recovery from PE failures as per Section 17.2/RFC  
657 7432 [39].  
658  
659

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## 660 9 QoS

661 The MPLS network supporting the Carrier Ethernet services has to provide QoS and service level  
662 agreements. The QoS capabilities must be end-to-end, which includes both ACs and MPLS  
663 domains. Usually an MPLS network will support guaranteeing sufficient bandwidth if available to  
664 support new and existing Carrier Ethernet connections conforming to all SLA metrics including  
665 protection mechanisms.

666  
667 DiffServ-TE classes of service is used to support MEF 23.1 [45] “CoS Labels” to achieve a  
668 particular level of performance. MPLS DiffServ-TE enables the advantages of both DiffServ and  
669 TE. The DiffServ-TE requirement is to make separate bandwidth reservations for different classes  
670 of traffic. RFC 3564 [14] provides the concept of a class type (CT).

671  
672 The following capabilities are to be supported by the PEs:

- 673
- 674 [R-34] The PE MUST support at least 4 CoS and associated service metrics (e.g. delay,  
675 delay variation, packet loss) as defined in MEF 22.1 [44] “EVC Requirements”.
  - 676
  - 677 [R-35] The PE SHOULD support Connection Admission Control to guarantee sufficient  
678 bandwidth is available to support new connection conforming to all SLA metrics defined in  
679 MEF 10.2 [42].
  - 680
  - 681 [R-36] The PE SHOULD support Differentiated Service aware MPLS traffic engineering  
682 as per RFC 4124 [19].
  - 683
  - 684 [R-37] The ingress PE MUST map the PCP (in the PRI field of the 802.1Q VLAN tag  
685 IEEE 802.1Q [6]) into the TC field of the MPLS label stack.

### 686 9.1 Tunnel CoS mapping and marking

687 Two types of LSPs are defined in RFC 3270 [11]:

- 688
- 689 [R-38] The PE and P routers MUST support E-LSP as per Section 1.2/RFC 3270 [11]:  
690 LSPs which can transport multiple Ordered Aggregates, so that the TC field of the MPLS  
691 Shim Header conveys to the LSR the PHB to be applied to the packet (covering both  
692 information about the packet's scheduling treatment and its drop precedence).
  - 693
  - 694 [R-39] The PE and P routers MAY support L-LSP as per Section 1.3/RFC 3270 [11]: LSPs  
695 which only transport a single Ordered Aggregate, so that the packet's scheduling treatment  
696 is inferred by the LSR exclusively from the packet's label value while the packet's drop  
697 precedence is conveyed in the TC field of the MPLS Shim Header.
  - 698
  - 699 [R-40] The PE MUST support COS marking in the TC bits of the LSP labels.
  - 700
  - 701 [R-41] The PE MUST support the Pipe model as per RFC 3270 [11].
- 702  
703



## 704 **10 PSN resiliency**

705 In EVPN, the PEs are connected over an underlying PSN infrastructure. For EVPN resiliency, the  
706 PSN must necessarily be resilient. When the PEs are connected by an MPLS infrastructure then  
707 the resiliency mechanisms in MPLS such as fast reroute (FRR) are required. This section lists the  
708 resiliency requirements for MPLS. If the MPLS infrastructure is run over another layer (e.g. a L1  
709 network) the resiliency requirements of the other layers are considered to be outside the scope of  
710 this section. When resiliency mechanisms are available at multiple layers the resiliency  
711 mechanism at a layer must be triggered only after a sufficient delay to let the resiliency mechanism  
712 of the underlying layer to take effect.

713  
714 MPLS resiliency requires failure detection mechanisms and LSP recovery mechanisms. To speed  
715 up total recovery time, local-repair mechanisms with pre-computed, pre-established  
716 alternate/backup paths should be used whenever possible. Section 10.1 lists the failure detection  
717 requirements and Section 10.2 lists the requirements for LSP recovery.

718  
719 MPLS resiliency is also affected by the restart of control-plane protocols. The MPLS requirements  
720 to support resiliency of control protocols are listed in Section 10.3.

### 721 **10.1 Failure detection**

722 The failure detection mechanism that triggers the recovery mechanisms should have a low failure  
723 detection time and also a low overhead. In order for the deployment to allow a choice of routing  
724 protocols, the failure detection mechanism should be independent of specific routing protocols.  
725 The Bidirectional Forwarding Detection (BFD) protocol specified in RFC 5880 [32] provides such  
726 a mechanism. For MPLS LSP BFD requirements see Section 8.3.1.

727  
728 [R-42] The PE and P routers **MUST** support BFD for single hops as per RFC 5881 [33]

### 729 **10.2 LSP recovery**

730 The LSP recovery mechanism should support local repair mechanisms with pre-computed and pre-  
731 established alternate/backup paths for both RSVP-TE RFC 3209 [10] and LDP RFC 5036 [25]  
732 signaled LSPs. Recovery from different types of failure such as link, node, etc. should be  
733 supported.

734  
735 [R-43] The PE and P routers **MUST** support the facility backup method of doing fast  
736 reroute (FRR) for RSVP-TE LSP Tunnels as per RFC 4090 [18].

737  
738 [R-44] The PE and P routers **SHOULD** support the one-to-one backup method of doing  
739 fast reroute (FRR) for RSVP-TE LSP Tunnels as per RFC 4090 [18].

740  
741 [R-45] The PE and P routers **MUST** support the loop-free alternates (LFA) method of FRR  
742 for LDP LSPs as per RFC 5286 [29] as well as support LFA FRR for the IGP on whose  
743 routes LDP depends.

744

### 745 10.3 Control plane resiliency

746 To prevent LSPs from going down due to control-plane protocols restart, the graceful restart  
747 control-plane resiliency mechanism is required.

748

749 [R-46] The PE and P routers **MUST** support RSVP-TE graceful restart as specified in  
750 Section 9/RFC 3473 [12] as well as graceful restart for the routing protocols on which  
751 RSVP-TE path computation depends.

752

753 [R-47] The PE and P routers **MUST** support LDP graceful restart as specified in RFC 3478  
754 [13] as well as graceful restart for the routing protocols on whose routes LDP depends.

755

756 [R-48] The PE and P routers **SHOULD** support OSPF graceful restart as specified in RFC  
757 3623 [15].

758

759 [R-49] The PE and P routers **SHOULD** support IS-IS graceful restart as specified in RFC  
760 5306 [17].

761

762

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## 763 **11 BGP MPLS-Based Ethernet VPN**

764 This section covers the generic BGP MPLS-based Ethernet VPN requirements. Specific  
765 requirements such as multicast that are applicable to a subset of Ethernet VPN services (e.g. EP-  
766 LAN, EVP-LAN, etc) are covered in subsequent sections.  
767

768 EVPN overcomes the limitations of current E-Line and E-LAN services supported by VPLS (RFC  
769 4761 [23], RFC 4762[24]) and VPWS. EVPN provides flexible multi-homing with all-active  
770 redundancy mode, MAC learning using control plane, multicast optimization, provisioning  
771 simplicity and network resiliency between edge nodes.  
772

773 The EVPN specification supports several ways for PE nodes to connect, but this TR only supports  
774 use of MPLS, which enable easy interworking with TR-224 [4] based Ethernet services.

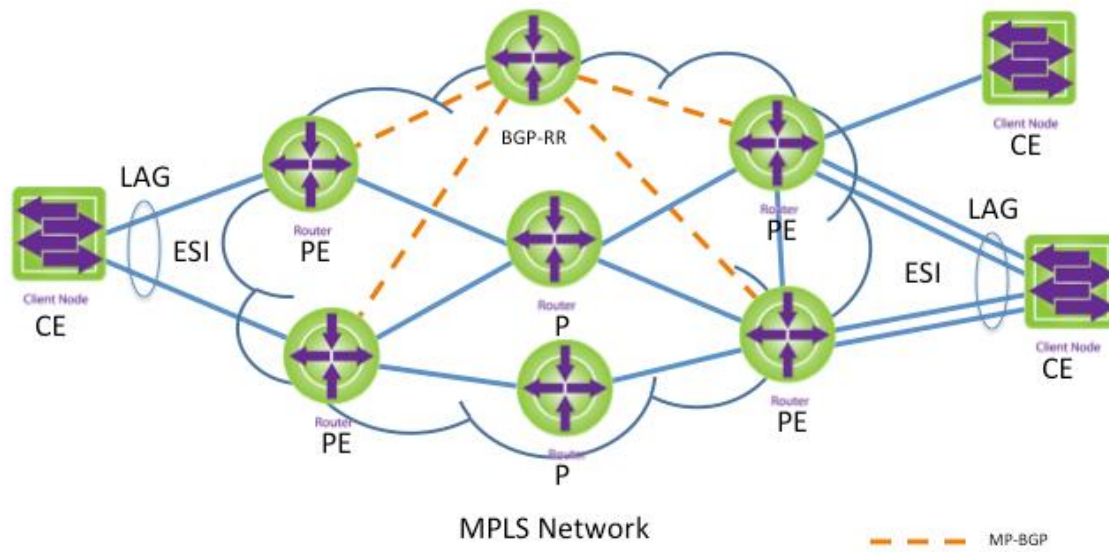
### 775 **11.1 Reference Architecture and Overview**

776 Figure 3 describes EVPN for the next-generation of Ethernet services. An EVPN instance  
777 comprises of CEs connected to PEs, which are part of the MPLS network. The PEs provide virtual  
778 Layer 2 bridge connectivity between CEs. The PEs are connected by an underlying MPLS  
779 network that provides QoS and resiliency.  
780

781 Unlike VPLS, which uses only data-plane based MAC learning, EVPN uses the control plane  
782 based MAC learning for remote MACs. EVPN uses MP-BGP to distribute MAC routes and  
783 allows fine-grained control over MAC route distribution.  
784

785 EVPN instance (EVI) is an EVPN routing and forwarding instance on a PE. If a CE is multi-  
786 homed to two or more PEs, the set of Ethernet links constitute an Ethernet Segment (ES). Each  
787 Ethernet Segment is identified using a unique Ethernet Segment identifier (ESI). For additional  
788 details see RFC 7432 [39].  
789

790

791  
792  
793

**Figure 3 EVPN Architecture for Ethernet services using BGP MPLS**

## 794 11.2 EVPN Service Interfaces

795 EVPN defines several types of service interfaces. See Section 6/RFC 7432 [39] for details. These  
796 service interfaces are consistent with MEF-defined services and provide easy migration to EVPN  
797 infrastructure for even richer service offerings. The various types of service interfaces include  
798 mapping of specific VLANs or their bundles and even allow service awareness when they are  
799 mapped to EVPN instances. The requirements for the support of various service interfaces are  
800 specified in the subsections of the respective services.

