Authors: IJ. Wijnands   M. Mishra (Editor)
         Individual   Cisco Systems, Inc.
         K. Raza   Z. Zhang
         Cisco Systems, Inc.   Juniper Networks
         A. Gulko
         Edward Jones wealth management

mLDP Extensions for Multi-Topology Routing

Abstract

Multi-Topology Routing (MTR) is a technology to enable service
differentiation within an IP network. Flexible Algorithm (FA) is
another mechanism of creating a sub-topology within a topology using
defined topology constraints and computation algorithm. In order to
deploy mLDP (Multipoint label distribution protocol) in a network
that supports MTR and/or FA, mLDP is required to become topology and
FA aware. This document specifies extensions to mLDP to support MTR
with FA such that when building a Multipoint LSPs(Label Switched
Paths) it can follow a particular topology and algorithm.

Status of This Memo

This Internet-Draft is submitted in full conformance with the
provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering
Task Force (IETF). Note that other groups may also distribute
working documents as Internet-Drafts. The list of current Internet-
Drafts is at https://datatracker.ietf.org/drafts/current/.

Internet-Drafts are draft documents valid for a maximum of six
months and may be updated, replaced, or obsoleted by other documents
at any time. It is inappropriate to use Internet-Drafts as reference
material or to cite them other than as "work in progress."

This Internet-Draft will expire on 12 October 2024.

Copyright Notice

Table of Contents

1. Glossary

MT - Multi-Topology

MT-ID - Multi-Topology Identifier

MTR - Multi-Topology Routing

IGP - Interior Gateway Protocol

MP - Multipoint (P2MP or MP2MP)

LDP - Label Distribution Protocol

mLDP - Multipoint LDP

P2MP - Point-to-Multipoint

MP2MP - Multipoint-to-Multipoint

FEC - Forwarding Equivalence Class

LSP - Label Switched Path

FA - Flexible Algorithm

IPA - IGP Algorithm

2. Introduction

Multi-Topology Routing (MTR) is a technology to enable service
differentiation within an IP network. IGP protocols (OSPF and IS-IS)
and LDP have already been extended to support MTR. To support MTR,
an IGP maintains independent IP topologies, termed as "Multi-
Topologies" (MT), and computes/installs routes per topology. OSPF
extensions [RFC4915] and ISIS extensions [RFC5120] specify the MT
extensions under respective IGPs. To support IGP MT, similar LDP
extensions [RFC7307] have been specified to make LDP MT-aware and be
able to setup unicast Label Switched Paths (LSPs) along IGP MT
routing paths.

A more light weight mechanism to define constraint-based topologies
is the Flexible Algorithm (FA) [RFC9350]. FA can be seen as creating
a sub-topology within a topology using defined topology constraints
and computation algorithm. This can be done within a MTR topology or
the default Topology. An instance of such a sub-topology is
identified by a 1 octet value as documented in [RFC9350]). Flexible
Algorithm is a mechanism to create a sub-topology, but in the future
different algorithms might be defined on how to achieve that. For
that reason, in the remainder of this document, we'll refer to this
as the IGP Algorithm (IPA).

Multipoint LDP (mLDP) refers to extensions in LDP to setup multi-
point LSPs (point-to-multipoint (P2MP) or multipoint-to-multipoint
(MP2MP)), by means of set of extensions and procedures defined in
[RFC6388]. In order to deploy mLDP in a network that supports MTR
and FA, mLDP is required to become topology and algorithm aware.
This document specifies extensions to mLDP to support MTR/IPA such
that when building a Multi-Point LSPs it can follow a particular
topology and alogirthm. This means that the identifier for the

particular topology to be used by mLDP have to become a 2-tuple (MTR
Topology Id, IGP Algorithm).

3. Specification of Requirements

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
"SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this
document are to be interpreted as described in [RFC2119].

In this document, these words will appear with that interpretation
only when in ALL CAPS. Lower case uses of these words are not to be
interpreted as carrying RFC-2119 significance.

4. MT Scoped mLDP FECs

As defined in [RFC7307], MPLS Multi-Topology Identifier (MT-ID) is
an identifier that is used to associate an LSP with a certain MTR
topology. In the context of MP LSPs, this identifier is part of the
mLDP FEC encoding so that LDP peers are able to setup an MP LSP via
their own defined MTR policy. In order to avoid conflicting MTR
policies for the same mLDP FEC, the MT-ID needs to be a part of the
FEC, so that different MT-ID values will result in unique MP-LSP FEC
elements.

