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**Requirements for multipoint extensions to the Label Distribution
Protocol**

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Abstract

   This document lists a set of functional requirements for Label
   Distribution Protocol (LDP) extensions for setting up point-to-
   multipoint (P2MP) and potentially multipoint-to-multipoint (MP2MP)
   Label Switched Paths (LSP), in order to deliver point-to-multipoint
   applications over a Multi Protocol Label Switching (MPLS)
   infrastructure. It is intended that solutions that specify LDP
   procedures for setting up P2MP and MP2MP LSP satisfy these
   requirements.

Conventions used in this document

   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.

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## 1. Terminology

     LSR: Label Switching Router

     LSP: MPLS Label Switched Path

     Ingress LSR: Router acting as a sender of an LSP

     Egress LSR: Router acting as a receiver of an LSP

     P2P LSP: A LSP that has one unique Ingress LSR and one unique
              Egress LSR

     MP2P LSP: A LSP that has one or more Ingress LSRs and one unique
              Egress LSR

     P2MP LSP: A LSP that has one unique Ingress LSR and one or more
              Egress LSRs

     MP2MP LSP: A bidirectional LSP connecting a group of two or more
                LSRs acting equally as Ingress LSR or Egress
                LSR

     Leaf LSR: Egress LSR of a P2MP LSP or Ingress/Egress LSR of a
              MP2MP LSP

     MP LSP: P2MP LSP or MP2MP LSP

     Transit LSR: A LSR of a MP LSP that has one or more downstream
                  LSRs

     Branch LSR: A LSR of a P2MP LSP that has more than one downstream
                 LSRs

     Hub LSR: A LSR of a MP2MP LSP that has two or more
              neighbour LSRs

     Bud LSR: A LSR of a MP LSP that is an egress but also has one or
              more directly connected downstream LSRs

**2**. **Introduction**

   Many operators have deployed LDP [LDP] for setting up point-to-point
   (P2P) and multipoint-to-point (MP2P) LSPs, in order to offer point-to
   -point services in MPLS backbones.

   There are emerging requirements for supporting delivery of point-to-
   multipoint applications in MPLS backbones, such as those defined in
   [L3VPN-MCAST] and [L2VPN-MCAST].

   An interesting and useful approach for operators who want to support
   point-to-multipoint traffic delivery on an MPLS backbone and have
   already deployed LDP for P2P traffic would be to rely on LDP
   extensions in order to setup point-to-multipoint (P2MP) LSPs and
   potentially multipoint-to-multipoint (MP2MP) LSPs. This would bring
   consistency with P2P MPLS applications and would ease the delivery of
   point-to-multipoint applications in an MPLS backbone.

   This document lists a set of requirements for LDP extensions, for
   setting up P2MP LSPs and potentially MP2MP LSPs, so as to deliver
   P2MP traffic over a MPLS infrastructure.
   It is intended that solutions that specify LDP procedures for P2MP
   and MP2MP LSP setup, satisfy these requirements.

   Note that generic requirements for point-to-multipoint extensions to
   MPLS are out of the scope of this document. Rather this document
   describes solution specific requirements related to LDP extensions in
   order to set up P2MP and MP2MP LSPs.

   Other mechanisms could be used for setting up P2MP and MP2MP LSPs,
   such as for instance PIM extensions, but these are out of the scope
   of this document. The objective is not to compare these mechanisms
   but rather to focus on the requirements for an LDP extension
   approach.

   Section 3 points out the problem statement. Section 4 illustrates
   application scenarios. Finally section 5 addresses detailed
   requirements.