### 801 11.2.1 VLAN-Based Service Interfaces

802 This service interface supports a single broadcast domain or VLAN per-EVPN instance.  
803 This service interface can be used to support E-LAN or E-Line for a single broadcast domain with  
804 customer VLANs having local significance. Ethernet frames transported over an MPLS network  
805 remain tagged with the originating VID. VID translation can be performed on the destination PE.  
806

### 807 11.2.2 VLAN Bundle Service Interfaces

808 This service interface supports a bundle of VLAN over one EVPN instance. Multiple VLANs  
809 share the same bridge. It supports an N:1 mapping between VLAN ID and MAC-VRF. This  
810 service interface requires that MAC addresses are unique across VLANs of the EVI and VID  
811 translation is not allowed.  
812

813 This service interface also supports a special case known as a port-based VLAN Bundle service  
814 interface, where all the VLANs on a port are part of the same service and map to the same bundle.

### 815 **11.2.3 VLAN-Aware Bundle Service Interfaces**

816 This service interface is an additional service interface defined in EVPN that is not supported by  
817 TR-224 or VPLS. It provides customers with a single E-LAN service for multiple broadcast  
818 domains. With this service interface, an EVPN instance consists of multiple broadcast domains or  
819 VLANs, with each VLAN having its own bridge domain. Like the VLAN bundle service  
820 interface, this interface supports N:1 mapping between VLAN ID and EVI. Since bridge domains  
821 are separate, it allows for local VID translation.

822  
823 This service interface also supports a special case known as a port-based VLAN-Aware bundle  
824 service interface, where all the VLANs on a port are part of the same service and map to the same  
825 bundle.

## 826 **11.3 Data Plane**

### 827 **11.3.1 Underlying PSN transport**

828 [R-50] The PEs MUST support MPLS as the underlying PSN transport as specified in  
829 Section 4/RFC 7432 [39].

### 830 **11.3.2 VPN encapsulation**

831 To distinguish packets received over the PSN destined to different EVPN instances, MPLS labels  
832 must be used as described in Section 4/RFC 7432 [39]. The specific data plane operations  
833 applicable to a service are specified in the subsections of the respective service.

### 834 **11.3.3 VID Translation**

835 [R-51] The PEs MUST support VID translation for packets received from the PSN and sent  
836 to the CE, when supporting service interfaces as specified in Section 6/RFC 7432 [39].

### 837 **11.3.4 Frame Ordering**

838 Section 18/RFC 7432 specifies frame ordering. In order to avoid misordering, it is recommended  
839 that P routers not use deep packet inspection to do ECMP.

840  
841 [R-52] The P routers SHOULD NOT do deep packet inspection for ECMP. RFC 6790 [36]  
842 specifies techniques so that P routers do effective load balancing without the need for deep  
843 packet inspection.

844

## 845 **11.4 Control Plane**

846 The EVPN PEs signal and learn MAC address over the control plane. RFC 7432 adds BGP  
847 extended communities, which allow PE routers to advertise and learn MAC addresses and Ethernet  
848 segments. This is one of the major differences with the VPLS solution, which relies on data-plane  
849 learning. EVPN added four Route types and communities. For additional details see RFC 7432  
850 [39].

851  
852 [R-53] The PEs MUST support MP-BGP as a control protocol for EVPN as specified in  
853 Section 4 and 7/RFC 7432 [39].

854  
855 Note: The detailed control protocol requirements of MP-BGP are specified in the  
856 subsections of the respective services.

857  
858 With MPLS data plane, BGP routes also signal the MPLS labels associated with MAC addresses  
859 and Ethernet segments. This separates EVPN from a VPLS solution. EVPNs do not use  
860 Pseudowires.

## 861 11.5 Multi-Homing and Load balancing

862 Due to rapid increase of data traffic, running the network in active/standby mode can be  
863 inefficient. In addition to better link utilization, multi-homed connections also offer greater  
864 resiliency and reliability against the failure of one connection or node. Multi-homing includes the  
865 ability of establishing multiple connections between PEs and to load-balance across those  
866 connections. For additional details on multi-homing see Section 8/RFC 7432 [39]. EVPNs  
867 supports both single-active and all-active multi-homing with load balancing. VPLS only supports  
868 single-active multi-homing.

869  
870 With support for both all-active per-service and all-active per-flow multi-homing, EVPNs enables  
871 better load balancing across peering PEs as compared to VPLS that cannot load balance across  
872 peering PEs.

873  
874 It must be possible to connect a CE to two or more PEs for purposes of multi-homing and load  
875 balancing as specified in Section 8 and 14/RFC 7432 [39].

### 876 11.5.1 All-Active Redundancy Mode

877 All-active redundancy mode allows the CE device to connect via a “single” Ethernet bundle to  
878 multiple PEs using LAG. All the PEs must be allowed to forward traffic to/from that Ethernet  
879 Segment.

880  
881 [R-54] PE router MUST support “All-Active redundancy mode” as specified in Section  
882 14/RFC 7432 [39].

883

### 884 11.5.2 Single-Active Redundancy Mode

885 In this mode, when a CE is connected to two or more PEs over an Ethernet segment, only a single  
886 PE must be allowed to forward traffic to/from that Ethernet Segment. In this mode the CE device  
887 connect via “separate” Ethernet bundles to multiple PEs.  
888

889 [R-55] PE router MUST support “Single-Active redundancy mode” as specified in Section  
890 14/RFC 7432 [39].

## 891 11.6 Fast Convergence

892 Section 17/RFC 7432 provides failure recovery from different types of network failures. VPLS  
893 relies on the underlying MPLS capabilities such as Fast Reroute. Lack of all-active multi-homing  
894 in VPLS makes it difficult to achieve fast restoration in case of an edge node or edge link failure.  
895

896 [R-56] The PEs MUST support convergence as specified in Section 17/RFC 7432 [39].  
897  
898

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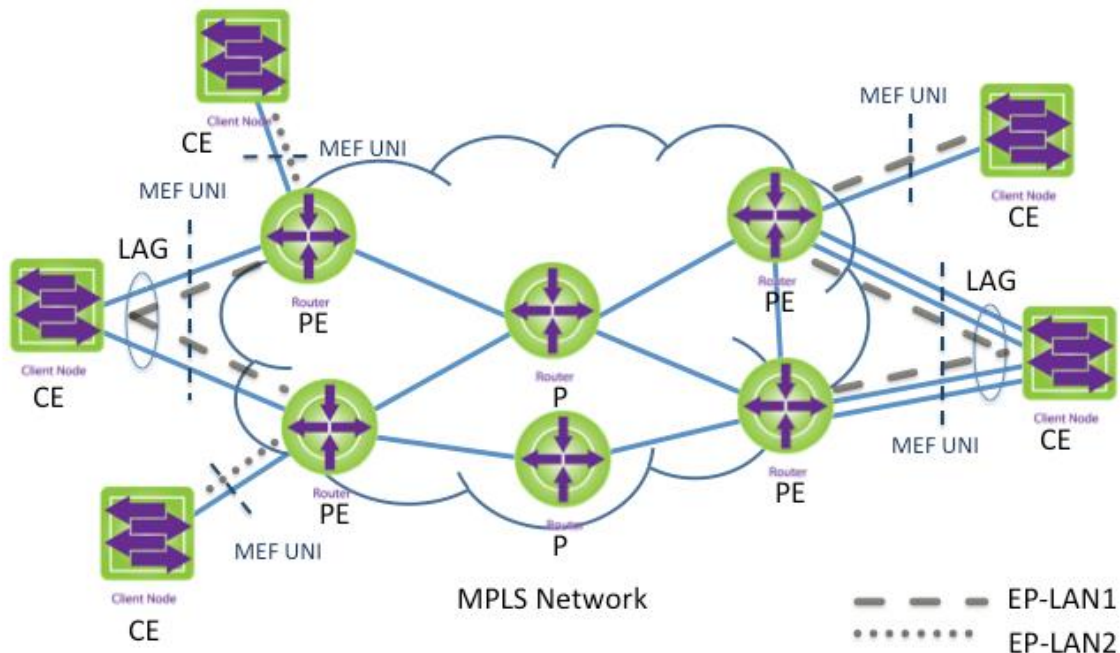
899 **12 EVPN enabled multipoint to multipoint Ethernet VPN services (E-LAN)**

900 The EVPN technology enables the creation of multipoint-to-multipoint Ethernet VPN services  
 901 over an MPLS network. EVPN can be used to create the EP-LAN and EVP-LAN services of the  
 902 E-LAN service type defined by MEF 6.2. A high-level reference architecture of how these  
 903 services are architected using EVPN along with the list of the supported service attributes is  
 904 described in Section 12.1 and 12.2. In addition to the Carrier Ethernet defined service  
 905 characteristics, EVPN significantly enhances important service characteristics such as reliability  
 906 and scalability. The EVPN requirements for multipoint-to-multipoint Ethernet VPN services are  
 907 listed in Section 12.3.