The same applies to the IPA. The IPA needs to be encoded as part of
the mLDP FEC to create unique MP-LSPs and at the same time is used
to signal to mLDP (hop-by-hop) which Algorithm needs to be used to
create the MP-LSP.

Since the MT-ID and IPA are part of the FEC, they apply to all the
LDP messages that potentially include an mLDP FEC element.

4.1. MP FEC Extensions for MT

Following subsections propose the extensions to bind an mLDP FEC to
a topology. The mLDP MT extensions reuse some of the extensions
specified in [RFC7307].

4.1.1. MP FEC Element

Base mLDP specification [RFC6388] defines MP FEC Element as follows:

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | MP FEC type   |      Address Family       |    AF Length  |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                    Root Node Address                         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |    Opaque Length          |        Opaque Value              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                                 +
   ~                                                              ~
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
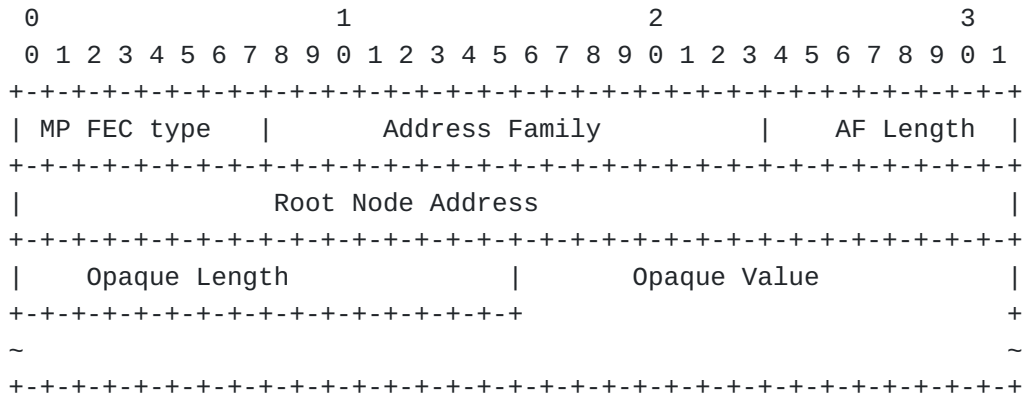
              Figure 1: MP FEC Element Format [RFC6388]

Where "Root Node Address" encoding is as defined for given "Address
Family", and whose length (in octets) is specified by the "AF
Length" field.

To extend MP FEC elements for MT, the {MT-ID, IPA} is a tuple that
is relevant in the context of the root address of the MP LSP. The
{MT-ID, IPA} tuple determines in which (sub)-topology the root
address needs to be resolved. Since the {MT-ID, IPA} tuple should be
considered part of the mLDP FEC, the most natural place to encode
this tuple is as part of the root address. While encoding it, we
also propose to use "MT IP" Address Families as described in
following sub section.

4.1.2. MT IP Address Families

[RFC7307] has specified new address families, named "MT IP" and "MT
IPv6", to allow specification of an IP prefix within a topology
scope. In addition to using this address family for mLDP, we also
use 8 bits of the 16 bits Reserved field to encode the IGP Algorithm
(IPA) Registry. The resulting format of the data associated with
these new Address Families is as follows:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          IPv4 Address                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Reserved   |      IPA      |            MT-ID               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+


