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Label Distribution Protocol Extensions for Point-to-Multipoint and Multipoint-to-Multipoint Label Switched Paths
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Abstract

This document describes extensions to the Label Distribution Protocol (LDP) for the setup of point to multi-point (P2MP) and multipoint-to-multipoint (MP2MP) Label Switched Paths (LSPs) in Multi-Protocol Label Switching (MPLS) networks. The solution relies on LDP without

requiring a multicast routing protocol in the network. Protocol elements and procedures for this solution are described for building such LSPs in a receiver-initiated manner. There can be various applications for P2MP/MP2MP LSPs, for example IP multicast or support for multicast in BGP/MPLS L3VPNs. Specification of how such applications can use a LDP signaled P2MP/MP2MP LSP is outside the scope of this document.

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1. Introduction

The LDP protocol is described in [1]. It defines mechanisms for setting up point-to-point (P2P) and multipoint-to-point (MP2P) LSPs in the network. This document describes extensions to LDP for setting up point-to-multipoint (P2MP) and multipoint-to-multipoint (MP2MP) LSPs. These are collectively referred to as multipoint LSPs (MP LSPs). A P2MP LSP allows traffic from a single root (or ingress) node to be delivered to a number of leaf (or egress) nodes. A MP2MP LSP allows traffic from multiple ingress nodes to be delivered to multiple egress nodes. Only a single copy of the packet will be sent on any link traversed by the MP LSP (see note at end of Section 2.3.1). This is accomplished without the use of a multicast protocol in the network. There can be several MP LSPs rooted at a given ingress node, each with its own identifier.

The solution assumes that the leaf nodes of the MP LSP know the root node and identifier of the MP LSP to which they belong. The mechanisms for the distribution of this information are outside the scope of this document. The specification of how an application can use a MP LSP signaled by LDP is also outside the scope of this document.

Interested readers may also wish to peruse the requirement draft [4] and other documents [8] and [9].

1.1. 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 [2].

1.2. Terminology

The following terminology is taken from [4].

P2P LSP: An LSP that has one Ingress LSR and one Egress LSR.

P2MP LSP: An LSP that has one Ingress LSR and one or more Egress LSRs.

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

MP2MP LSP: A LSP that connects a set of leaf nodes, acting indifferently as ingress or egress.

MP LSP: A multipoint LSP, either a P2MP or an MP2MP LSP.

Ingress LSR: Source of the P2MP LSP, also referred to as root node.

Egress LSR: One of potentially many destinations of an LSP, also referred to as leaf node in the case of P2MP and MP2MP LSPs.

Transit LSR: An LSR that has one or more directly connected downstream LSRs.

Bud LSR: An LSR that is an egress but also has one or more directly connected downstream LSRs.

2. Setting up P2MP LSPs with LDP

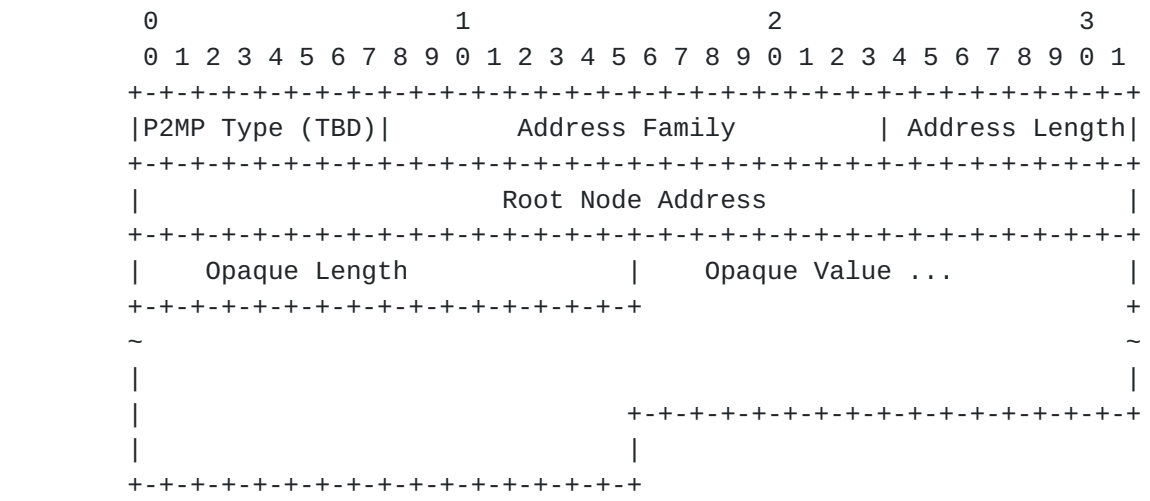
A P2MP LSP consists of a single root node, zero or more transit nodes and one or more leaf nodes. Leaf nodes initiate P2MP LSP setup and tear-down. Leaf nodes also install forwarding state to deliver the traffic received on a P2MP LSP to wherever it needs to go; how this is done is outside the scope of this document. Transit nodes install MPLS forwarding state and propagate the P2MP LSP setup (and tear-down) toward the root. The root node installs forwarding state to map traffic into the P2MP LSP; how the root node determines which traffic should go over the P2MP LSP is outside the scope of this document.