908 **12.1 Ethernet Private LAN (EP-LAN)**

909 The Ethernet Private LAN (EP-LAN) service uses a multipoint-to-multipoint EVC. In a  
 910 multipoint EVC, two or more UNIs must be associated with one another. The EP-LAN service is  
 911 defined to provide CE-VLAN tag preservation and tunneling of key Layer 2 control protocols. A  
 912 key advantage of this service is that VLANs can be configured across the sites without any need to  
 913 coordinate with the service provider.  
 914

915 EP-LAN provides connectivity to customers with multiple sites, such that all sites appear to be on  
 916 the same local area network. Each interface is configured for “All to One Bundling”. EP-LAN  
 917 supports CE-VLAN CoS preservation. Service multiplexing is disabled on the UNI.  
 918  
 919



920 **Figure 4 Ethernet Private LAN (EP-LAN) Service**

921  
 922  
 923



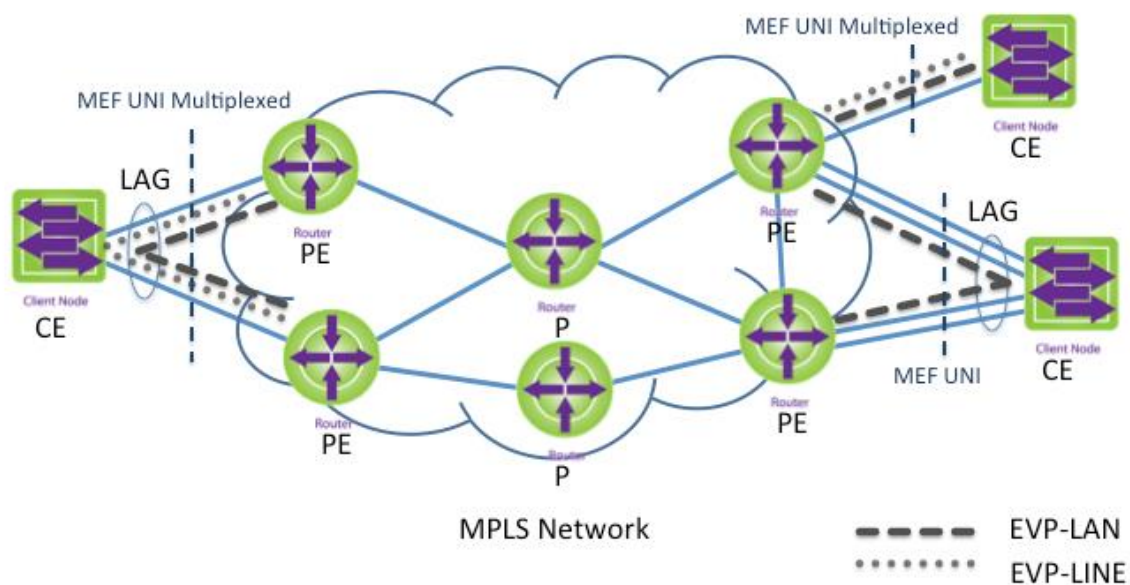
## 924 12.2 Ethernet Virtual Private LAN (EVP-LAN)

925 The Ethernet Virtual Private LAN (EVP-LAN) service allows service multiplexing at the UNI. It  
 926 allows users of an E-LAN service type to interconnect their UNIs and at the same time access  
 927 other services (e.g. E-Line). Figure 5 shows an example of multiple services access from a single  
 928 UNI. In this example, the user has an EVP-LAN service for multipoint data connectivity and an  
 929 EVPL service (P2P EVC) for accessing a value-add service from one of the UNIs.

930

931 Bundling can be used on the UNI in the EVP-LAN service and supports CE-VLAN tag  
 932 preservation. All to One Bundling is disabled.

933



934

935 **Figure 5 Ethernet Virtual Private LAN (EVP-LAN) Service**

936

## 937 12.3 EVPN for establishing EP-LAN and EVP-LAN

938 Section 5 provides an overview of PPVPN in MPLS networks. It also outlines the comparison of  
 939 Layer 2 Ethernet VPNs in MPLS networks using VPLS and EVPNs.

940

941 EVPN provides support for the E-LAN service type in MPLS networks as described in Section 11.  
 942 RFC 7432 describes procedures for BGP MPLS-based Ethernet VPNS. EVPN requires extensions  
 943 to existing IP/MPLS protocols. EVPN supports both provisioning and signaling for Ethernet  
 944 VPNs and incorporate flexibility for service delivery over Layer 3 networks.

945

946 The PE supports BGP MPLS-based Ethernet VPN signaling and provisioning as specified in [R-  
 947 53] of Section 11.4.

948

## 949 **12.3.1 Service Interfaces**

950 EVPN supports several service connectivity options for delivering MEF services. They are  
951 provided in Section 11.2. MEF service requirements for EP-LAN and EVP-LAN are different.  
952 For EP-LAN, each interface is configured for “All to One Bundling”. For EVP-LAN “All to One  
953 Bundling” is disabled. VLAN-Aware Bundle service interface is not supported in VPLS-based  
954 implementation (TR-224). When interworking with TR-224, it is recommended not to use VLAN-  
955 Aware Bundle service interface. This service interface provides a more flexible service offering  
956 and is commonly used for data center interconnect.

### 957 **12.3.1.1 Service Interfaces for EP-LAN**

958 [R-57] The PE routers **MUST** support Port-based Service Interface as defined in Section  
959 6.2.1/RFC 7432 [39].

960

961 [R-58] The PE routers **SHOULD** support Port-Based VLAN-Aware Service Interface as  
962 defined in Section 6.3.1/RFC 7432 [39].

#### 963 **12.3.1.1.1 Data Center Considerations**

964 If the PE router is designed for use in a data center interconnect environment, the following  
965 requirement is applicable:

966

967 [R-59] The PE routers **MUST** support Port-Based VLAN-Aware Service Interface as  
968 defined in Section 6.3.1/RFC 7432 [39].

### 969 **12.3.1.2 Service Interfaces for EVP-LAN**

970 [R-60] The PE routers **MUST** Support VLAN-based Service Interface as defined in Section  
971 6.1/RFC 7432 [39].

972

973 [R-61] The PE routers **MUST** support VLAN Bundle Service Interface as defined in  
974 Section 6.2/RFC 7432 [39]

975

976 [R-62] The PE routers **SHOULD** support VLAN-Aware Bundle Service Interface as  
977 defined in Section 6.3/RFC 7432 [39].

#### 978 **12.3.1.2.1 Data Center Considerations**

979 If the PE router is designed for use in a data center interconnect environment, the following  
980 requirement is applicable:

981

982 [R-63] The PE routers **MUST** support VLAN-Aware Bundle Service Interface as defined  
983 in Section 6.3/RFC 7432 [39].

984

985

## 986 **12.3.2 Data plane**

987 The requirements for data plane per Section 11.3 are applicable.

### 988 **12.3.2.1 Local learning**

989 [R-64] The PE MUST be able to do data-plane learning of MAC addresses using IEEE  
990 Ethernet learning procedures for packets received from the CEs connected to it as specified  
991 in Section 9.1/RFC 7432 [39].

### 992 **12.3.2.2 Remote learning**

993 [R-65] The PE MUST be able to do control-plane learning of MAC addresses using MP-  
994 BGP's MAC Advertisement route for CEs that are connected to remote PEs as specified in  
995 Section 9.2/RFC 7432 [39].

## 996 **12.3.3 Tunnel signaling**

997 The PEs are connected by MPLS Label Switch Paths (LSPs) acting as PSN tunnels. Traffic  
998 Engineered PSN tunnels must be used when specific path (e.g. for protection purpose), QoS, or  
999 bandwidth constraints are required.

1000

1001 [R-66] PE and P routers MUST support dynamic signaling to setup both TE LSPs and  
1002 routed LSPs. See Section 7.1 for details.

## 1003 **12.3.4 Routing**

1004 The requirements for routing per Section 7.2 are applicable.

## 1005 **12.3.5 Multi-Homing and Load balancing**

1006 The requirements for multi-homing and load balancing per Section 11.5 are applicable.

### 1007 **12.3.5.1 Load balancing at intermediate nodes**

1008 When load balancing, packets that belong to a given 'flow' must be mapped to the same port.

1009 Intermediate P nodes have no information about the type of the payload inside the LSP.

1010 Intermediate LSR should make a forwarding choice based on the MPLS label stack. In order to  
1011 avoid any mis-ordering of frames, the requirements specified in Section 11.3.4 apply.

1012

1013 The PE that has knowledge of the Ethernet service (e.g. Bundling or multiclass service) can take  
1014 further action. IETF RFC 6790 [36] provide methods of assigning labels to flows, or flow groups,  
1015 such that Label Switching Routers can achieve better load balancing.