 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          IPv6 Address                         |
|                                                               |
|                                                               |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Reserved   |      IPA      |            MT-ID               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
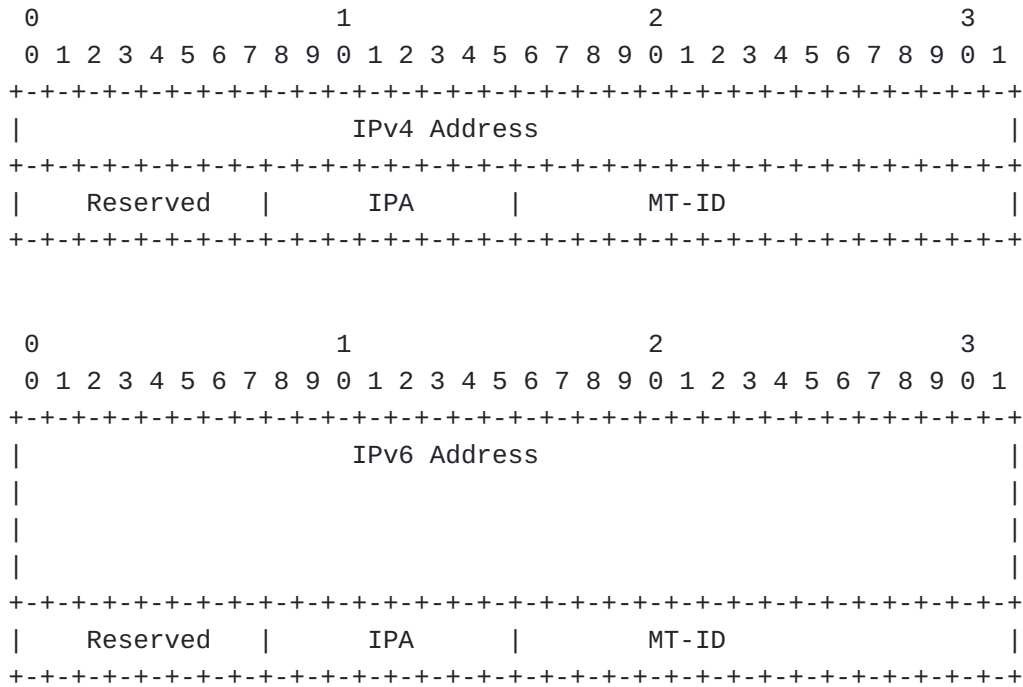
Figure 2: Modified MT IP Address Families Data Format

Where:

   IPv4/IPv6 Address: An IP address corresponding to "MT IP" and "MT
   IPv6" address families respectively.

   IPA: The IGP Algorithm, values are from the IGP Algorithm
   registry.

   Reserved: This 8-bit field MUST be zero on transmission and
   ignored on receipt.

