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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

It would be advantageous for Communications Service Providers (CSP)
to support Multiple Topologies (MT) within MPLS environments
(MPLS-MT). Beneficial MPLS-MT deployment scenarios 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.

3. 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.

4. Signaling Extensions

4.1. 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 (4.2 New Address Families: MT IP) defines
   the extension required to bind "prefix-related" FEC to a topology.

4.2. 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                                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
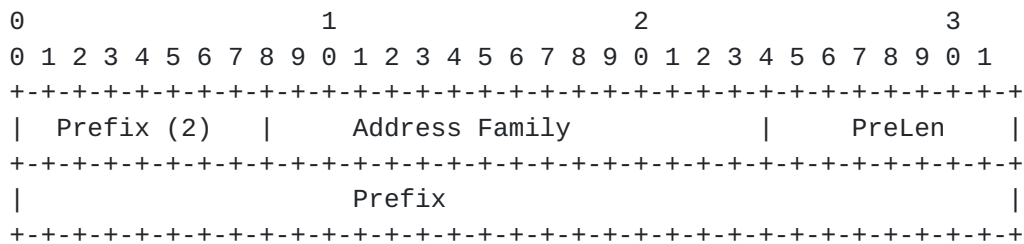
Figure 1: Prefix FEC Element Format [RFC5036]

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              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
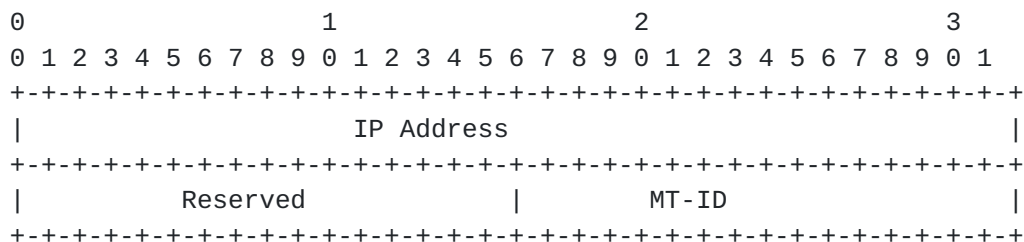
Figure 2: MT IP Address Family Format

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.

[Editors Note - RFC[5036] doesn't specify the handling of unknown
Address Family. After we have introduced the two new address family
here, RFC[5036] need to be updated to add the handling procedure for

the unknown address families.

4.3. LDP FEC Elements with MT IP AF

When introducing the new Address Family, it will make the extension
to all the prefix-related FEC Elements by nature. This 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 will 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
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 | Prefix (2)   | Address Family (MT IP/MT IPv6)|    PreLen    |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                         Prefix                               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |          Reserved          |           MT-ID                 |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
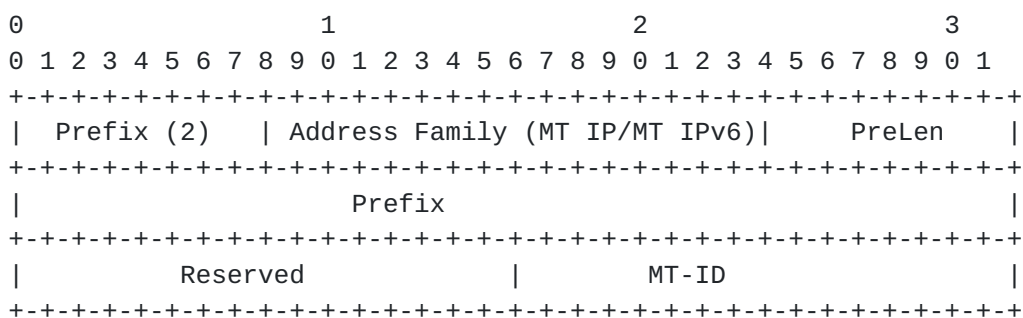
Figure 3: MT Prefix FEC Element Format

Similarly, the MT mLDP FEC elements will be encoded 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 ...             |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                                +
  ~                                                             ~
  |                                                             |
  |                             +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |                             |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
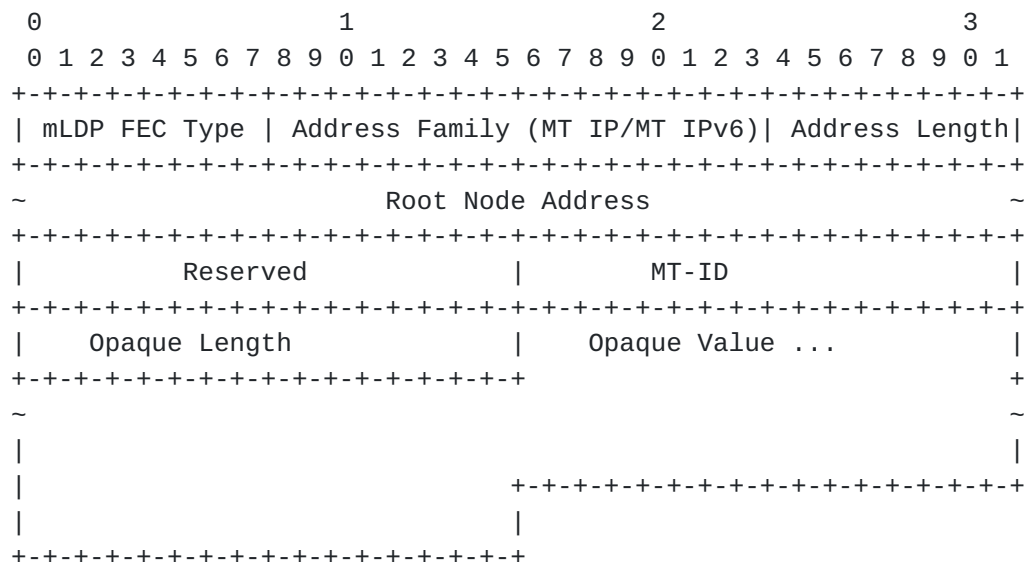
Figure 4: MT mLDP FEC Element Format