1016

1017 [R-67] The PE SHOULD support Entropy Labels as per RFC 6790 [36].

1018

1019  
1020  
1021

## 1022 **12.3.6 OAM**

### 1023 **12.3.6.1 Ethernet Link OAM**

1024 The Ethernet link OAM is supported as per Section 8.1.1.

### 1025 **12.3.6.2 Label Switched Paths (LSP) OAM**

1026 LSP OAM is supported as per Section 8.3.1.

### 1027 **12.3.6.3 MEF Service OAM**

1028 MEF service is supported as per Section 8.1.2.

## 1029 **12.3.7 Convergence**

1030 Failure recovery from different types of network failure is supported as per Section 8.3.2.

## 1031 **12.3.8 PSN Resiliency**

1032 PSN resiliency is supported as per Section 10.

1033

### 1034 **12.3.8.1 Fast Convergence**

1035 Fast convergence is supported as per Section 11.6.

## 1036 **12.3.9 Multicast and Broadcast**

1037 [R-68] PE routers SHOULD support multicast and broadcast traffic as per Section 16/RFC  
1038 7432 [39].

## 1039 **12.3.10 QoS**

1040 In general, an E-LAN service type can provide a best effort service with no performance  
1041 assurance. In certain cases, an E-LAN service type can be defined with performance objectives  
1042 (see Section 9.2/MEF 6.2 [50].

1043

1044 [R-69] PE routers SHOULD support the QoS mapping as per Section 9.

## 1045 **12.3.11 Security**

1046 [R-70] PE routers MUST support security as per Section 19/RFC 7432 [39].

## 1047 12.4 Support of service attributes for EP-LAN and EVP-LAN

1048 Section 9.2/MEF 6.2 [50] specifies the E-LAN service type that is the basis for LAN services.  
1049 Section 10.3 and 10.4/MEF 6.2 [50] provides service attributes and parameters for EP-LAN and  
1050 EVP-LAN services respectively. TR-224 refers to MEF 6.1 and MEF 10.2. TR-350 uses the  
1051 backward compatible subset of the revised specifications MEF 6.2 [50] (see Appendix B) and  
1052 MEF 10.3 [49] to achieve the equivalent function.

1053  
1054 Some of the service attributes and parameters are provided by Ethernet physical interface and  
1055 service provisioning (e.g., Physical medium, Speed, Mode, MAC layer, EVC type, maximum  
1056 number of EVCs, etc.). This section only describes those service attributes and parameters that are  
1057 relevant to transporting the EVPN traffic over PSN.

### 1058 12.4.1 Bandwidth Profile

1059 A bandwidth profile defines how rate enforcement of Ethernet frames is applied at an UNI.  
1060 Bandwidth profiles enable offering service bandwidth below the UNI access speed (aka Speed)  
1061 and limit the amount of traffic entering the network per the terms of the SLA.

1062  
1063 For LAN services, bandwidth profiles can be optionally specified per-UNI (ingress and egress),  
1064 per-EVC (ingress and egress), and/or per CoS (ingress and egress). An E-LAN service can be  
1065 provided as a best effort service without any bandwidth guarantee.

1066  
1067 [R-71] A PE SHOULD support the bandwidth profile algorithm as per the portion of  
1068 Section 12/MEF 10.3 [49] that is backward compatible with MEF 10.2 [42].

1069  
1070 In order to support bandwidth profile, technique such as admission control and Diffserv-TE as  
1071 specified in Section 9 are used.

### 1072 12.4.2 Bundling

1073 Section 9.12/MEF 10.3 [49] specifies the bundling service attribute. Bundling implies “A UNI  
1074 attribute in which more than one CE-VLAN ID can be associated with an EVC”. All to one  
1075 bundling enabled is a special case of bundling. It implies “A UNI attribute in which all CE-VLAN  
1076 IDs are associated with a single EVC”. Table 12/MEF 10.3 [49] provides valid combinations for  
1077 “All to one bundling” and “Service multiplexing” attributes.

1078  
1079 EP-LAN must have “All to one bundling” attribute enabled. For EVP-LAN the bundling attribute  
1080 can be enabled or disabled. However, for EVP-LAN “All to one bundling” must be disabled.

1081

### 1082 12.4.3 CE-VLAN ID preservation for EVC

1083 CE-VLAN ID preservation service attribute defines whether the CE-VLAN ID is preserved  
1084 (unmodified) across the EVC.

1085  
1086 For EP-LAN, CE-VLAN ID preservation must be enabled and CE-VLAN ID is preserved for EVC  
1087 over the PSN.

1088  
1089 For EVP-LAN, if CE-VLAN ID preservation is enabled, CE-VLAN ID is preserved for EVC over  
1090 the PSN.

1091  
1092 Note: If CE-VLAN ID preservation is enabled, No VID translation is supported for the EVC.  
1093 EVP-LAN can support VID translation when using EVPN service type “VLAN-Based Service  
1094 type” and “VLAN-Aware Bundle service interface”.

#### 1095 **12.4.4 CE-VLAN CoS preservation for EVC**

1096 CE-VLAN CoS preservation service attribute defines whether the CE-VLAN CoS bits are  
1097 preserved (unmodified) across the EVC.

1098  
1099 For EP-LAN, CE-VLAN CoS preservation must be enabled (see Table 15/MEF 6.2 [50]) and CE-  
1100 VLAN CoS is preserved for EVC over PSN.

1101  
1102 For EVP-LAN, CE-VLAN CoS preservation can be either enabled or disabled (see Table 18/MEF  
1103 6.2). In an EVC with CE-VLAN CoS preservation is enabled, the EVPN preserves the CoS bits  
1104 over PSN.

#### 1105 **12.4.5 EVC Maximum Service Frame Size**

1106 The mapping from “EVC Maximum Service Frame Size” to “EVC MTU” is provided in Table 40  
1107 Appendix B of MEF 6.2 [50].

1108  
1109 The EVC Maximum Service Frame Size size is configurable with a default value of 1600 byte.

1110  
1111 When Ethernet frames are transported in MPLS networks, the MPLS packet includes the labels,  
1112 and the EVC frame as payload. The path MTU is the largest packet size that can traverse this path  
1113 without fragmentation. The ingress PE can use Path MTU Discovery to find the actual path MTU.

1114  
1115 [R-72] PE SHOULD support configurable EVC Maximum Service Frame Size of at least  
1116 1600 bytes (see Table 6/MEF 6.2).

1117  
1118  
1119  
1120

#### 1121 **12.4.6 Frame delivery**

1122 The frame delivery policy rules enable the service provider to specify how different frame types  
1123 are handled by a PE. They enable setting specific rules for forwarding, discarding or conditionally  
1124 forwarding specific frame types. The frame types used by the rules are:

- 1125
- 1126 • Unicast
  - 1127 • Multicast
  - 1128 • Broadcast

1129

[R-73] PE MUST support setting policy function of frame delivery rules for  
1130 forwarding, discarding or conditionally forwarding unicast, multicast and  
1131 broadcast frames per EP-LAN and EVP-LAN services.  
1132

### 1133 **12.4.7 Layer 2 control protocols**

1134 The Layer 2 control protocol processing is independent of the EVC at the UNI. L2CP handling  
1135 rules are set according to the definition of Section 8/MEF 6.1.1 [48] and differ per-service type.  
1136 The PE policy function supports setting of rules for handling L2CP per service type.

1137

1138 EVC L2CP handling per service type can be set to:

- 1139 • Discard – Drop the frame.
- 1140 • Peer can be applicable: For example L2CP/LAMP, Link OAM, Port Authentication, and E-  
1141 LMI.
- 1142 • Tunnel – Pass to the egress UNI.

1143

[R-74] PE MUST support policy function setting of rules for handling L2CP per service  
1144 type as specified in Section 8/MEF 6.1.1 [48].  
1145

1146

1147 Note: This specification only supports MEF 6.1.1 for L2CP processing  
1148 requirements. Support of multiple-CEN L2CP MEF 45 [51] is outside the scope of  
1149 this document.