4.1.3. MT MP FEC Element

By using extended MT IP Address Family, the resultant MT MP FEC
element is to be encoded as follows:

```
0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| MP FEC type  |  AF (MT IP/ MT IPv6)     |     AF Length  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Root Node Address                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Reserved   |     IPA     |        MT-ID                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Opaque Length          |        Opaque Value          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                              +
~                                                           ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
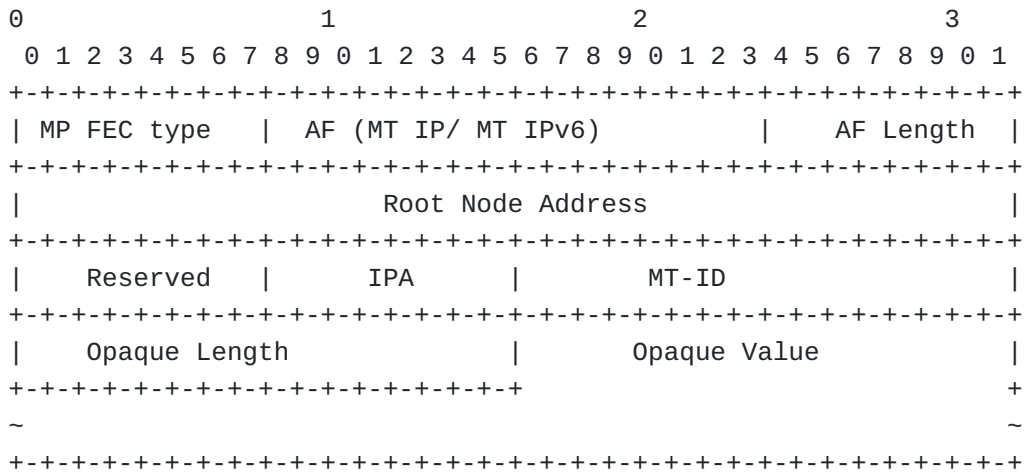
Figure 3: IP MT-Scoped MP FEC Element Format

In the context of this document, the applicable LDP FECs for MT mLDP
include:

  *MP FEC Elements:

    -P2MP (type 0x6)

    -MP2MP-up (type 0x7)

    -MP2MP-down (type 0x8)

  *Typed Wildcard FEC Element (type 0x5)

In case of "Typed Wildcard FEC Element", the sub FEC Element type
MUST be one of the MP FECs listed above.

This specification allows the use of Topology-scoped mLDP FECs in
LDP label and notification messages, as applicable.

[RFC6514] defines the PMSI tunnel attribute for MVPN. When the
Tunnel Type is set to mLDP P2MP LSP, the Tunnel Identifier is a P2MP
FEC Element. When the Tunnel Type is set to mLDP Multipoint-to-
Multipoint (MP2MP) LSP, the Tunnel Identifier is an MP2MP FEC
Element. For deploying mLDP in a network that supports MTR and FA,
New MT MP FEC element SHOULD be used as the Tunnel Identifier.

4.2. Topology IDs

This document assumes the same definitions and procedures associated
with MPLS MT-ID as defined in [RFC7307] specification.

5. MT Multipoint Capability

"MT Multipoint Capability" is a new LDP capability, defined in
accordance with LDP Capability definition guidelines [RFC5561], that
is to be advertised to its peers by an mLDP speaker to announce its
capability to support MTR and the procedures specified in this
document. This capability MAY be sent either in an Initialization
message at the session establishment time, or in a Capability
message dynamically during the lifetime of a session (only if
"Dynamic Announcement" capability [RFC5561] has been successfully
negotiated with the peer).

The format of this capability is as follows:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|U|F|  MT Multipoint Cap.(IANA) |          Length               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|S| Reserved    |
+-+-+-+-+-+-+-+-+
```
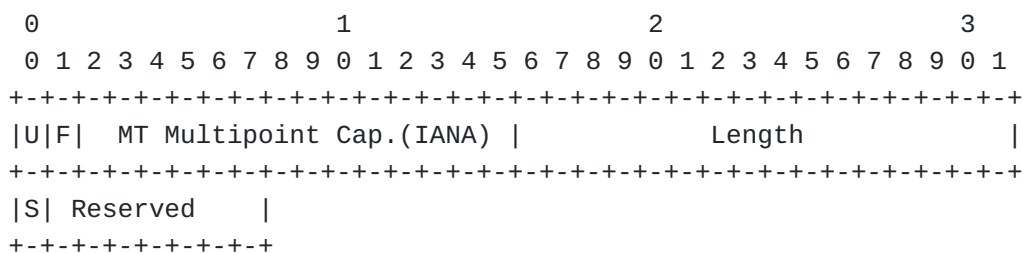
              Figure 4: MT Multipoint Capability TLV Format

Where:

   U- and F-bits: MUST be 1 and 0, respectively, as per Section 3 of
   LDP Capabilities [RFC5561].

   MT Multipoint Capaility: TLV type (IANA assigned).

   Length: The length (in octets) of TLV. The value of this field
   MUST be 1 as there is no Capability-specific data [RFC5561] that
   follows in the TLV.

   S-bit: Set to 1 to announce and 0 to withdraw the capability (as
   per [RFC5561].

An mLDP speaker that has successfully advertised and negotiated "MT
Multipoint" capability MUST support the following:

  1. Topology-scoped mLDP FECs in LDP messages (Section 4.1)

  2. Topology-scoped mLDP forwarding setup (Section 7)

6. MT Applicability on FEC-based features

6.1. Typed Wildcard MP FEC Elements

[RFC5918] extends base LDP and defines Typed Wildcard FEC Element
framework. Typed Wildcard FEC element can be used in any LDP message
to specify a wildcard operation for a given type of FEC.

The MT extensions proposed in document do not require any extension
in procedures for Typed Wildcard FEC Element support [RFC5918], and
these procedures apply as-is to Multipoint MT FEC wildcarding. Like
Typed Wildcard MT Prefix FEC Element, as defined in [RFC7307], the
MT extensions allow use of "MT IP" or "MT IPv6" in the Address
Family field of the Typed Wildcard MP FEC element in order to use
wildcard operations for MP FECs in the context of a given (sub)-
topology as identified by the MT-ID and IPA field.