For the setup of a P2MP LSP with LDP, we define one new protocol entity, the P2MP FEC Element to be used in the FEC TLV. The description of the P2MP FEC Element follows.

2.1. The P2MP FEC Element

The P2MP FEC Element consists of the address of the root of the P2MP LSP and an opaque value. The opaque value consists of one or more LDP MP Opaque Value Elements. The opaque value is unique within the context of the root node. The combination of (Root Node Address, Opaque Value) uniquely identifies a P2MP LSP within the MPLS network.

The P2MP FEC element is encoded as follows:



Type: The type of the P2MP FEC element is to be assigned by IANA.

Address Family: Two octet quantity containing a value from ADDRESS FAMILY NUMBERS in [3] that encodes the address family for the Root LSR Address.

Address Length: Length of the Root LSR Address in octets.

Root Node Address: A host address encoded according to the Address Family field.

Opaque Length: The length of the Opaque Value, in octets.

Opaque Value: One or more MP Opaque Value elements, uniquely identifying the P2MP LSP in the context of the Root Node. This is described in the next section.

If the Address Family is IPv4, the Address Length MUST be 4; if the Address Family is IPv6, the Address Length MUST be 16. No other Address Lengths are defined at present.

If the Address Length doesn't match the defined length for the Address Family, the receiver SHOULD abort processing the message containing the FEC Element, and send an "Unknown FEC" Notification

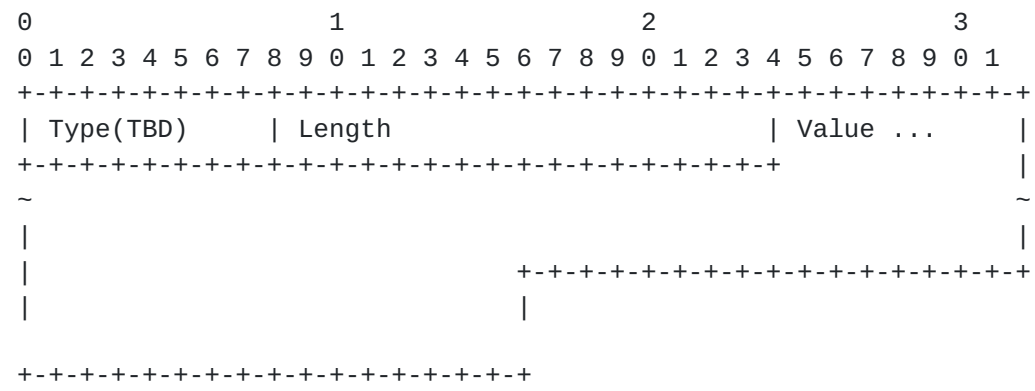
message to its LDP peer signaling an error.

If a FEC TLV contains a P2MP FEC Element, the P2MP FEC Element MUST be the only FEC Element in the FEC TLV.

2.2. The LDP MP Opaque Value Element

The LDP MP Opaque Value Element is used in the P2MP and MP2MP FEC elements defined in subsequent sections. It carries information that is meaningful to leaf (and bud) LSRs, but need not be interpreted by non-leaf LSRs.

The LDP MP Opaque Value Element is encoded as follows:



Type: The type of the LDP MP Opaque Value Element is to be assigned by IANA.

Length: The length of the Value field, in octets.

Value: String of Length octets, to be interpreted as specified by the Type field.

