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LDP Extensions for Multi Topology Routing
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Abstract

Multi-Topology (MT) routing is supported in IP networks with the use of MT aware IGP protocols. In order to provide MT routing within Multiprotocol Label Switching (MPLS) Label Distribution Protocol (LDP) networks new extensions are required.

This document describes the LDP protocol extensions required to support MT routing in an MPLS environment.

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1. Terminology

This document uses MPLS terminology defined in [RFC5036]. Additional terms are defined below:

- o MT-ID: A 16 bit value used to represent the Multi-Topology ID.

- o Default MT Topology: A topology that is built using the MT-ID default value of 0.

- o MT Topology: A topology that is built using the corresponding MT-ID.

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 RFC 2119 [RFC2119].

2. Introduction

Multi-Topology (MT) routing is supported in IP networks with the use of MT aware IGP protocols. It would be advantageous for communications Service Providers (CSP) to support Multiple Topologies (MT) within MPLS environments (MPLS-MT). Beneficial MPLS-MT deployment applications include:

- o A CSP may want to assign varying QoS profiles to traffic, based on a specific MT.

- o Separate routing and MPLS domains may be used to isolated multicast and IPv6 islands within the backbone network.

- o Specific IP address space could be routed across an MT based on security or operational isolation requirements.

- o Low latency links could be assigned to an MT for delay sensitive traffic.

o Management traffic could be separated from customer traffic using multiple MTs, where the management traffic MT does not use links that carries customer traffic.

This document describes the LDP procedures and protocol extensions required to support MT routing in an MPLS environment.

3. Signaling Extensions

3.1. Topology-Scoped FEC

LDP assigns and binds a label to a FEC, where a FEC is a list of one of more FEC elements. To setup LSPs for unicast IP routing paths, LDP assigns local labels for IP prefixes, and advertises these labels to its peers so that an LSP is setup along the routing path. To setup MT LSPs for IP prefixes under a given topology scope, the LDP "prefix-related" FEC element must be extended to include topology info. This infers that MT-ID becomes an attribute of Prefix-related FEC element, and all FEC-Label binding operations are performed under the context of given topology (MT-ID).

The following Subsection (3.2 New Address Families: MT IP) defines the extension required to bind "prefix-related" FEC to a topology.

3.2. New Address Families: MT IP

The LDP base specification [RFC5036] (Section 4.1) defines the "Prefix" 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Prefix (2)   |     Address Family            |     PreLen    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Prefix                                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 1: Prefix FEC Element Format [RFC5036]

Where "Prefix" encoding is as defined for given "Address Family", and whose length (in bits) is specified by the "PreLen" field.

To extend IP address families for MT, two new Address Families named "MT IP" and "MT IPv6" are used to specify IPv4 and IPv6 prefixes within a topology scope.

The format of data associated with these new Address Family is:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     IP Address                                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Reserved             |        MT-ID                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2: MT IP Address Family Format

Where "IP Address" is an IPv4 and IPv6 address/prefix for "MT IP" and "MT IPv6" AF respectively, and the field "MT-ID" corresponds to 16-bit Topology ID for given address.

Where 16-bit "MT-ID" field defines the Topology ID, and the definition and usage of the rest fields in the FEC Elements are same as defined for IP/IPv6 AF. The value of MT-ID 0 corresponds to default topology and MUST be ignored on receipt so as to not cause any conflict/confusion with existing non-MT procedures.

The proposed FEC Elements with "MT IP" Address Family can be used in any LDP message and procedures that currently specify and allow the use of FEC Elements with IP/IPv6 Address Family.

3.3. LDP FEC Elements with MT IP AF

The following section specifies the format extensions of the existing LDP FEC Elements. The "Address Family" of these FEC elements will be set to "MT IP" or "MT IPv6".

The MT Prefix FEC element encoding 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Prefix (2)   | Address Family (MT IP/MT IPv6)|     PreLen    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Prefix                                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Reserved             |        MT-ID                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3: MT Prefix FEC Element Format

Similarly, the MT mLDP FEC elements encoding is as follows, where the mLDP FEC Type can be P2MP(6), MP2MP-up(7), and MP2MP-down(8):

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| mLDP FEC Type | Address Family (MT IP/MT IPv6)| Address Length|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~                       Root Node Address                       ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Reserved             |        MT-ID                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Opaque Length              |    Opaque Value ...           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               +
~                                                               ~
|                                                               |
|                               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4: MT mLDP FEC Element Format

The MT Typed Wildcard FEC element encoding 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Typed Wcard (5)|    FEC Type   |    Len = 6    |  AF = MT IP ..|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|... or MT IPv6 |         MT ID                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 5: MT Typed Wildcard FEC Element

3.4. IGP MT-ID Mapping and Translation

The non-reserved non-special IGP MT-ID values can be used/carried in LDP as-is and need no translation. However, there is a need for translating reserved/special IGP MT-ID values to corresponding LDP MT-IDs. The corresponding special/reserved LDP MT-ID values are defined in later section 10.