This document proposes following format and encoding for a Typed
Wildcard MP FEC element:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Typed Wcard (5)| Type = MP FEC |   Len = 6     | AF = MT IP ..|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|... or MT IPv6 |    Reserved   |      IPA      |     MT-ID     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|MT ID (contd.) |
+-+-+-+-+-+-+-+-+
```

Figure 5: Typed Wildcard MT MP FEC Element

Where:

   Type: One of MP FEC Element type (P2MP, MP2MPup, MP2MP-down).

   MT ID: MPLS MT ID

   IPA: The IGP Algorithm, values are from the IGP Algorithm
   registry.

The proposed format allows an LSR to perform wildcard MP FEC
operations under the scope of a (sub-)topology.

6.2. End-of-LIB

[RFC5919] specifies extensions and procedures that allows an LDP
speaker to signal its End-of-LIB (i.e. convergence) for a given FEC
type towards a peer. MT extensions for MP FEC do not require any

change in these procedures and they apply as-is to MT MP FEC elements. This means that an MT mLDP speaker MAY signal its convergence per (sub-)topology using MT Typed Wildcard MP FEC element.

7. Topology-Scoped Signaling and Forwarding

Since the {MT-ID, IPA} tuple is part of an mLDP FEC, there is no need to support the concept of multiple (sub-)topology forwarding tables in mLDP. Each MP LSP will be unique due to the tuple being part of the FEC. There is also no need to have specific label forwarding tables per topology, and each MP LSP will have its own unique local label in the table. However, In order to implement MTR in an mLDP network, the selection procedures for upstream LSR and downstream forwarding interface need to be changed.

7.1. Upstream LSR selection

The procedures as described in RFC-6388 section-2.4.1.1 depend on the best path to reach the root. When the {MT-ID, IPA} tuple is signaled as part of the FEC, this tuple is used to select the (sub-)topology that must be used to find the best path to the root address. Using the next-hop from this best path, a LDP peer is selected following the procedures as defined in [RFC6388].

7.2. Downstream forwarding interface selection

The procedures as described in RFC-6388 section-2.4.1.2 describe how a downstream forwarding interface is selected. In these procedures, any interface leading to the downstream LDP neighbor can be considered as candidate forwarding interface. When the {MT-ID, IPA} tuple is part of the FEC, this is no longer true. An interface must only be selected if it is part of the same (sub-)topology that was signaled in the mLDP FEC element. Besides this restriction, the other procedures in [RFC6388] apply.

8. LSP Ping Extensions

[RFC6425] defines procedures to detect data plane failures in Multipoint MPLS LSPs. Section 3.1.2 of [RFC6425] defines new Sub-Types and Sub-TLVs for Multipoint LDP FECs to be sent in "Target FEC Stack" TLV of an MPLS echo request message [RFC8029].

To support LSP ping for MT Multipoint LSPs, this document uses existing sub-types "P2MP LDP FEC Stack" and "MP2MP LDP FEC Stack" defined in [RFC6425]. The proposed extension is to specify "MT IP" or "MT IPv6" in the "Address Family" field, set the "Address Length" field to 8 (for MT IP) or 20 (for MT IPv6), and encode the sub-TLV with additional {MT-ID, IPA} information as an extension to the