2.2.1. The Generic LSP Identifier

The generic LSP identifier is a type of Opaque Value Element encoded as follows:

Type: 1 (to be assigned by IANA)

Length: 4

Value: A 32bit integer, unique in the context of the root, as identified by the root's address.

This type of opaque value element is recommended when mapping of traffic to LSPs is non-algorithmic, and done by means outside LDP.

2.3. Using the P2MP FEC Element

This section defines the rules for the processing and propagation of the P2MP FEC Element. The following notation is used in the processing rules:

1. P2MP FEC Element <X, Y>: a FEC Element with Root Node Address X and Opaque Value Y.

2. P2MP Label Map <X, Y, L>: a Label Map message with a FEC TLV with a single P2MP FEC Element <X, Y> and Label TLV with label L.

3. P2MP Label Withdraw <X, Y, L>: a Label Withdraw message with a FEC TLV with a single P2MP FEC Element <X, Y> and Label TLV with label L.

4. P2MP LSP <X, Y> (or simply <X, Y>): a P2MP LSP with Root Node Address X and Opaque Value Y.

5. The notation L' -> {<I1, L1> <I2, L2> ..., <In, Ln>} on LSR X means that on receiving a packet with label L', X makes n copies of the packet. For copy i of the packet, X swaps L' with Li and sends it out over interface Ii.

The procedures below are organized by the role which the node plays in the P2MP LSP. Node Z knows that it is a leaf node by a discovery process which is outside the scope of this document. During the course of protocol operation, the root node recognizes its role because it owns the Root Node Address. A transit node is any node (other than the root node) that receives a P2MP Label Map message (i.e., one that has leaf nodes downstream of it).

Note that a transit node (and indeed the root node) may also be a leaf node.

2.3.1. Label Map

The following lists procedures for generating and processing P2MP Label Map messages for nodes that participate in a P2MP LSP. An LSR should apply those procedures that apply to it, based on its role in the P2MP LSP.

For the approach described here we use downstream assigned labels. On Ethernet networks this may be less optimal, see Section 5.

2.3.1.1. Determining one's 'upstream LSR'

A node Z that is part of P2MP LSP <X, Y> determines the LDP peer U which lies on the best path from Z to the root node X. If there are more than one such LDP peers, only one of them is picked. U is Z's "Upstream LSR" for <X, Y>.

When there are several candidate upstream LSRs, the LSR MAY select one upstream LSR using the following procedure:

1. The candidate upstream LSRs are numbered from lower to higher IP address

2. The following hash is performed: H = (Sum Opaque value) modulo N, where N is the number of candidate upstream LSRs

3. The selected upstream LSR U is the LSR that has the number H.

This allows for load balancing of a set of LSPs among a set of candidate upstream LSRs, while ensuring that on a LAN interface a single upstream LSR is selected.

2.3.1.2. Leaf Operation

A leaf node Z of P2MP LSP <X, Y> determines its upstream LSR U for <X, Y> as per Section 2.3.1.1, allocates a label L, and sends a P2MP Label Map <X, Y, L> to U.

2.3.1.3. Transit Node operation

Suppose a transit node Z receives a P2MP Label Map <X, Y, L> from LDP peer T. Z checks whether it already has state for <X, Y>. If not, Z allocates a label L', and installs state to swap L' with L over interface I associated with peer T. Z also determines its upstream LSR U for <X, Y> as per Section 2.3.1.1, and sends a P2MP Label Map <X, Y, L'> to U.

If Z already has state for <X, Y>, then Z does not send a Label Map

message for P2MP LSP <X, Y>. All that Z needs to do in this case is update its forwarding state. Assuming its old forwarding state was L'-> {<I1, L1> <I2, L2> ..., <In, Ln>}, its new forwarding state becomes L'-> {<I1, L1> <I2, L2> ..., <In, Ln>, <I, L>}.

2.3.1.4. Root Node Operation

Suppose the root node Z receives a P2MP Label Map <X, Y, L> from peer T. Z checks whether it already has forwarding state for <X, Y>. If not, Z creates forwarding state to push label L onto the traffic that Z wants to forward over the P2MP LSP (how this traffic is determined is outside the scope of this document).

If Z already has forwarding state for <X, Y>, then Z adds "push label L, send over interface I" to the nexthop, where I is the interface associated with peer T.

2.3.2. Label Withdraw

The following lists procedures for generating and processing P2MP Label Withdraw messages for nodes that participate in a P2MP LSP. An LSR should apply those procedures that apply to it, based on its role in the P2MP LSP.