3.5. LDP MT Capability Advertisement

We specify a new LDP capability, named "Multi-Topology (MT)", which is defined in accordance with LDP Capability definition guidelines [RFC5561]. The LDP "MT" capability can be advertised by an LDP speaker to its peers either during the LDP session initialization or after the LDP session is setup to announce LSR capability to support MTR for the given IP address family.

The "MT" capability is specified using "Multi-Topology Capability" TLV. The "Multi-Topology Capability" TLV format is in accordance with LDP capability guidelines as defined in [RFC5561]. To be able to specify IP address family, the capability specific data (i.e. "Capability Data" field of Capability TLV) is populated using "Typed Wildcard FEC Element" as defined in [RFC5918].

The format of "Multi-Topology Capability" 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|U|F| Multi-Topology Cap.(IANA) |            Length             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|S| Reserved    |                                               |
+-+-+-+-+-+-+-+-+                                               |
~                Typed Wildcard FEC element(s)                  ~
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 6: Multi-Topology Capability TLV Format

Where:

- o U- and F-bits: MUST be 1 and 0, respectively, as per Section 3 of LDP Capabilities [RFC5561].
- o Multi-Topology Capability: Capability TLV type (IANA assigned)
- o S-bit: MUST be 1 if used in LDP "Initialization" message. MAY be set to 0 or 1 in dynamic "Capability" message to advertise or withdraw the capability respectively.
- o Typed Wildcard FEC element(s): One or more elements specified as the "Capability data".
- o Length: The length (in octets) of TLV.

The encoding of Typed Wcard FEC element, as defined in [RFC5561], is defined in the Section 3.3 of this document.

3.6. Procedures

To announce its MT capability for an IP address family, LDP FEC type, and Multi Topology, an LDP speaker MAY send "MT Capability" including the exact Typed Wildcard FEC element with corresponding "Address Family" field (i.e. set to "MT IP" for IPv4 and set to "MT IPv6" for IPv6 address family), corresponding "FEC

Type" field (i.e. set to "P2P", "P2MP", "MP2MP"), and corresponding "MT-ID". To announce its MT capability for both IPv4 and IPv6 address family, or for multiple FEC types, or for multiple Multi Topologies, an LDP speaker MAY send "MT Capability" with one or more MT Typed FEC elements in it.

- o The capability for supporting multi-topology in LDP can be advertised during LDP session initialization stage by including the LDP MT capability TLV in LDP Initialization message. After an LDP session is established, the MT capability can also be advertised or withdrawn using Capability message (only if "Dynamic Announcement" capability [RFC5561] has already been successfully negotiated).

- o If an LSR has not advertised MT capability, its peer must not send messages that include MT identifier to this LSR.

- o If an LSR receives a Label Mapping message with MT parameter from downstream LSR-D and its upstream LSR-U has not advertised MT capability, an LSP for the MT will not be established.

- o We propose to add a new notification event to signal the upstream that the downstream is not capable.

- o If an LSR is changed from non-MT capable to MT capable, it sets the S bit in MT capability TLV and advertises via the Capability message. The existing LSP is treated as LSP for default MT (ID 0).

- o If an LSR is changed from LDP-MT capable to non-MT capable, it may initiate withdraw of all label mapping for existing LSPs of all non-default MTs. Then it clears the S bit in MT capability TLV and advertises via the Capability message.

- o If an LSR is changed from IGP-MT capable to non-MT capable, it may wait until the routes update to withdraw FEC and release the label mapping for existing LSPs of specific MT.

3.7. LDP Sessions

Depending on the number of label spaces supported, if a single global label space is supported, there will be one session supported for each pair of peer, even there are multiple topologies supported between these two peers. If there are different label spaces supported for different topologies, which means that label spaces overlap with each other for different MTs, then it is suggested to establish multiple sessions for multiple topologies between these two peers. In this case, multiple LSR-IDs need to be allocated beforehand so that each multiple topology can have its own label space ID.