"Root LSR Address" field. The resultant format of sub-tlv is as
follows:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Address Family (MT IP/MT IPv6) | Address Length|               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+               |
~                       Root LSR Address (Cont.)                ~
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Reserved    |      IPA       |          MT-ID               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|        Opaque Length          |        Opaque Value ...       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               +
~                                                               ~
|                               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
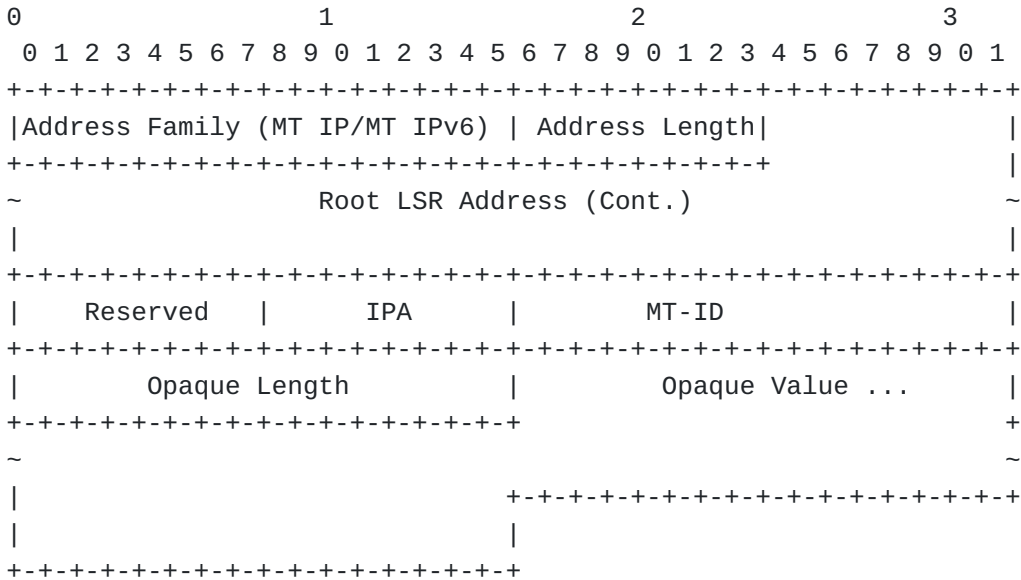
Figure 6: Multipoint LDP FEC Stack Sub-TLV Format for MT

The rules and procedures of using this new sub-TLV in an MPLS echo
request message are same as defined for P2MP/MP2MP LDP FEC Stack
Sub-TLV in [RFC6425] with only difference being that Root LSR
address is now (sub-)topology scoped.

9. Implementation Status

[Note to the RFC Editor - remove this section before publication, as
well as remove the reference to [RFC7942]

This section records the status of known implementations of the
protocol defined by this specification at the time of posting of
this Internet-Draft, and is based on a proposal described in
[RFC7942] . The description of implementations in this section is
intended to assist the IETF in its decision processes in progressing
drafts to RFCs. Please note that the listing of any individual
implementation here does not imply endorsement by the IETF.
Furthermore, no effort has been spent to verify the information
presented here that was supplied by IETF contributors. This is not
intended as, and must not be construed to be, a catalog of available
implementations or their features. Readers are advised to note that
other implementations may exist.

According to [RFC7942] , "this will allow reviewers and working
groups to assign due consideration to documents that have the
benefit of running code, which may serve as evidence of valuable
experimentation and feedback that have made the implemented

protocols more mature. It is up to the individual working groups to
use this information as they see fit".

9.1. Cisco Systems

The feature has been implemented on IOS-XR.

   *Organization: Cisco Systems

   *Implementation: Cisco systems IOS-XR has an implementation

   *Description: The implementation has been done.

   *Maturity Level: Product

   *Contact: mankamis@cisco.com

10. Security Considerations

This extension to mLDP does not introduce any new security
considerations beyond that already apply to the base LDP
specification [RFC5036], base mLDP specification [RFC6388], and MPLS
security framework [RFC5920].

11. IANA Considerations

This document defines a new LDP capability parameter TLV. IANA is
requested to assign the lowest available value after 0x0500 from
"TLV Type Name Space" in the "Label Distribution Protocol (LDP)
Parameters" registry within "Label Distribution Protocol (LDP) Name
Spaces" as the new code point for the LDP TLV code point.