2.3.2.1. Leaf Operation

If a leaf node Z discovers (by means outside the scope of this document) that it is no longer a leaf of the P2MP LSP, it SHOULD send a Label Withdraw <X, Y, L> to its upstream LSR U for <X, Y>, where L is the label it had previously advertised to U for <X, Y>.

2.3.2.2. Transit Node Operation

If a transit node Z receives a Label Withdraw message <X, Y, L> from a node W, it deletes label L from its forwarding state, and sends a Label Release message with label L to W.

If deleting L from Z's forwarding state for P2MP LSP <X, Y> results in no state remaining for <X, Y>, then Z propagates the Label Withdraw for <X, Y>, to its upstream T, by sending a Label Withdraw <X, Y, L1> where L1 is the label Z had previously advertised to T for <X, Y>.

2.3.2.3. Root Node Operation

The procedure when the root node of a P2MP LSP receives a Label Withdraw message are the same as for transit nodes, except that it would not propagate the Label Withdraw upstream (as it has no

upstream).

2.3.2.4. Upstream LSR change

If, for a given node Z participating in a P2MP LSP <X, Y>, the upstream LSR changes, say from U to U', then Z MUST update its forwarding state by deleting the state for label L, allocating a new label, L', for <X,Y>, and installing the forwarding state for L'. In addition Z MUST send a Label Map <X, Y, L'> to U' and send a Label Withdraw <X, Y, L> to U.

3. Shared Trees

The mechanism described above shows how to build a tree with a single root and multiple leaves, i.e., a P2MP LSP. One can use essentially the same mechanism to build Shared Trees with LDP. A Shared Tree can be used by a group of routers that want to multicast traffic among themselves, i.e., each node is both a root node (when it sources traffic) and a leaf node (when any other member of the group sources traffic). A Shared Tree offers similar functionality to a MP2MP LSP, but the underlying multicasting mechanism uses a P2MP LSP. One example where a Shared Tree is useful is video-conferencing. Another is Virtual Private LAN Service (VPLS) [7], where for some types of traffic, each device participating in a VPLS must send packets to every other device in that VPLS.

One way to build a Shared Tree is to build an LDP P2MP LSP rooted at a common point, the Shared Root (SR), and whose leaves are all the members of the group. Each member of the Shared Tree unicasts traffic to the SR (using, for example, the MP2P LSP created by the unicast LDP FEC advertised by the SR); the SR then splices this traffic into the LDP P2MP LSP. The SR may be (but need not be) a member of the multicast group.

A major advantage of this approach is that no further protocol mechanisms beyond the one already described are needed to set up a Shared Tree. Furthermore, a Shared Tree is very efficient in terms of the multicast state in the network, and is reasonably efficient in terms of the bandwidth required to send traffic.

A property of this approach is that a sender will receive its own packets as part of the multicast; thus a sender must be prepared to recognize and discard packets that it itself has sent. For a number of applications (for example, VPLS), this requirement is easy to meet. Another consideration is the various techniques that can be used to splice unicast LDP MP2P LSPs to the LDP P2MP LSP; these will be described in a later revision.

4. Setting up MP2MP LSPs with LDP

An MP2MP LSP is much like a P2MP LSP in that it consists of a single root node, zero or more transit nodes and one or more leaf LSRs acting equally as Ingress or Egress LSR. A leaf node participates in the setup of an MP2MP LSP by establishing both a downstream LSP, which is much like a P2MP LSP from the root, and an upstream LSP which is used to send traffic toward the root and other leaf nodes. Transit nodes support the setup by propagating the upstream and downstream LSP setup toward the root and installing the necessary MPLS forwarding state. The transmission of packets from the root node of a MP2MP LSP to the receivers is identical to that for a P2MP LSP. Traffic from a leaf node follows the upstream LSP toward the root node and branches downward along the downstream LSP as required to reach other leaf nodes. Mapping traffic to the MP2MP LSP may happen at any leaf node. How that mapping is established is outside the scope of this document.