3. Problem Statement and Requirements Overview

3.1. Problem Statement

   Many operators have deployed LDP [LDP] for setting up P2P and MP2P
   MPLS LSPs as PE-to-PE tunnels so as to carry point-to-point traffic
   essentially in Layer 3 and Layer 2 VPN networks.
   There are emerging requirements for supporting multicast traffic
   delivery within these VPN infrastructures ([L3VPN-MCAST] and [L2VPN-
   MCAST]).
   For various reasons, including consistency with P2P applications, and
   taking full advantages of MPLS network infrastructure, it would be
   highly desirable to use MPLS LSPs for the delivery of multicast
   traffic.
   This could be implemented by setting up a group of P2P or MP2P LSPs,
   but such an approach may be sub-optimal since it would result in data
   replication at the ingress LSR, and bandwidth inefficiency (duplicate
   data traffic within the network).
   Hence new mechanisms are required that would allow traffic from an
   Ingress LSR to be efficiently delivered to a number of Egress LSRs in
   an MPLS backbone, avoiding duplicate copies of a packet on a given
   link.

   Such efficient traffic delivery requires setting up P2MP LSPs. A P2MP
   LSPs is an LSP starting at an Ingress LSR, and ending on a set of one
   or more Egress LSRs. Traffic sent by the Ingress LSR is replicated on
   one or more Branch LSRs down to Egress LSRs.

   Requirements for setting up P2MP TE LSPs have been expressed in
   [P2MP-TE-REQ].  RSVP-TE extensions for setting up P2MP Traffic
   Engineered LSPs have been defined in [P2MP-TE-RSVP]. This approach is
   useful, in network environments where Traffic Engineering
   capabilities are required.
   However, for operators that deployed LDP for setting up PE-to-PE
   unicast MPLS LSPs, and without the need of traffic engineering, an
   interesting approach would be using LDP extensions for setting up
   P2MP LSPs.

   Note that there are other alternatives for setting up P2MP (e.g. PIM
   extensions defined in [PIM-MPLS]), that could be useful in various
   situations. These are out of the scope of this document.

   This document focuses on the LDP approach for setting up P2MP LSPs.
   The following gives a set of guidelines that a specification of LDP
   extensions for setting up P2MP LSPs should follow.

**3.2. Requirements overview**

   The multi-point (MP) LDP mechanism MUST support setting up P2MP LSPs,
   i.e. LSPs with one Ingress LSR and one or more egress LSRs, with
   traffic replication at some Branch LSRs.

   For traffic delivery between a group of N LSRs which are acting
   indifferently as Ingress or Egress LSRs, it could be preferable to
   setup MP2MP LSP connecting all these LSRs, instead of having N P2MP
   LSPs. This would significantly reduce the amount of states that must
   be maintained on a given LSR.
   The traffic sent by any Leaf LSRs of a MP2MP LSP is delivered to all
   other Leaf LSRs of the MP2MP LSP.

   Hence the MP LDP mechanism SHOULD also allow setting up MP2MP LSPs,
   connecting a group of leaf LSRs.

   Note that in the following we use the term MP LSP when referring
   to P2MP and MP2MP LSPs.

   The MP LDP mechanism MUST allow the arbitrary addition or removal of
   leaves associated with a MP LSP.

   The MP LDP mechanism MUST interoperate seamlessly with existing P2P
   and MP2P LDP mechanisms.
   It is of paramount importance that MP LDP mechanisms MUST NOT impede
   the operation of existing P2P/MP2P LSPs.

   Also the MP LDP mechanism SHOULD scale independently from the number
   of Leaf LSRs. For example, it SHOULD NOT create an extraordinary
   number of LFIB entries even as the number of leaves increases.


**4. Application scenarios**

To be completed in next revision

**5**. Detailed Requirements

**5.1**. MP LSPs

**5.1.1**. P2MP LSP

   The MP LDP mechanism MUST support setting up P2MP LSPs.

   A P2MP LSP has one Ingress LSR and one or more Egress LSRs. Traffic
   sent by the Ingress LSR is received by all Egress LSRs. The specific
   aspects related to P2MP LSP is the action required at
   a Branch LSR, where data replication occurs. Incoming labelled data
   is appropriately replicated to several outgoing interfaces which may
   use different labels. Only one copy of a packet MUST be sent on a
   given link of a P2MP LSP.

   A P2MP LSP MUST be identified by a constant and unique identifier
   within the whole LDP domain, whatever the number of leaves, which
   may vary dynamically.
   This identifier will be used so as to add/remove leaves to/from the
   P2MP tree.