```
+-----+-----------------+--------------+------------------------+
|Value| Description     | Reference    | Notes/Registration Date |
+-----+-----------------+--------------+------------------------+
| TBA | MT Multipoint   | This document |                        |
|     | Capability      |              |                        |
+-----+-----------------+--------------+------------------------+
```

Figure 7: IANA Code Point

12. Contributor

Anuj Budhiraja Cisco systems

13. Acknowledgments

The authors would like to acknowledge Eric Rosen for his input on this specification.

14. References

14.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate
           Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/
           RFC2119, March 1997, <https://www.rfc-editor.org/info/
           rfc2119>.

[RFC4915] Psenak, P., Mirtorabi, S., Roy, A., Nguyen, L., and P.
           Pillay-Esnault, "Multi-Topology (MT) Routing in OSPF",
           RFC 4915, DOI 10.17487/RFC4915, June 2007, <https://
           www.rfc-editor.org/info/rfc4915>.

[RFC5120] Przygienda, T., Shen, N., and N. Sheth, "M-ISIS: Multi
           Topology (MT) Routing in Intermediate System to
           Intermediate Systems (IS-ISs)", RFC 5120, DOI 10.17487/
           RFC5120, February 2008, <https://www.rfc-editor.org/info/
           rfc5120>.

[RFC6388] Wijnands, IJ., Ed., Minei, I., Ed., Kompella, K., and B.
           Thomas, "Label Distribution Protocol Extensions for
           Point-to-Multipoint and Multipoint-to-Multipoint Label
           Switched Paths", RFC 6388, DOI 10.17487/RFC6388, November
           2011, <https://www.rfc-editor.org/info/rfc6388>.

[RFC6425] Saxena, S., Ed., Swallow, G., Ali, Z., Farrel, A.,
           Yasukawa, S., and T. Nadeau, "Detecting Data-Plane
           Failures in Point-to-Multipoint MPLS - Extensions to LSP
           Ping", RFC 6425, DOI 10.17487/RFC6425, November 2011,
           <https://www.rfc-editor.org/info/rfc6425>.

[RFC6514] Aggarwal, R., Rosen, E., Morin, T., and Y. Rekhter, "BGP
           Encodings and Procedures for Multicast in MPLS/BGP IP
           VPNs", RFC 6514, DOI 10.17487/RFC6514, February 2012,
           <https://www.rfc-editor.org/info/rfc6514>.

[RFC7307] Zhao, Q., Raza, K., Zhou, C., Fang, L., Li, L., and D.
           King, "LDP Extensions for Multi-Topology", RFC 7307, DOI
           10.17487/RFC7307, July 2014, <https://www.rfc-editor.org/
           info/rfc7307>.

[RFC7942] Sheffer, Y. and A. Farrel, "Improving Awareness of
           Running Code: The Implementation Status Section", BCP

205, RFC 7942, DOI 10.17487/RFC7942, July 2016, <https://www.rfc-editor.org/info/rfc7942>.

[RFC8029] Kompella, K., Swallow, G., Pignataro, C., Ed., Kumar, N., Aldrin, S., and M. Chen, "Detecting Multiprotocol Label Switched (MPLS) Data-Plane Failures", RFC 8029, DOI 10.17487/RFC8029, March 2017, <https://www.rfc-editor.org/info/rfc8029>.

[RFC9350] Psenak, P., Ed., Hegde, S., Filsfils, C., Talaulikar, K., and A. Gulko, "IGP Flexible Algorithm", RFC 9350, DOI 10.17487/RFC9350, February 2023, <https://www.rfc-editor.org/info/rfc9350>.

14.2. Informative References

[RFC5036] Andersson, L., Ed., Minei, I., Ed., and B. Thomas, Ed., "LDP Specification", RFC 5036, DOI 10.17487/RFC5036, October 2007, <https://www.rfc-editor.org/info/rfc5036>.

[RFC5561] Thomas, B., Raza, K., Aggarwal, S., Aggarwal, R., and JL. Le Roux, "LDP Capabilities", RFC 5561, DOI 10.17487/RFC5561, July 2009, <https://www.rfc-editor.org/info/rfc5561>.

[RFC5918] Asati, R., Minei, I., and B. Thomas, "Label Distribution Protocol (LDP) 'Typed Wildcard' Forward Equivalence Class (FEC)", RFC 5918, DOI 10.17487/RFC5918, August 2010, <https://www.rfc-editor.org/info/rfc5918>.

[RFC5919] Asati, R., Mohapatra, P., Chen, E., and B. Thomas, "Signaling LDP Label Advertisement Completion", RFC 5919, DOI 10.17487/RFC5919, August 2010, <https://www.rfc-editor.org/info/rfc5919>.

[RFC5920] Fang, L., Ed., "Security Framework for MPLS and GMPLS Networks", RFC 5920, DOI 10.17487/RFC5920, July 2010, <https://www.rfc-editor.org/info/rfc5920>.

Authors' Addresses

IJsbrand Wijnands
Individual

Email: ice@braindump.be

Mankamana Mishra
Cisco Systems, Inc.
821 Alder Drive
Milpitas, CA 95035

United States of America

Email: mankamis@cisco.com

Kamran Raza
Cisco Systems, Inc.
2000 Innovation Drive
Kanata ON K2K-3E8
Canada

Email: skraza@cisco.com

Zhaohui Zhang
Juniper Networks
10 Technology Park Dr.
Westford, MA 01886
United States of America

Email: zzhang@juniper.net

Arkadiy Gulko
Edward Jones wealth management
United States of America

Email: Arkadiy.gulko@edwardjones.com