3.8. Reserved MT ID Values

Certain MT topologies are assigned to serve predetermined purposes:

Default-MT: Default topology. This corresponds to OSPF default IPv4 and IPv6, as well as ISIS default IPv4. A value of 0 is proposed.

ISIS IPv6 MT: ISIS default MT-ID for IPv6.

Wildcard-MT: This corresponds to All-Topologies. A value of 65535 (0xffff) is proposed.

We propose a new IANA registry "LDP Multi-Topology ID Name Space" under IANA "LDP Parameter" namespace to keep LDP MT-ID reserved value.

If an LSR receives a FEC element with an "MT-ID" value that is "Reserved" for future use (and not IANA allocated yet), the LSR must abort the processing of the FEC element, and SHOULD send a notification message with status code "Invalid MT-ID" to the sender.

4. MT Applicability on FEC-based features

4.1. Typed Wildcard FEC Element

[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/action for given type of FEC.

The MT extensions proposed in document do not require any extension in procedures for Typed Wildcard FEC element, and these procedures apply as-is to MT wildcarding. The MT extensions, though, allow use of "MT IP" or "MT IPv6" in the Address Family field of the Typed Wildcard FEC element in order to use wildcard operations in the context of a given topology. The use of MT-scoped address family also allows us to specify MT-ID in these operations.

The proposed format in section 4.3 allows an LSR to perform wildcard FEC operations under the scope of a topology. If an LSR wishes to perform wildcard operation that applies to all topologies, it can use "Wildcard Topology" MT-ID as defined in section 4.8. For instance, upon local un-configuration of topology "x", an LSR may send wildcard label withdraw with MT-ID "x" to withdraw all its labels from peer that were advertised under the scope of topology "x". On the other hand, upon some global configuration change, an LSR may send wildcard label withdraw with MT-ID set to "Wildcard Topology" to withdraw all its labels under all topologies from the peer.

4.2. End-of-LIB

[RFC5919] specifies extensions and procedures for an LDP speaker to signal its convergence for given FEC type towards a peer. The procedures defined in [RFC5919] apply as-is to MT FEC element. This means that an LDP speaker MAY signal its IP convergence using Typed Wildcard FEC element, and its MT IP convergence per topology using MT Typed Wildcard FEC element (as defined in earlier section).

5. Error Handling

The extensions defined in this document utilise the existing LDP error handling defined in [RFC5036]. If an LSR receives an error notification from a peer for an MPLS-MT session, it terminates the LDP session by closing the TCP transport connection for the session and discarding all MT-ID label mappings learned via the session.

5.1. MT Error Notification "Invalid Topology ID"

If an LSR has advertized an MT Capability TLV using the Initialization message or Capability message, which includes Typed Wildcard FEC Element(s) with specific MT-ID(s), and it receives an MT message with a MT-ID which is not included in the supported list, it should response this "Invalid Topology ID" status code.

6. Backwards Compatibility

The MPLS-MT solution is backwards compatible with existing LDP enhancements defined in [RFC5036], including message authenticity, integrity of message, and topology loop detection.

7. MPLS Forwarding in MT

Although forwarding is out of the scope of this draft, we include some forwarding consideration for informational purpose here.

The specified signaling mechanisms allow all the topologies to share the platform-specific label space; this is the feature that allows the existing data plane techniques to be used; and the specified signaling mechanisms do not provide any way for the data plane to associate a given packet with a context-specific label space.

8. Security Consideration

No specific security issues with the proposed solutions are known. The proposed extension in this document does not introduce any new

security considerations beyond that already apply to the base LDP specification [RFC5036] and [RFC5920].

9. IANA Considerations

The document introduces following new protocol elements that require IANA consideration and assignments:

- New LDP Capability TLV: "Multi-Topology Capability" TLV (requested code point: 0x510 from LDP registry "TLV Type Name Space").

- New Status Code: "Multi-Topology Capability not supported" (requested code point: 0x50 from LDP registry "Status Code Name Space").

- New Status Code: "Invalid Topology ID" (requested code point: 0x51 from LDP registry "Status Code Name Space").

- New Status Code: "Unknown Address Family" (requested code point: 0x52 from LDP registry "Status Code Name Space").