### 1150 **12.4.8 EVC performance**

1151 The performance parameters indicate the quality of service for that service instance. They consist  
1152 of the following:

- 1153 • Availability
- 1154 • Frame Delay
- 1155 • Frame delay variation
- 1156 • Frame loss ratio

1157

1158 The requirements for support of CoS and mapping are specified in QoS Section 9.  
1159

[R-75] The PE MUST support MEF SOAM performance monitoring as per MEF 35 [47].  
1160

1161

1162 For transport of SOAM see Section 8.2.

1163  
1164  
1165

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## 1166 **13 EVPN enabled point to point Ethernet VPN services (E-Line)**

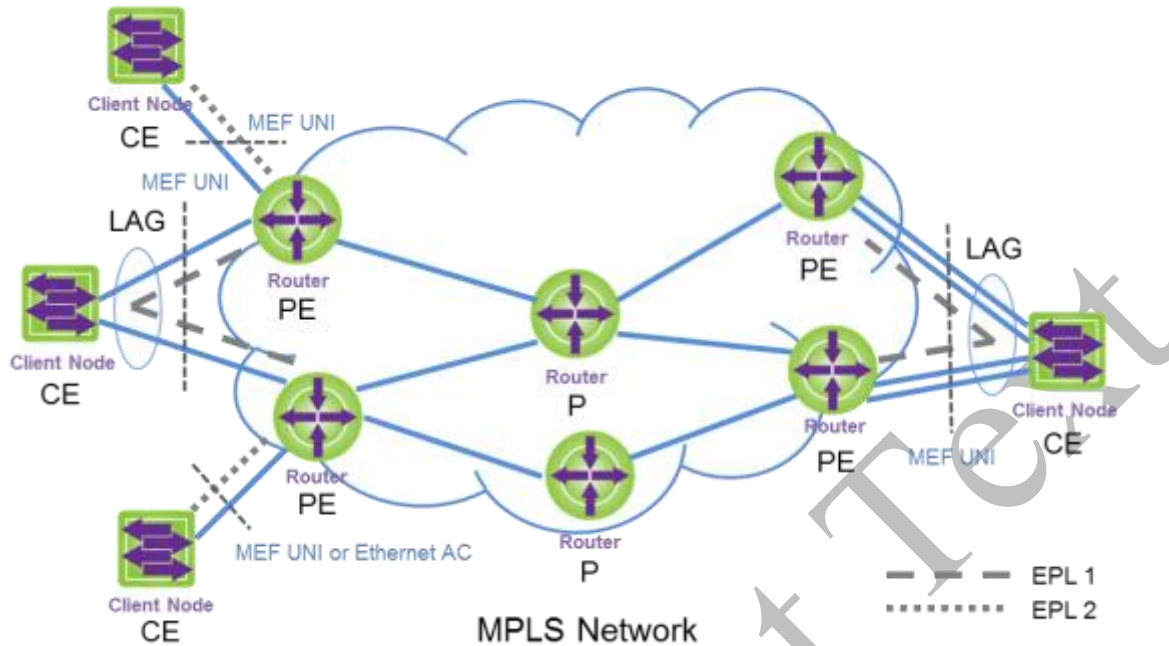
1167 The Ethernet Line service is defined in MEF 6.2 [50] and is based on a point-to-point Ethernet  
1168 Virtual Connection (EVC). Virtual Private Wire Service (VPWS) is a Layer 2 VPN service used  
1169 to emulate the E-Line service type in an MPLS network. draft-ietf-bess-evpn-vpws **Error! R**  
1170 **eference source not found.** describes how EVPN can be used to support VPWS in IP/MPLS  
1171 networks. The use of EVPN mechanisms for VPWS brings the benefits of EVPN to point-to-point  
1172 services. EVPN can be used to create the Ethernet Private Line (EPL) and Ethernet Virtual Private  
1173 Line (EVPL) services of the E-Line service type defined by MEF 6.2 [50].  
1174

1175 A high-level reference architecture of how these services are architected using EVPN along with  
1176 the list of the supported service attributes is described in Section 13.1 and 13.2. In addition to the  
1177 Carrier Ethernet-defined service characteristics, EVPN significantly enhances important service  
1178 characteristics such as reliability and scalability. The EVPN-VPWS requirements for point-to-  
1179 point Ethernet VPN services are listed in Section 13.3.

### 1180 **13.1 Ethernet Private Line (EPL)**

1181 Ethernet Private Line (EPL), uses a point-to-point EVC between two UNIs to provide a high  
1182 degree of transparency for service frames between UNIs it interconnects. The service frames,  
1183 headers, and most Layer 2 protocols are identical at both the source and destination UNI. It does  
1184 not allow for service multiplexing; that is, a dedicated UNI (physical interface) is used for the  
1185 EPL. The figure below shows EPL service.  
1186

1187 A key advantage of this service is that VLANs can be configured across the sites without any need  
1188 to coordinate with the service provider. Each interface is configured for “All to One Bundling”.  
1189 EPL supports CE-VLAN CoS preservation. For cases where an ingress bandwidth profile is  
1190 applied, the CE is expected to shape traffic.  
1191  
1192



**Figure 6 Ethernet Private Line (EPL) Service**

1193  
1194  
1195  
1196  
1197  
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1200  
1201  
1202

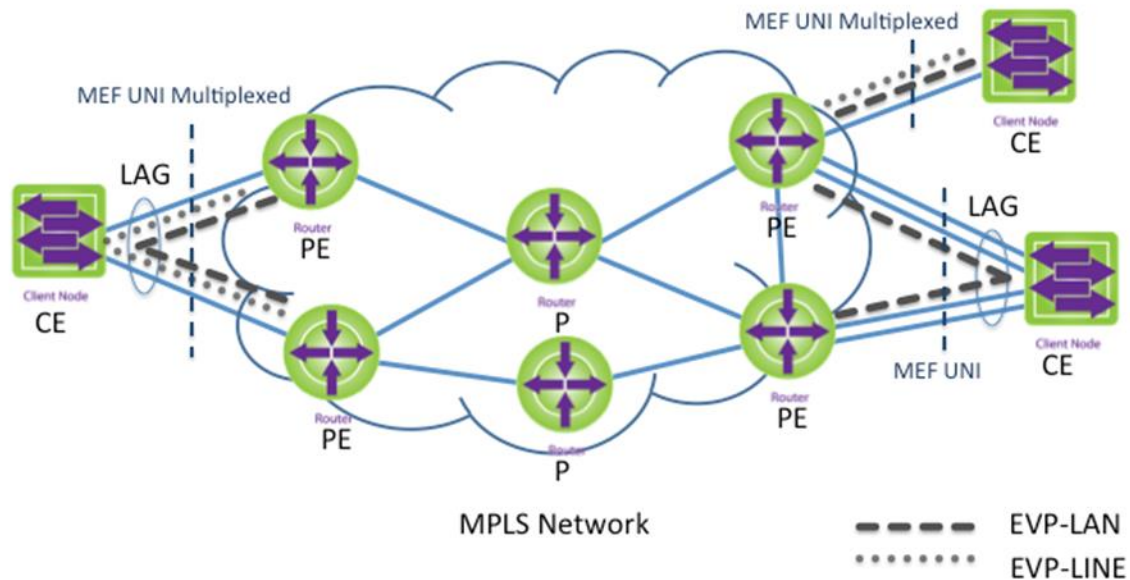
Ethernet Private Line (EPL):

- It replaces a TDM private line
- Dedicated UNIs for Point-to-Point connections
- Single Ethernet Virtual Connection (EVC) per UNI
- The most popular Ethernet service type due to its simplicity

### 1203 13.2 Ethernet Virtual Private Line (EVPL)

1204 Ethernet Virtual Private Line (EVPL) uses a point-to-point EVC between two UNIs, but does not  
1205 provide full transparency as with the EPL service. The EVPL service also allows for service  
1206 multiplexing, which means that more than one EVC can be supported at the UNI. Because service  
1207 multiplexing is permitted, some service frames may be sent to one EVC, while other service  
1208 frames may be sent to other EVCs. The service definition for EVPL is specified in Section  
1209 10.1/MEF 6.2 [50].

1210  
1211 EVPL is commonly used for connecting subscriber hub and branch locations. It allows users of an  
1212 E-Line service type to interconnect their UNIs and at the same time access other services (e.g. E-  
1213 LAN). Figure 7 shows an example of multiple services access from a single UNI. In this example,  
1214 the user has an EVP-LAN service for multipoint data connectivity and an EVPL service (P2P  
1215 EVC) for accessing a value-add service from one of the UNIs. Bundling can be used on the UNI  
1216 in the EVPL service and supports CE-VLAN tag preservation. All to One Bundling is disabled.



1217  
1218

Figure 7 Ethernet Virtual Private Line (EVPL) Service

### 1219 13.3 EVPN for establishing EPL and EVPL

1220 VPWS support in EVPN draft-ietf-bess-evpn-vpws **Error! Reference source not found.** describes how  
 1221 how EVPN can be used to support VPWS in IP/MPLS networks. EVPN enables the following  
 1222 service capabilities: single-active as well as all-active multi-homing; flow-based load balancing;  
 1223 and policy. It eliminates the need for PWs for point-to-point Ethernet services. EVPN has the  
 1224 ability to forward customer traffic at the PE without any MAC lookup because the MPLS label  
 1225 associated with the EVI is used. EVPL can be considered as a VPWS with only two-attachment  
 1226 circuits (AC) or MEF-UNIs. For additional details see draft-ietf-bess-evpn-vpws **Error! R**  
 1227 **eference source not found..**

1228

1229 RFC 7432 [39] describes procedures for BGP MPLS-based Ethernet VPNs. EVPN requires  
 1230 extensions to existing IP/MPLS protocols. EVPN supports both provisioning and signaling for  
 1231 Ethernet VPNs and incorporates flexibility for service delivery over Layer 3 networks.

1232

1233

1234 The PE supports BGP MPLS-based Ethernet VPN signaling and provisioning as specified in  
 1235 requirement [R-53] of Section 11.4.

#### 1236 13.3.1 Service Interfaces

1237 EVPN-VPWS supports several service connectivity options for delivering MEF services. They are  
 1238 provided in Section 2/draft-ietf-bess-evpn-vpws **Error! Reference source not found..** This s  
 1239 ervice does not use “VLAN-Aware Bundle Service interface”. .

1240

1241 MEF service requirements for EPL and EVPL are different. For EPL, each interface is configured  
1242 for “All to One Bundling”. For EVPL “All to One Bundling” is disabled.