**5.1.2**. MP2MP LSP

   The MP LDP mechanism SHOULD allow setting up MP2MP LSPs.

   A MP2MP LSP is a bidirectional LSP whose Leaf LSRs act indifferently
   as Ingress or Egress. Traffic sent by any Leaf LSRs is received by
   all other Leaf LSRs. Only one copy of a packet MUST be sent on a
   given link of a MP2MP LSP. The specific aspect related to a MP2MP LSP
   is the action required at Hub LSRs, where data replication occurs. A
   Hub LSR has more than two interfaces on the LSP. A Hub LSR replicates
   labeled packets received on any interface of the LSP to all other
   interfaces of the LSP, which may use different labels.
   A Leaf LSR of a MP2MP LSP MUST NOT receive back a packet it had
   previously transmitted on the MP2MP LSP.

   A MP2MP LSP MUST be identified by a constant and unique identifier
   within the whole LDP domain, whatever the number of leaves, which
   may vary dynamically.
   This identifier will be used so as to add and remove leaves to and
   from the MP2MP tree.

**5.1.3**. **MP LSP FEC**

   As with P2P MPLS technology [LDP], traffic MUST be classified into a
   FEC in this MP extension. All packets which belong to a particular
   P2MP or MP2MP FEC and which travel from a particular node MUST use
   the same MP LSP.

   As such, a solution MUST specify a FEC that is suitable for
   P2MP/MP2MP forwarding. Such P2MP/MP2MP FEC MUST be distinguished
   clearly from the exiting P2P/MP2P FEC.

**5.2**. **Setting up, tearing down and modifying MP LSPs**

   The MP LDP mechanism MUST support the establishment, maintenance and
   teardown of MP LSPs in a scalable manner. This MUST include both the
   existence of a large amount of MP LSPs within a single network and a
   large amount of leaf LSRs for a single MP LSP.

   In order to scale well with a large number of leaves it is
   RECOMMENDED to follow a leaf-initiated MP LSP setup approach. For
   that purpose, leaves will have to be aware of the MP LSP identifier.
   The way a Leaf LSR discovers MP LSPs identifiers SHOULD not be part
   of MP LDP extensions. Instead this SHOULD be part of the applications
   that will use MP LSPs, and it is out of the scope of this document.

   The MP LDP mechanism MUST allow the dynamic addition and removal of
   leaves to and from a MP LSP. It is RECOMMENDED that these operations
   be leaf-initiated.
   It is RECOMMENDED that these operations do not cause any additional
   processing except on the path from the Branch (or possibly Hub) LSR
   to the added or removed leaf LSR.

**5.3**. **Label Advertisement**

   The MP LDP mechanism SHOULD support downstream unsolicited label
   advertisement mode. This is well suited to a leaf-initiated approach
   and is consistent with P2P/MP2P LDP operations.

   In order to follow a leaf initiated LSP setup approach, MP LDP
   mechanism SHOULD support the Ordered label distribution control mode.
   Note that the Independent control mode is not relevant in a MP
   context, because the upstream LSRs cannot distribute labels
   independently like P2P/MP2P LDP, they must wait for label
   distribution from downstream LSRs.

   Upstream label allocation ([MPLS-UPSTREAM]) may be particularly
   useful to avoid packet replication on LAN interfaces of a MP LSP, or
   when encapsulating the MP LSP into a P2MP TE tunnel.

Hence the MP LDP mechanism SHOULD also support upstream solicited
   label advertisement mode, where the solicitation is made by the
   downstream LSR, but the label is assigned by the upstream LSR.

Note that the existing base LDP specification [[RFC3036](RFC3036)] does not
specify upstream solicited label advertisement. Hence specific
extensions SHOULD be defined.

## [5.4](5.4). Data Duplication

Data duplication refers to the receipt of multiple copies of a packet
by any leaf. Although this may be a marginal situation, it may also
be detrimental for certain applications. Hence, data duplication
SHOULD be avoided as much as possible, and limited to (hopefully
rare) transitory conditions.

Note, in particular, that data duplication might occur if MP LSP
rerouting is being performed (See also [section 5.6](section 5.6)).