And 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

4.4. 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.

4.5. 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].

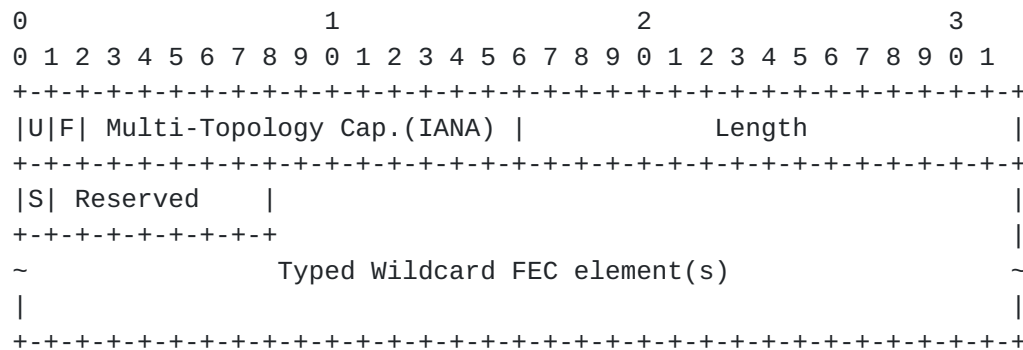The format of "Multi-Topology Capability" TLV is as follows:

```
   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 4.3 of this document.

4.6. Procedures

   To announce its MT capability for given IP address family, given LDP
   FEC type, and given 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

   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.

   o There will be case where IGP is MT capable but MPLS is not and the
      handling procedure for this case is TBD.

4.7. 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.

   [Editors Note - This section requires further discussion]

4.8. Reserved MT ID Values

   Certain MT topologies are assigned to serve pre-determined 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.

   [Editors Note - This section requires further discussion].

5. MT Applicability on FEC-based features

5.1. 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.

5.2. 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).

6. Error Handling

The extensions defined in this document utilise the existing LDP
error handling defined in [RFC5036]. Errors and events are signaled
to MPLS-MT peers using LDP notification messages. There are two
kinds of MPLS-MT notification messages:

1. Error Notifications.

These are used to signal fatal errors. 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.

2. Advisory Notifications.

These are used to pass an LSR information about the MT-ID LDP session
and the status of some previous message received from the peer.

6.1. MT Error Notifications

Multi-Topology Capability not supported.

Invalid Topology ID

6.2. MT Advisory Notifications

Unknown Address Family ("MT IP" and "MT IPv6")

7. 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.

8. 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.

9. 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].

10. IANA Considerations

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

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

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

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

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

```
        Registry:
        Range/Value     E    Description
        -------------   ---  -----------------------------
        0x00000050      1    Multi-Topology Capability not supported
        0x00000051      1    Invalid Topology ID
        0x00000052      0    Unknown Address Family
```

Figure 7: New Status Codes for LDP Multi Topology Extensions

o 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

o 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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   Eric Rosen, IJsbrand Wijnands, Dimitri Papadimitriou, Yiqun Chai for
   their valuable comments on this draft.

12. References

12.1. Normative References

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   [RFC5919] Asati, R., Mohapatra, P., Chen, E., and B. Thomas,
              "Signaling LDP Label Advertisement Completion", RFC 5919,
              August 2010.

   [RFC5918] Asati, R., Minei, I., and B. Thomas, "Label Distribution
              Protocol (LDP) 'Typed Wildcard' Forward Equivalence Class

(FEC)", RFC 5918, August 2010.

[RFC6388]   Wijnands, IJ., Minei, I., Kompella, K., and B. Thomas,
            "Label Distribution Protocol Extensions for Point-to-
            Multipoint and Multipoint-to-Multipoint Label Switched
            Paths", RFC 6388, November 2011.

12.2. Informative References

[RFC5920]   Fang, L., "Security Framework for MPLS and GMPLS
            Networks", RFC 5920, July 2010.

Appendix A. Appendix

A.1. Application Scenarios

A.1.1. 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.

A.1.2. Using MT for P2P Protection

We know that [IP-FRR-MT] can be used for configuring 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.

A.1.3. 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.

A.1.4. 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.

A.1.5. 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.

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