### 1243 13.3.1.1 Service Interfaces for EPL

1244 [R-76] The PE routers MUST support Port-based Service Interface as defined in Section  
1245 6.2.1/RFC 7432 [39].  
1246

### 1247 13.3.1.2 Service Interfaces for EVPL

1248 [R-77] The PE routers MUST Support VLAN-based Service Interface as defined in Section  
1249 2.1/draft-ietf-bess-evpn-vpws **Error! Reference source not found..**

1250  
1251 [R-78] The PE routers MUST support VLAN Bundle Service Interface as defined in  
1252 Section 2.2/draft-ietf-bess-evpn-vpws **Error! Reference source not found..**  
1253

## 1254 13.3.2 Operation

1255 PE routers must support point to point deployments as defined in Section 4/draft-ietf-bess-evpn-  
1256 vpws **Error! Reference source not found..**

## 1257 13.3.3 Data Plane

1258 The requirements for data plane per Section 11.3.1 and 11.3.2 are applicable.

### 1259 13.3.3.1 Local learning

1260 The requirements for local learning per Section 12.3.2.1 are applicable.

### 1261 13.3.3.2 Remote learning

1262 The requirements for remote learning per Section 12.3.2.2 are applicable.

## 1263 13.3.4 BGP extensions

1264 EVPN-VPWS uses the Ethernet A-D per-EVI route to signal VPWS services. An EVPN instance  
1265 MUST NOT be configured with both VPWS service instance and EVPN multipoint services.  
1266 draft-ietf-bess-evpn-vpws **Error! Reference source not found.** Section 3.1 adds a EVPN Layer 2 a  
1267 ttributes extended community.

1268  
1269 [R-79] The PE routers MUST support EVPN Layer 2 attributes extended community as  
1270 defined in Section 3.1/draft-ietf-bess-evpn-vpws **Error! Reference source not found..**

1271 **13.3.5 Tunnel signaling**

1272 The requirements for tunnel signaling per Section 12.3.3 are applicable.

1273 **13.3.6 Routing**

1274 The requirements for routing per Section 7.2 are applicable.

1275 **13.3.7 Multi-Homing and Load balancing**

1276 The requirements for multi-homing and load balancing per Section 11.5 are applicable.

1277 **13.3.7.1 Load balancing at intermediate nodes**

1278 The requirements for load balancing at intermediate nodes per Section 12.3.5.1 are  
1279 applicable.

1280 **13.3.8 OAM**

1281 **13.3.8.1 Ethernet Link OAM**

1282 The Ethernet link OAM is supported as per Section 8.1.1.

1283 **13.3.8.2 Label Switched Paths (LSP) OAM**

1284 LSP OAM is supported as per Section 8.3.1.

1285 **13.3.8.3 MEF Service OAM**

1286 MEF service is supported as per Section 8.2.

1287 **13.3.9 Convergence**

1288 Failure recovery from different types of network failure is supported as per Section 8.3.2.

1289 **13.3.10 PSN Resiliency**

1290 PSN resiliency is supported as per Section 10.

1291 **13.3.10.1 Fast Convergence**

1292 Fast convergence is supported as per Section 11.6.

1293 **13.3.11 QoS**

1294 E-Line service type can be defined with performance objectives (see Section 9.1/MEF 6.2 [50]).  
1295 PE routers MUST support the QoS mapping as per Section 9.

### 1296 **13.3.12 Security**

1297 [R-80] PE routers MUST support security as per Section 19/RFC 7432 [39].

## 1298 **13.4 Support of service attributes for EPL and EVPL**

1299 Section 9.1/MEF 6.2 [50] specifies the Ethernet Line (E-Line) Service Type that is the basis for a  
1300 broad range of Point-to-Point services. Section 10.1 and 10.2/MEF 6.2 [50] provides service  
1301 definitions for the Ethernet Private Line (EPL) Service and the Ethernet Virtual Private Line  
1302 (EVPL) Service that are based on the E-Line Service Type by defining the required Service  
1303 Attributes and related parameter values. The service attributes are tabulated in Section 8/MEF 6.2  
1304 [50].

1305  
1306 TR-224 refers to MEF 6.1 [41] and MEF 10.2 [42]. TR-350 uses the backward compatible subset  
1307 of the revised specifications MEF 6.2 [50] and MEF 10.3 [49] to achieve the equivalent function.  
1308 This addresses interworking with TR-224.

1309  
1310 This section only describes those Service Attributes and parameters that are relevant to  
1311 transporting the service over the PSN.

### 1312 **13.4.1 Bandwidth Profile**

1313 A bandwidth profile characterizes the lengths and arrival times of Service frames at a reference  
1314 point. Bandwidth profiles enable offering service bandwidth below the UNI access speed (aka  
1315 Speed) and limit the amount of traffic entering the network per the terms of the SLA.

1316  
1317 For the EPL and EVPL service, bandwidth profiles can be optionally specified per-UNI (ingress  
1318 and egress), per-EVC (ingress and egress), and/or per CoS (ingress and egress) as specified in  
1319 Section 10.1 and 10.2/MEF 6.2 [50]. The EPL and EVPL service can be provided as a best effort  
1320 service without any bandwidth guarantee.

1321  
1322 Note: Bandwidth profiles can be optionally provisioned per UNI (ingress and egress). They are not  
1323 carried by EVPN protocols.

1324  
1325 [R-81] A PE SHOULD support the bandwidth profile algorithm as per the portion of  
1326 Section 12/MEF 10.3 [49] that is backward compatible with MEF 10.2 [42].

1327  
1328 In order to support bandwidth profile, technique such as admission control and Diffserv-TE as  
1329 specified in Section 9 are used.

### 1330 **13.4.2 Bundling**

1331 Bundling is defined in Section 2/MEF 10.3 [49] as “A UNI Service attribute in which more than  
1332 one CE-VLAN ID can be associated with an EVC” and is described in Section 9.12/MEF 10.3  
1333 [49]. All to one bundling defined as “A UNI attribute in which all CE-VLAN IDs are associated  
1334 with a single EVC” is a special case of Bundling Enabled and is described in Section 9.13/MEF  
1335 10.3 [49]. Table 12/MEF 10.3 [49] provides valid combinations for “Service multiplexing”,  
1336 “Bundling” and “All to one bundling” attributes.  
1337  
1338 EPL must have the “Bundling” attribute as disabled and “All to one bundling” attribute as enabled.  
1339 For EVPL the “Bundling” attribute can be enabled or disabled, but “All to one bundling” must be  
1340 disabled.

### 1341 **13.4.3 CE-VLAN ID preservation for EVC**

1342 For EPL, CE-VLAN ID preservation must be enabled and CE-VLAN ID is preserved for EVC  
1343 over the PSN.  
1344

1345 For EVPL, if CE-VLAN ID preservation is enabled, CE-VLAN ID is preserved for EVC over the  
1346 PSN.  
1347

1348 Note: If CE-VLAN ID preservation is enabled, No VID translation is supported for the EVC.  
1349 EVPL can support VID translation when using EVPN service type “VLAN-Based Service type”.

### 1350 **13.4.4 CE-VLAN CoS preservation for EVC**

1351 CE-VLAN CoS preservation service attribute defines whether the CE-VLAN CoS bits are  
1352 preserved (unmodified) across the EVC.  
1353

1354 For EPL, CE-VLAN CoS preservation may be enabled or disabled (see Table 12/MEF 6.2 [50]).  
1355 For EVPL CE-VLAN CoS is supported as per sec 10.3/MEF 6.2 [50] and may be enabled or  
1356 disabled. In an EVC with CE-VLAN CoS preservation is enabled, the EVPN preserves the CoS  
1357 bits over PSN.

### 1358 **13.4.5 EVC Maximum Service Frame Size**

1359 The mapping from “EVC Maximum Service Frame Size” to “EVC MTU” is provided in Table 40  
1360 Appendix B of MEF 6.2 [50].  
1361

1362 The EVC Maximum Service Frame Size is configurable with a default value of 1600 bytes.  
1363

1364 When Ethernet frames are transported in MPLS networks, the MPLS packet includes the labels,  
1365 and the EVC frame as payload. The path MTU is the largest packet size that can traverse this path  
1366 without fragmentation. The ingress PE can use Path MTU Discovery to find the actual path MTU.  
1367

1368 [R-82] PE SHOULD support configurable EVC Maximum Service Frame Size of at least  
1369 1600 bytes (see Table 6/MEF 6.2 [50]).

### 1370 **13.4.6 Frame delivery**

1371 The frame delivery policy rules enable the service provider to specify how different frame types  
1372 are handled by a PE. They enable setting specific rules for forwarding, discarding or conditionally  
1373 forwarding specific frame types. The frame types used by the rules are:

- 1374
- 1375 • Unicast
  - 1376 • Multicast
  - 1377 • Broadcast

1378

1379 [R-83] PE MUST support setting policy function of frame delivery rules for forwarding,  
1380 discarding or conditionally forwarding unicast, multicast and broadcast frames per EPL and  
1381 EVPL services.

### 1382 **13.4.7 Layer 2 control protocols**

1383 The Layer 2 control protocol processing is independent of the EVC at the UNI. L2CP handling  
1384 rules are set according to the definition of Section 8/MEF 6.1.1 [48] and differ per-service type.  
1385 The PE policy function supports setting of rules for handling L2CP per service type.

1386

1387 EVC L2CP handling per service type can be set to:

- 1388 • Discard – Drop the frame.
- 1389 • Peer can be applicable: For example L2CP/LAMP, Link OAM, Port Authentication, and E-  
1390 LMI.
- 1391 • Tunnel – Pass to the egress UNI.