## [5.5](5.5). Avoiding loops

The MP LDP mechanism SHOULD have a mechanism to avoid routing loops
even during transient events. Furthermore, the MP LDP mechanism MUST
avoid routing loops that may trigger unexpected non-localized
exponential growth of traffic. Note that any loop-avoidance mechanism
MUST respect scalability requirements, and particularly SHOULD scale
independently from the number of Leaf LSRs.

## [5.6](5.6). MP LSP routing

As with P2P and MP2P LDP LSPs, the MP LDP mechanism MUST support hop-
by-hop LSP routing. MP LSP LDP-based routing SHOULD rely upon the
information maintained in LSR Routing Information Bases (RIB). For
instance, P2MP LSP routing could rely upon a shortest path to the
Ingress LSR, and MP2MP LSP routing could rely upon a shortest path to
one or more specific Hub LSRs. Note that unlike P2P/MP2P LDP routing,
Equal Cost Multi Path (ECMP) MUST be avoided with MP LDP routing.

## [5.7](5.7). MP LSP Re-routing

The MP LDP mechanism MUST support the rerouting of a MP LSP in the
following cases:
      -A better path exists (e.g. new link, netric change)
      -Network failure (link or node)
      -Planned maintenance

## [5.7.1](5.7.1). Rerouting on a Better Path

The MP LDP mechanism MUST allow for rerouting of a MP LSP in case a
better path is created in the network, for instance as a result of a
metric change, or the addition of links or nodes.
Traffic disruption MUST be minimized during such rerouting. It is
RECOMMENDED that devices perform make-before-break for traffic on MP

LSPÆs to minimize traffic disruption.
   It SHOULD be feasible to avoid packet loss during such rerouting.

   Unnecessary data duplication during such rerouting MUST also be
   minimized.

**5.7.2**. **Rerouting due to a Network Failure**

   The MP LDP mechanism MUST allow for rerouting of a MP LSP in case of
   link or node failure(s). The rerouting time SHOULD be minimized as
   much as possible so as to reduce traffic disruption.

   A mechanism MUST be defined to prevent constant MP LSP teardown and
   rebuild which may be caused by the instability of a specific
   link/node in the network.

**5.7.3**. **Rerouting Due to Planned Maintenance**

   The MP LDP mechanism MUST support planned maintenance operations. It
   SHOULD be possible to reroute a MP-LSP before a link/node is
   deactivated for maintenance purposes. Traffic disruption MUST be
   minimized during such rerouting. It SHOULD be feasible to avoid
   packet loss during such rerouting.
   Unnecessary traffic duplication during such rerouting MUST also be
   minimized.

**5.8**. **Support for LAN interfaces**

   The MP LDP mechanism MUST provide a way for a Hub/Branch LSR to send
   a single copy of the data onto an Ethernet LAN interface and reach
   multiple adjacent downstream nodes. This requires that the same label
   be negotiated will all downstream LSRs for the LSP. In order to ease
   such negotiation an upstream label allocation approach may be used.

**5.9**. **Support for encapsulation in P2P and P2MP TE tunnels**

   The MP LDP mechanism MUST support nesting MP LSPs into P2P and P2MP
   TE tunnels.
   The MP LDP mechanism MUST provide a way for a Hub/Branch LSR of a MP
   LPS, which is also a Head End LSR of a P2MP TE tunnel, to send a
   single copy of the data onto the tunnel and reach all downstream LSRs
   on the MP LSP, which are also Egress LSRs of the tunnel. As with LAN
   interfaces, this requires that the same LDP label be negotiated with
   all downstream LSRs for the MP LDP LSP. In order to ease such
   negotiation, an upstream label allocation approach may be used.

**5.10**. **Label spaces**

   Labels for MP LSPs and P2P/MP2P LSPs MAY be assigned from shared or
   dedicated label spaces.
   MPLS Context Specific Label Spaces ([UPSTREAM-LABEL]) and
   particularly Upstream label spaces and Tunnel label spaces MAY be

required to support upstream label allocation so as to avoid packet
replication on LAN or P2MP TE Tunnel interfaces.