Due to how a MP2MP LSP is built a leaf LSR that is sending packets on the MP2MP LSP does not receive its own packets. There is also no additional mechanism needed on the root or transit LSR to match upstream traffic to the downstream forwarding state. Packets that are forwarded over a MP2MP LSP will not traverse a link more than once, with the exception of LAN links which are discussed in Section 4.2.1

For the setup of a MP2MP LSP with LDP we define 2 new protocol entities, the MP2MP downstream FEC and upstream FEC element. Both elements will be used in the FEC TLV. The description of the MP2MP elements follow.

4.1. The MP2MP downstream and upstream FEC elements.

The structure, encoding and error handling for the MP2MP downstream and upstream FEC elements are the same as for the P2MP FEC element described in Section 2.1. The difference is that two new FEC types are used: MP2MP downstream type (TBD) and MP2MP upstream type (TBD).

If a FEC TLV contains an MP2MP FEC Element, the MP2MP FEC Element MUST be the only FEC Element in the FEC TLV.

4.2. Using the MP2MP FEC elements

This section defines the rules for the processing and propagation of the MP2MP FEC elements. The following notation is used in the processing rules:

1. MP2MP downstream LSP <X, Y> (or simply downstream <X, Y>): an MP2MP LSP downstream path with root node address X and opaque value Y.

2. MP2MP upstream LSP <X, Y, D> (or simply upstream <X, Y, D>): a MP2MP LSP upstream path for downstream node D with root node address X and opaque value Y.

3. MP2MP downstream FEC element <X, Y>: a FEC element with root node address X and opaque value Y used for a downstream MP2MP LSP.

4. MP2MP upstream FEC element <X, Y>: a FEC element with root node address X and opaque value Y used for an upstream MP2MP LSP.

5. MP2MP Label Map downstream <X, Y, L>: A Label Map message with a FEC TLV with a single MP2MP downstream FEC element <X, Y> and label TLV with label L.

6. MP2MP Label Map upstream <X, Y, Lu>: A Label Map message with a FEC TLV with a single MP2MP upstream FEC element <X, Y> and label TLV with label Lu.

7. MP2MP Label Withdraw downstream <X, Y, L>: a Label Withdraw message with a FEC TLV with a single MP2MP downstream FEC element <X, Y> and label TLV with label L.

8. MP2MP Label Withdraw upstream <X, Y, Lu>: a Label Withdraw message with a FEC TLV with a single MP2MP upstream FEC element <X, Y> and label TLV with label Lu.

The procedures below are organized by the role which the node plays in the MP2MP LSP. Node Z knows that it is a leaf node by a discovery process which is outside the scope of this document. During the course of the protocol operation, the root node recognizes its role because it owns the root node address. A transit node is any node (other then the root node) that receives a MP2MP Label Map message (i.e., one that has leaf nodes downstream of it).

Note that a transit node (and indeed the root node) may also be a leaf node and the root node does not have to be an ingress LSR or leaf of the MP2MP LSP.

4.2.1. MP2MP Label Map upstream and downstream

The following lists procedures for generating and processing MP2MP Label Map messages for nodes that participate in a MP2MP LSP. An LSR should apply those procedures that apply to it, based on its role in the MP2MP LSP.

For the approach described here if there are several receivers for a MP2MP LSP on a LAN, packets are replicated over the LAN. This may not be optimal; optimizing this case is for further study, see [5].

4.2.1.1. Determining one's upstream MP2MP LSR

Determining the upstream LDP peer U for a MP2MP LSP <X, Y> follows the procedure for a P2MP LSP described in Section 2.3.1.1.

4.2.1.2. Determining one's downstream MP2MP LSR

A LDP peer U which receives a MP2MP Label Map downstream from a LDP peer D will treat D as downstream MP2MP LSR.

4.2.1.3. MP2MP leaf node operation

A leaf node Z of a MP2MP LSP <X, Y> determines its upstream LSR U for <X, Y> as per Section 4.2.1.1, allocates a label L, and sends a MP2MP Label Map downstream <X, Y, L> to U.

Leaf node Z expects an MP2MP Label Map upstream <X, Y, Lu> from node U in response to the MP2MP Label Map downstream it sent to node U. Z checks whether it already has forwarding state for upstream <X, Y>. If not, Z creates forwarding state to push label Lu onto the traffic that Z wants to forward over the MP2MP LSP. How it determines what traffic to forward on this MP2MP LSP is outside the scope of this document.