1392

1393 [R-84] PE MUST support policy function setting of rules for handling L2CP per service  
1394 type as specified in Section 8/MEF 6.1.1 [48].

1395

1396 Note: This specification only supports MEF 6.1.1 for L2CP processing requirements.  
1397 Support of multiple-CEN L2CP MEF 45 [51] is outside the scope of this document.

### 1398 **13.4.8 EVC performance**

1399 The performance parameters indicate the quality of service for that service instance. They consist  
1400 of the following:

- 1401 • Availability
- 1402 • Frame Delay
- 1403 • Frame delay variation
- 1404 • Frame loss ratio

1405

1406 The requirements for support of CoS and mapping are specified in QoS Section 9.

1407

1408 [R-85] The PE MUST support MEF SOAM performance monitoring as per MEF 35 [47].  
1409



1410 For transport of SOAM see Section 8.2.

### 1411 **13.4.9 Multiple Class of Service**

1412 MEF 6.1 [41] introduced services that were allowed multiple Classes of Service. The different  
1413 ways that EVCs can be created to support such a service is defined in Section 11.4.9/MEF 6.1 [41].

1414

1415 [R-86] The PE MUST support a single class of service for an EVC by using a single value  
1416 for the TC bits in the MPLS label stack.

1417

1418 [R-87] The PE MUST support a multiple class of service for an EVC by using multiple  
1419 values for the TC bits in the MPLS label stack.

1420

1421

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## 1422 **14 EVPN enabled Rooted-multipoint Ethernet VPN services (E-Tree)**

1423 MEF Ethernet Tree (E-Tree) service type is based upon a Rooted-multipoint Ethernet Virtual  
1424 connection. The EVPN technology enables the creation of E-Tree services over an MPLS network.  
1425 EVPN can be used to create the EP-Tree and EVP-Tree services of the E-Tree service type defined  
1426 by MEF 6.2 [50]. In an E-Tree service, endpoints are labeled as either Root or Leaf sites. Root  
1427 sites can communicate with all other sites. Leaf sites can communicate with Root sites but not with  
1428 other Leaf sites.

1429  
1430 This service could be useful for internet access or video over IP application, such as  
1431 multicast/broadcast packet video.

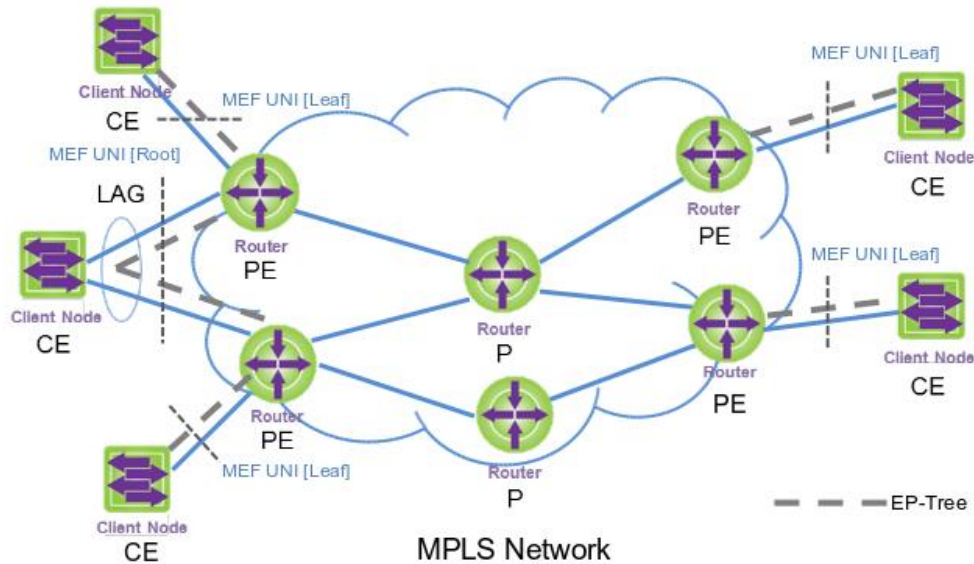
1432  
1433 High-level services are described in Section 14.1 and 14.2. In addition to the Carrier Ethernet  
1434 defined service characteristics, EVPN significantly enhances important service characteristics such  
1435 as reliability and scalability. The EVPN requirements for E-Tree Ethernet VPN services are listed  
1436 in Section 14.3.

### 1437 **14.1 Ethernet Private Tree (EP-Tree)**

1438 The Ethernet Private Tree (EP-Tree) service uses a Rooted-multipoint EVC. In a multipoint EVC,  
1439 two or more UNIs must be associated with one another. The EP-Tree service is defined to provide  
1440 CE-VLAN tag preservation and tunneling of key Layer 2 control protocols. A key advantage of  
1441 this service is that VLANs can be configured across the sites without any need to coordinate with  
1442 the service provider.

1443  
1444 Each interface is configured for “All to One Bundling”. EP-LAN supports CE-VLAN CoS  
1445 preservation. Service multiplexing is disabled on the UNI.

1446



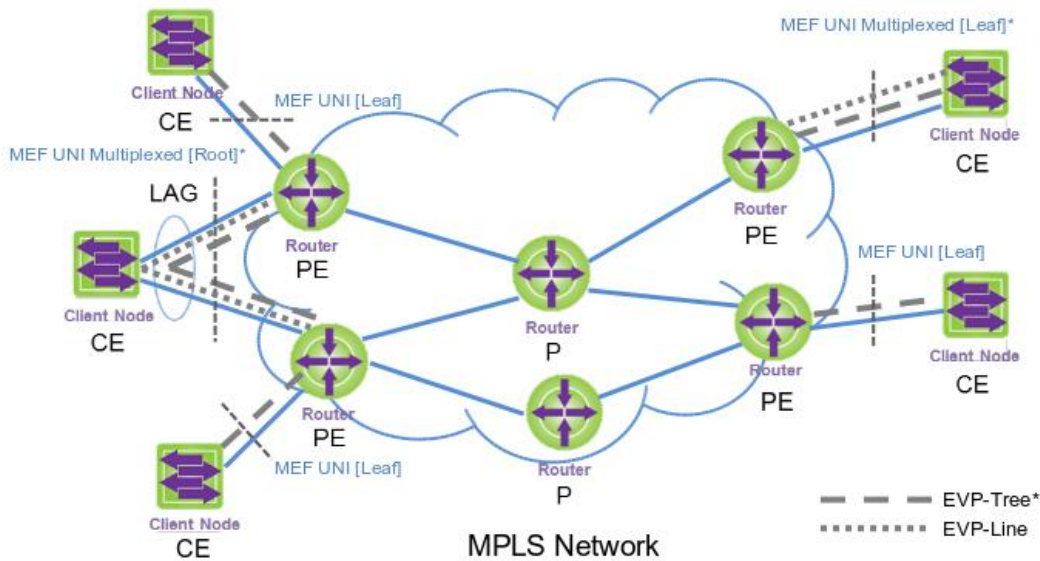
1447  
1448  
1449

**Figure 8 Ethernet Private Tree (EP-Tree) Service**

1450 **14.2 Ethernet Virtual Private Tree (EVP-Tree)**

1451 The Ethernet Virtual Private Tree (EVP-Tree) service allows service multiplexing at the UNI. It  
1452 allows users of an E-Tree service to interconnect their UNIs and at the same time access other  
1453 services (e.g. E-Line). Figure 9 shows an example of multiple services access from a single UNI.  
1454 In this example, the user has an EVP-Tree service for Rooted-multipoint data connectivity and an  
1455 EVPL service (P2P EVC) for accessing a value-add service from one of the UNIs.

1456  
1457 Bundling can be used on the UNI in the EVP-Tree service and supports CE-VLAN tag  
1458 preservation. All to One Bundling is disabled.  
1459



1460  
1461  
1462  
1463

**Figure 9 Ethernet Virtual Private Tree (EVP-Tree) Service**

### 1464 14.3 EVPN for establishing EP-Tree and EVP-Tree

1465 L2VPN service provides multipoint to multipoint connectivity for Ethernet across an IP or MPLS  
1466 Network. A generic E-LAN/E-Tree service is always bidirectional in the sense that ingress frames  
1467 can originate at any endpoint in the service.  
1468

1469 The only difference between E-LAN and E-Tree is:

- 1470 • E-LAN has Root endpoints only, which implies there is no communication restriction
- 1471 between endpoints.
- 1472 • E-Tree has both Root and Leaf endpoints, which implies there is a need to enforce
- 1473 communication restriction between Leaf endpoints.

1474  
1475 RFC 7387[38] proposes the solution framework for supporting E-Tree service in MPLS networks.  
1476 The document identifies additional components to emulate E-Tree service using Ethernet LAN  
1477 service over MPLS network.  
1478

1479 EVPN provides support for the E-LAN service type in MPLS networks as described in Section 11.  
1480 RFC 7432 [39] describes procedures for BGP MPLS-based Ethernet VPNS. EVPN requires  
1481 extensions to existing IP/MPLS protocols. EVPN supports both provisioning and signaling for  
1482 Ethernet VPNS and incorporates flexibility for service delivery over Layer 3 networks.  
1483

1484 The PE supports BGP MPLS-based Ethernet VPN signaling and provisioning as specified in [R-  
1485 53] of Section 11.4.

1486 draft-ietf-bess-evpn-etree [52] describes how EVPN can be used to support E-Tree in IP/MPLS  
1487 networks. The RFC discusses how the functional requirements for E-Tree service can be  
1488 implemented efficiently with EVPN.