Note that dedicated label spaces will require the establishment of separate MP LDP sessions.

## [5.11](5.11). IPv4/IPv6 support

The MP LDP mechanism MUST be equally applicable to IPv4 and IPv6 traffic. Likewise, it SHOULD be possible to convey both kinds of traffic in a given MP LSP facility.

Also the MP LDP mechanism MUST support the establishment of LDP sessions over both IPv4 and IPv6 control planes.

## [5.12](5.12). Multi-Area LSPs

The MP LDP mechanism MUST support the establishment of multi-area MP LSPs, i.e. LSPs whose leaves do not all reside in the same IGP area. This SHOULD be possible without requiring the advertisement of Leaf LSRs' addresses across IGP areas.

## [5.13](5.13). OAM

LDP management tools ([[LDP-MIB](LDP-MIB)],...) MUST be enhanced to support MP LDP extensions. This may yield a new MIB module, which may possibly be inherited from the LDP MIB.

In order to facilitate correct management, MP LDP LSPs MUST have unique identifiers, otherwise it is impossible to determine which LSP is being managed.
OAM facilities will have special demands in MP MPLS environments especially within the context of tracing the paths and determining the connectivity of MP LSPs. Further and precise requirements and mechanisms for OAM purpose are out of the scope of this document. It is expected that a separate document will cover these requirements and mechanisms.

## [5.14](5.14). Graceful Restart and Fault Recovery

LDP Graceful Restart mechanisms [[LDP-GR](LDP-GR)] and Fault Recovery [[LDP-FT](LDP-FT)] mechanisms SHOULD be enhanced to support MP LDP LSPs.

Particularly [[LDP-GR](LDP-GR)] applies only to downstream unsolicited label distribution. Hence new mechanisms are required to account for upstream label assignment, particularly in multi segment LANs.

## [5.15](5.15). Robustness

A solution SHOULD avoid whatever single points of failures or propose some technical solutions for a failover mechanism (e.g., redundancy/ failover of Hub LSRs).

**5.16. Scalability**

   Scalability is a key requirement for the MP LDP mechanism.
   It MUST be designed to scale well with an increase in the number of
   any of the following:
      - number of Leaf LSRs per MP LSP
      - number of Branch/Hub LSRs per MP LSP
      - number of MP LSPs per LSR

   The size of a MP LSP state on a LSR SHOULD be independent of the
   number of leaves, and SHOULD only depend on the number of adjacent
   LSRs.

**5.16.1. Orders of magnitude of the expected numbers of MP LSPs and
          leaves per LSP in operational networks**

   To be completed in next revision

**5.17. Backward Compatibility**

   In order to allow for a smooth migration, the MP LDP mechanism SHOULD
   offer as much backward compatibility as possible. In particular, the
   solution SHOULD allow the setup of a MP LSP along non branch/hub
   transit LSRs that do not support MP LDP extensions.

   Also, the MP LDP solution MUST interoperate seamlessly with current
   LDP mechanisms and inherit its capability sets from [LDP]. The MP LDP
   solution MUST not impede the operation of P2P/MP2P LSPs. A MP LSP
   solution MUST be designed in such a way that it allows P2P/MP2P and
   MP LSPs to be signalled on the same interface.

**6. Evaluation criteria**

**6.1. Performances**

      The solution will be evaluated with respect to the following
      criteria:

      (1) Time (in msec) to add or remove a Leaf LSR
      (2) Time (in msec) to repair a MP LSP in case of link or node
          failure
      (3) Scalability (state size, number of messages, message size).

   Particularly, the MP LDP mechanism SHOULD be designed so that
   convergence times in case of link or node failure are minimized, in
   order to limit traffic disruption.

**6.2. Complexity and Risks**

The proposed solution SHOULD not introduce complexity to the current
LDP operations to such a degree that it would affect the stability
and diminish the benefits of deploying such MP LDP solution.

## 7. Security Considerations

This document does not introduce any new security issues beyond those inherent to LDP [LDP] and a MP LDP solution may use the same mechanisms.

## 8. Acknowledgment

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