4.2.1.4. MP2MP transit node operation

When node Z receives a MP2MP Label Map downstream <X, Y, L> from peer D associated with interface I, it checks whether it has forwarding state for downstream <X, Y>. If not, Z allocates a label L' and installs downstream forwarding state to swap label L' with label L over interface I. Z also determines its upstream LSR U for <X, Y> as per Section 4.2.1.1, and sends a MP2MP Label Map downstream <X, Y, L'> to U.

If Z already has forwarding state for downstream <X, Y>, all that Z needs to do is update its forwarding state. Assuming its old forwarding state was L'-> {<I1, L1> <I2, L2> ..., <In, Ln>}, its new

forwarding state becomes L'-> {<I1, L1> <I2, L2> ..., <In, Ln>, <I, L>}.

Node Z checks whether it already has forwarding state upstream <X, Y, D>. If it does, then no further action needs to happen. If it does not, it allocates a label Lu and creates a new label swap for Lu from the label swap(s) from the forwarding state downstream <X, Y>, omitting the swap on interface I for node D. This allows upstream traffic to follow the MP2MP tree down to other node(s) except the node from which Z received the MP2MP Label Map downstream <X, Y, L>. Node Z determines the downstream MP2MP LSR as per Section 4.2.1.2, and sends a MP2MP Label Map upstream <X, Y, Lu> to node D.

Transit node Z will also receive a MP2MP Label Map upstream <X, Y, Lu> in response to the MP2MP Label Map downstream sent to node U associated with interface Iu. Node Z will add label swap Lu over interface Iu to the forwarding state upstream <X, Y, D>. This allows packets to go up the tree towards the root node.

4.2.1.5. MP2MP root node operation

4.2.1.5.1. Root node is also a leaf

Suppose root/leaf node Z receives a MP2MP Label Map downstream <X, Y, L> from node D associated with interface I. Z checks whether it already has forwarding state downstream <X, Y>. If not, Z creates forwarding state for downstream to push label L on traffic that Z wants to forward down the MP2MP LSP. How it determines what traffic to forward on this MP2MP LSP is outside the scope of this document. If Z already has forwarding state for downstream <X, Y>, then Z will add the label push for L over interface I to it.

Node Z checks if it has forwarding state for upstream <X, Y, D>. If not, Z allocates a label Lu and creates upstream forwarding state to push Lu with the label push(s) from the forwarding state downstream <X, Y>, except the push on interface I for node D. This allows upstream traffic to go down the MP2MP to other node(s), except the node from which the traffic was received. Node Z determines the downstream MP2MP LSR as per section Section 4.2.1.2, and sends a MP2MP Label Map upstream <X, Y, Lu> to node D. Since Z is the root of the tree Z will not send a MP2MP downstream map and will not receive a MP2MP upstream map.

4.2.1.5.2. Root node is not a leaf

Suppose the root node Z receives a MP2MP Label Map dowbstream <X, Y, L> from node D associated with interface I. Z checks whether it already has forwarding state for downstream <X, Y>. If not, Z

creates downstream forwarding state and installs a outgoing label L over interface I. If Z already has forwarding state for downstream <X, Y>, then Z will add label L over interface I to the existing state.

Node Z checks if it has forwarding state for upstream <X, Y, D>. If not, Z allocates a label Lu and creates forwarding state to swap Lu with the label swap(s) from the forwarding state downstream <X, Y>, except the swap for node D. This allows upstream traffic to go down the MP2MP to other node(s), except the node is was received from. Root node Z determines the downstream MP2MP LSR D as per Section 4.2.1.2, and sends a MP2MP Label Map upstream <X, Y, Lu> to it. Since Z is the root of the tree Z will not send a MP2MP downstream map and will not receive a MP2MP upstream map.

4.2.2. MP2MP Label Withdraw

The following lists procedures for generating and processing MP2MP Label Withdraw messages for nodes that participate in a MP2MP LSP. An LSR should apply those procedures that apply to it, based on its role in the MP2MP LSP.

4.2.2.1. MP2MP leaf operation

If a leaf node Z discovers (by means outside the scope of this document) that it is no longer a leaf of the MP2MP LSP, it SHOULD send a downstream Label Withdraw <X, Y, L> to its upstream LSR U for <X, Y>, where L is the label it had previously advertised to U for <X,Y>.

Leaf node Z expects the upstream router U to respond by sending a downstream label release for L and a upstream Label Withdraw for <X, Y, Lu> to remove Lu from the upstream state. Node Z will remove label Lu from its upstream state and send a label release message with label Lu to U.