### 1489 **14.3.1 E-Tree support in EVPN**

#### 1490 **14.3.1.1 E-Tree Scenarios and EVPN Support**

1491 The support for E-Tree services in EVPN is divided into different scenarios, depending on the site  
1492 association (Root/Leaf) per PE or Access Ethernet Segment. They are described in section 2/  
1493 draft-ietf-bess-evpn-etree [52].

1494  
1495 [R-88] The PE routers MUST Support Leaf or Root site(s) per PE as defined in Section  
1496 2.1/ draft-ietf-bess-evpn-etree [52].

1497  
1498 [R-89] The PE routers MUST Support Leaf or Root site(s) per Attachment Circuit (AC) as  
1499 defined in Section 2.2/ draft-ietf-bess-evpn-etree [52].

1500

#### 1501 **14.3.1.2 E-Tree Extended Community**

1502 A new BGP extended community is used for leaf indication. They are described draft-  
1503 ietf-bess-evpn-etree [52].

1504  
1505 [R-90] The PE routers MUST Support BGP extended community encoding as defined in  
1506 Section 5/ draft-ietf-bess-evpn-etree [52].

#### 1507 **14.3.1.3 E-Tree Operation for EVPN**

1508 RFC 7432 [39] has inherent capability to support E-Tree service. It adds a new  
1509 BGP extended community for leaf indication. The E-Tree operations for EVPN are  
1510 described in section 3/ draft-ietf-bess-evpn-etree [52].

1511 [R-91] The PE routers MUST Support E-Tree operation for EVPN as defined in Section 3/  
1512 draft-ietf-bess-evpn-etree [52].

### 1513 **14.3.2 Service Interfaces**

1514 EVPN supports several service connectivity options for delivering MEF services. They are  
1515 provided in Section 11.2. MEF service requirements for EP-LAN and EVP-LAN are different.  
1516 For EP-LAN, each interface is configured for “All to One Bundling”. For EVP-LAN “All to One  
1517 Bundling” is disabled.

#### 1518 **14.3.2.1 Service Interfaces for EP-Tree**

1519 [R-92] The PE routers MUST support Port-based Service Interface as defined in Section  
1520 6.2.1/RFC 7432 [39].

- 1521
- 1522 **14.3.2.2 Service Interfaces for EVP-Tree**
- 1523 [R-93] The PE routers MUST Support VLAN-based Service Interface as defined in Section  
1524 6.1/RFC 7432 [39].
- 1525
- 1526 [R-94] The PE routers MUST support VLAN Bundle Service Interface as defined in  
1527 Section 6.2/RFC 7432 [39]
- 1528 **14.3.3 Data plane**
- 1529 The requirements for data plane per Section 12.3.2 are applicable.
- 1530 **14.3.4 Tunnel signaling**
- 1531 The requirements for tunnel signaling per Section 12.3.3 are applicable.
- 1532 **14.3.5 Routing**
- 1533 The requirements for routing per Section 7.2 are applicable.
- 1534 **14.3.6 Multi-Homing and Load balancing**
- 1535 The requirements for multi-homing and load balancing per Section 12.3.5 are applicable.
- 1536 **14.3.7 OAM**
- 1537 The requirements for OAM per Section 12.3.6 are applicable.
- 1538 **14.3.8 Convergence**
- 1539 Failure recovery from different types of network failure is supported as per Section 8.3.2.
- 1540 **14.3.9 PSN Resiliency**
- 1541 PSN resiliency is supported as per Section 10.  
1542
- 1543 **14.3.9.1 Fast Convergence**
- 1544 Fast convergence is supported as per Section 11.6.
- 1545 **14.3.10 Multicast and Broadcast**

1546 [R-95] PE routers SHOULD support multicast and broadcast traffic as per Section 16/RFC  
1547 7432 [39].

### 1548 **14.3.11 QoS**

1549 In general, an E-Tree service type can provide a best effort service with no performance assurance.  
1550 In certain cases, an E-Tree service type can be defined with performance objectives (see Section  
1551 9.2/MEF 6.2 [50].

1552  
1553 [R-96] PE routers SHOULD support the QoS mapping as per Section 9.

### 1554 **14.3.12 Security**

1555 [R-97] PE routers MUST support security as per Section 19/RFC 7432 [39].  
1556

## 1557 **14.4 Support of service attributes for EP-Tree and EVP-Tree**

1558 Section 9.3/MEF 6.2 [50] specifies the E-Tree service type. Section 10.5 and 10.6/MEF 6.2 [50]  
1559 provides service attributes and parameters for EP-Tree and EVP-Tree services respectively. TR-  
1560 224 refers to MEF 6.1 [41] and MEF 10.2. TR-350 uses the backward compatible subset of the  
1561 revised specifications MEF 6.2 [50] (see Appendix B) and MEF 10.3 [49] to achieve the  
1562 equivalent function.

1563  
1564 Some of the service attributes and parameters are provided by Ethernet physical interface and  
1565 service provisioning (e.g., Physical medium, Speed, Mode, MAC layer, EVC type, maximum  
1566 number of EVCs, etc.). This section only describes those service attributes and parameters that are  
1567 relevant to transporting the EVPN traffic over PSN.

### 1568 **14.4.1 Bandwidth Profile**

1569 A bandwidth profile defines how rate enforcement of Ethernet frames is applied at an UNI.  
1570 Bandwidth profiles enable offering service bandwidth below the UNI access speed (aka Speed)  
1571 and limit the amount of traffic entering the network per the terms of the SLA.

1572  
1573 For Tree services, bandwidth profiles can be optionally specified per-UNI (ingress and egress),  
1574 per-EVC (ingress and egress), and/or per CoS (ingress and egress). An E-Tree service can be  
1575 provided as a best effort service without any bandwidth guarantee.

1576  
1577 Note: Bandwidth profiles can be optionally provisioned. They are not carried by EVPN protocols.  
1578

1579  
1580 [R-98] A PE SHOULD support the bandwidth profile algorithm as per the portion of  
1581 Section 12/MEF 10.3 [49] that is backward compatible with MEF 10.2 [42].  
1582

1583 In order to support bandwidth profile, technique such as admission control and Diffserv-TE as  
1584 specified in Section 9 are used.

#### 1585 **14.4.2 Bundling**

1586 Section 9.12/MEF 10.3 [49] specifies the bundling service attribute. Bundling implies “A UNI  
1587 attribute in which more than one CE-VLAN ID can be associated with an EVC”. All to one  
1588 bundling enabled is a special case of bundling. It implies “A UNI attribute in which all CE-VLAN  
1589 IDs are associated with a single EVC”. Table 12/MEF 10.3 [49] provides valid combinations for  
1590 “All to one bundling” and “Service multiplexing” attributes.

1591  
1592 EP-Tree must have “All to one bundling” attribute enabled. For EVP-Tree the bundling attribute  
1593 can be enabled or disabled. However, for EVP-Tree “All to one bundling” must be disabled.

#### 1594 **14.4.3 CE-VLAN ID preservation for EVC**

1595 CE-VLAN ID preservation service attribute defines whether the CE-VLAN ID is preserved  
1596 (unmodified) across the EVC.

1597  
1598 For EP-Tree, CE-VLAN ID preservation must be enabled and CE-VLAN ID is preserved for EVC  
1599 over the PSN.

1600  
1601 For EVP-Tree, if CE-VLAN ID preservation is enabled, CE-VLAN ID is preserved for EVC over  
1602 the PSN.

1603  
1604 Note: If CE-VLAN ID preservation is enabled, No VID translation is supported for the EVC.  
1605 EVP-Tree can support VID translation when using EVPN service type “VLAN-Based Service  
1606 type”.

#### 1607 **14.4.4 CE-VLAN CoS preservation for EVC**

1608 CE-VLAN CoS preservation service attribute defines whether the CE-VLAN CoS bits are  
1609 preserved (unmodified) across the EVC.

1610  
1611 For EP-Tree, CE-VLAN CoS preservation must be enabled (see Table 21/MEF 6.2 [50]) and CE-  
1612 VLAN CoS is preserved for EVC over PSN.

1613  
1614 For EVP-Tree, CE-VLAN CoS preservation can be either enabled or disabled (see Table 24/MEF  
1615 6.2). In an EVC with CE-VLAN CoS preservation is enabled, the EVPN preserves the CoS bits  
1616 over PSN.

#### 1617 **14.4.5 EVC Maximum Service Frame Size**

1618 The requirements for EVC maximum service frame size per Section 12.4.5 are applicable.



**1619 14.4.6 Frame delivery**

1620 The frame delivery policy rules enable the service provider to specify how different frame types  
1621 are handled by a PE. They enable setting specific rules for forwarding, discarding or conditionally  
1622 forwarding specific frame types. The frame types used by the rules are:

1623

- 1624 • Unicast
- 1625 • Multicast
- 1626 • Broadcast

1627

1628 [R-99] PE MUST support setting policy function of frame delivery rules for  
1629 forwarding, discarding or conditionally forwarding unicast, multicast and  
1630 broadcast frames per EP-Tree and EVP-Tree services.

**1631 14.4.7 Layer 2 control protocols**

1632 The requirements for Layer 2 control protocols per Section 12.4.7 are applicable.

1633

**1634 14.4.8 EVC performance**

1635 The requirements for EVC performance per Section 12.4.8 are applicable.

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End of Broadband Forum Technical Report TR-350

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