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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, in order for Multipoint LSPs(Label Switched Paths) to follow a particular topology and algorithm.

Status of This Memo

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1. Glossary

FA - Flexible Algorithm

FEC - Forwarding Equivalence Class

IGP - Interior Gateway Protocol

IPA - IGP Algorithm

LDP - Label Distribution Protocol

LSP - Label Switched Path

mLDP - Multipoint LDP

MP - Multipoint (P2MP or MP2MP)

MP2MP - Multipoint-to-Multipoint

MT - Multi-Topology

MT-ID - Multi-Topology Identifier

MTR - Multi-Topology Routing

MVPN - Multicast over Virtual Private Network defined in section 2.3 of [RFC6513]

P2MP - Point-to-Multipoint

PMSI - Provider Multicast Service Interfaces [RFC6513]

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 IS-IS 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 lightweight 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 algorithms. This can be done within an MTR topology or the default Topology. An instance of such a sub-topology is identified by a 1 octet value (Flex-Algorithm) as documented in [RFC9350]). A 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.

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 a 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/IGP Algorithm such that when building a Multi-Point LSPs it can follow a particular topology and algorithm. 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", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

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 IGP Algorithm. The IGP Algorithm needs to be encoded as part of the mLDP FEC to create unique MP-LSPs. The IGP Algorithm is also used to signal to mLDP (hop-by-hop) which Algorithm needs to be used to create the MP-LSP.

Since the MT-ID and IGP Algorithm 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

The following subsections define the extensions to bind an mLDP FEC to a topology. These 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 the "Root Node Address" encoding is defined according to the given "Address Family" with its length (in octets) specified by the "AF Length" field.

To extend MP FEC elements for MT, the {MT-ID, IPA} tuple is relevant in the context of the root address of the MP LSP. This tuple determines the (sub)-topology in which the root address needs to be resolved. As the {MT-ID, IPA} tuple should be considered part of the mLDP FEC, it is most naturally encoded as part of the root address.

4.1.2. MT IP Address Families

[RFC7307] specifies new address families, named "MT IP" and "MT IPv6," to allow for the specification of an IP prefix within a topology scope. In addition to using these address families for mLDP, 8 bits of the 16-bit Reserved field are utilized to encode the IGP Algorithm Types (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 Types registry.

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

4.1.3. MT MP FEC Element

By using the extended MT IP Address Family, the resulting MT MP FEC element should 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 ([RFC6388]) include:

* MP FEC Elements:

  - P2MP (type 0x6)

  - MP2MP-up (type 0x7)

  - MP2MP-down (type 0x8)

* Typed Wildcard FEC Element (type 0x5 defined in [RFC5918])

In case of "Typed Wildcard FEC Element", the 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, and specifies that when the Tunnel Type is set to mLDP P2MP LSP, the Tunnel Identifier is a P2MP FEC Element, and when the Tunnel Type is set to mLDP Multipoint-to-Multipoint (MP2MP) LSP, the Tunnel Identifier is an MP2MP FEC Element. When the extension defined in this specification is in use, the "IP MT-Scoped MP FEC Element Format" form of the respective FEC elements MUST be used in these two cases.

4.2. Topology IDs

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

5. MT Multipoint Capability

The "MT Multipoint Capability" is a new LDP capability, defined in accordance with the LDP Capability definition guidelines outlined in [RFC5561]. An mLDP speaker advertises this capability to its peers to announce its support for MTR and the procedures specified in this document. This capability MAY be sent either in an Initialization message at session establishment or dynamically during the session's lifetime via a Capability message, provided that the "Dynamic Announcement" capability from [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 Capability |            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 Capability: TLV type.

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. Length: This field specifies the length of the TLV in octets. The value of this field MUST be 1, as there is no Capability-specific data [[RFC5561]] following 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, defined in this document, do not require any extension to procedures for Typed Wildcard FEC Element support [RFC5918], and these procedures apply as-is to Multipoint MT FEC wildcarding. Similar to Typed Wildcard MT Prefix FEC Element, as defined in [RFC7307], the MT extensions allow the use of "MT IP" or "MT IPv6" in the Address Family field of the Typed Wildcard MP FEC element. This is done 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 defines the 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 Types registry.

The defined 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 allow an LDP speaker to signal its End-of-LIB for a given FEC type to a peer. By leveraging the End-of-LIB message, LDP ensures that label distribution remains consistent and reliable, even during network disruptions or maintenance activities. The MT extensions for MP FEC do not require any modifications to these procedures and apply as-is to MT MP FEC elements. Consequently, an MT mLDP speaker MAY signal its convergence per (sub-)topology using the 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 LSP Ping 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 the same as defined for P2MP/MP2MP LDP FEC Stack Sub-TLV in [RFC6425]. The only difference is that the 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. Capability has been used from [RFC7307] and plan to update the value once IANA assigns new value.

*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 applied to the base LDP specification [RFC5036], LDP extensions for Multi-Topology specification [RFC7307] 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 Capability	This document	

Figure 7: IANA Code Point

12. Contributor

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13. Acknowledgments

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

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