Registry:

Range/Value	E	Description
0x00000051	1	Invalid Topology ID

Figure 7: New Status Codes for LDP Multi Topology Extensions

- New address families under IANA registry "Address Family Numbers":

  - MT IP: Multi-Topology IP version 4 (requested codepoint: 26)
  - MT IPv6: Multi-Topology IP version 6 (requested codepoint: 27)

Figure 8: Address Family Numbers

- New registry "LDP Multi-Topology (MT) ID Name Space" under "LDP Parameter" namespace. The registry is defined as:

Range/Value	Name
0	Default Topology (ISIS and OSPF)
1-4095	Unassigned
4096	ISIS IPv6 routing topology (i.e. ISIS MT ID #2)
4097-65534	Reserved (for future allocation)
65535	Wildcard Topology (ISIS or OSPF)

Figure 9: LDP Multi-Topology (MT) ID Name Space

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Appendix A. Requirements

The following specific requirements and objectives have been defined in order to provide the functionality described in Section 2 (Introduction), and facilitate CSP configuration and operation:

o Minimise configuration and operation complexity of MPLS-MT across the network.

o The MPLS-MT solution SHOULD NOT require data-plane modification.

o The MPLS-MT solution MUST support multiple topologies. Allowing a an MPLS LSP to be established across a specific, or set of, multiple topologies.

o Control and filtering of LSPs using explicitly including or excluding multiple topologies MUST be supported.

o The MPLS-MT solution MUST be capable of supporting QoS mechanisms.

o The MPLS-MT solution MUST be backwards compatibility with existing LDP message authenticity and integrity techniques, and loop detection.

o Deployment of MPLS-MT within existing MPLS networks should be possible, with nodes not capable of MPLS-MT being unaffected.

Appendix B. Application Scenarios

B.1. Simplified Data-plane

IGP-MT requires additional data-plane resources maintain multiple forwarding for each configured MT. On the other hand, MPLS-MT does not change the data-plane system architecture, if an IGP-MT is mapped to an MPLS-MT. In case MPLS-MT, incoming label value itself can determine an MT, and hence it requires a single NHLFE space. MPLS-MT requires only MT-RIBs in the control-plane, no need to have MT-FIBs. Forwarding IP packets over a particular MT requires either configuration or some external means at every node, to maps an attribute of incoming IP packet header to IGP-MT, which is additional overhead for network management. Whereas, MPLS-MT mapping is required only at the ingress-PE of an MPLS-MT LSP, because of each node identifies MPLS-MT LSP switching based on incoming label, hence no additional configuration is required at every node.

B.2. Using MT for P2P Protection

Mechanisms exist that can configure alternate path via backup-mt, such that if primary link fails, then backup-MT can be used for forwarding. However, such techniques require special marking of IP packets that needs to be forwarded using backup-MT. MPLS-LDP-MT procedures simplify the forwarding of the MPLS packets over backup-MT, as MPLS-LDP-MT procedure distribute separate labels for each MT. How backup paths are computed depends on the implementation, and the algorithm. The MPLS-LDP-MT in conjunction with IGP-MT could be used to separate the primary traffic and backup traffic. For example, service providers can create a backup MT that consists of links that are meant only for backup traffic. Service providers can then establish bypass LSPs, standby LSPs, using backup MT, thus keeping undeterministic backup traffic away from the primary traffic.

B.3. Using MT for mLDP Protection

For the P2MP or MP2MP LSPs setup by using mLDP protocol, there is a need to setup a backup LSP to have an end to end protection for the primary LSP in the applications such as IPTV, where the end to end protection is a must. Since the mLDP LSP is setup following the IGP routes, the second LSP setup by following the IGP routes can not be guaranteed to have the link and node diversity from the primary LSP. By using MPLS-LDP-MT, two topology can be configured with complete link and node diversity, where the primary and secondary LSP can be set up independently within each topology. The two LSPs setup by this mechanism can protect each other end-to-end.

B.4. Service Separation

MPLS-MT procedures allow establishing two distinct LSPs for the same FEC, by advertising separate label mapping for each configured topology. Service providers can implement QoS using MPLS-MT procedures without requiring to create separate FEC address for each class. MPLS-MT can also be used separate multicast and unicast traffic.

B.5. An Alternative inter-AS VPN Solution

When the LSP is crossing multiple domains for the inter-as VPN scenarios, the LSP setup process can be done by configuring a set of routers which are in different domains into a new single domain with a new topology ID using the LDP multiple topology. All the routers belong this new topology will be used to carry the traffic across multiple domains and since they are in a single domain with the new topology ID, so the LDP LSP set up can be done without propagating VPN routes across AS boundaries.