4.2.2.2. MP2MP transit node operation

If a transit node Z receives a downstream label withdraw message <X, Y, L> from node D, it deletes label L from its forwarding state downstream <X, Y> and from all its upstream states for <X, Y>. Node Z sends a label release message with label L to D. Since node D is no longer part of the downstream forwarding state, Z cleans up the forwarding state upstream <X, Y, D> and sends a upstream Label Withdraw for <X, Y, Lu> to D.

If deleting L from Z's forwarding state for downstream <X, Y> results in no state remaining for <X, Y>, then Z propagates the Label

Withdraw <X, Y, L> to its upstream node U for <X,Y>.

4.2.2.3. MP2MP root node operation

The procedure when the root node of a MP2MP LSP receives a label withdraw message is the same as for transit nodes, except that the root node would not propagate the Label Withdraw upstream (as it has no upstream).

4.2.2.4. MP2MP Upstream LSR change

The procedure for changing the upstream LSR is the same as documented in Section 2.3.2.4, except it is applied to MP2MP FECs, using the procedures described in Section 4.2.1 through Section 4.2.2.3.

5. Upstream label allocation on Ethernet networks

On Ethernet networks the upstream LSR will send a copy of the packet to each receiver individually. If there is more then one receiver on the Ethernet we don't take full benefit of the multi-access capability of the network. We may optimize the bandwidth consumption on the Ethernet and replication overhead on the upstream LSR by using upstream label allocation [5]. Procedures on how to distribute upstream labels using LDP is documented in [6].

6. Root node redundancy for MP2MP LSPs

MP2MP leaf nodes must use the same root node to setup the MP2MP LSP. Otherwise there will be partitioned MP2MP LSP and traffic sourced by some leafs is not received by others. Having a single root node for a MP2MP LSP is a single point of failure, which is not preferred. We need a fast and efficient mechanism to recover from a root node failure.

6.1. Root node redundancy procedure

It is likely that the root node for a MP2MP LSP is defined statically. The root node address may be configured on each leaf statically or learned using a dynamic protocol. How MP2MP leafs learn about the root node is out of the scope of this document. A MP2MP LSP is uniquely identified by a opaque value and the root node address. Suppose that for the same opaque value we define two root node addresses and we build a tree to each root using the same opaque value. Effectively these will be treated as different MP2MP LSPs in the network. Since all leafs have setup a MP2MP LSP to each one of the root nodes for this opaque value, a sending leaf may pick either

of the two MP2MP LSPs to forward a packet on. The leaf nodes will receive the packet on one of the MP2MP LSPs, the client of the MP2MP LSP does not care on which MP2MP LSP the packet was received from, as long as they are for the same opaque value. The sending leaf MUST only forward a packet on one MP2MP LSP at a given point in time. The receiving leafs are unable to discard duplicate packets because they accept on both LSPs. Using both these MP2MP LSPs we can implement redundancy using the following procedures.

A sending leaf selects a single root node out of the available roots for a given opaque value. A good strategy MAY be to look at the unicast routing table and select a root that is closest according in terms of unicast metric. As soon as the root address of our active root disappears from the unicast routing table (or becomes less attractive) due to root node or link failure we can select a new best root address and start forwarding to it directly. If multiple root nodes have the same unicast metric, the highest root node addresses MAY be selected, or we MAY do per session load balancing over the root nodes.

All leafs participating in a MP2MP LSP MUST join to all the available root nodes for a given opaque value. Since the sending leaf may pick any MP2MP LSP, it must be prepared to receive on it.

The advantage of pre-building multiple MP2MP LSPs for a single opaque value is that we can converge from a root node failure as fast as the unicast routing protocol is able to notify us. There is no need for an additional protocol to advertise to the leaf nodes which root node is the active root. The root selection is a local leaf policy that does not need to be coordinated with other leafs. The disadvantage is that we are using more label resources depending on how many root nodes are defined.

7. Make before break

An upstream LSR is chosen based on the best path to reach the root of the MP LSP. When the best path to reach the root changes it needs to choose a new upstream LSR. Section 2.3.2.4 and Section 4.2.2.4 describes these procedures. When the best path to the root changes the LSP may be broken and packet forwarding is interrupted, in that case it needs to converge to a new upstream LSR ASAP. There are also scenarios where the best path changed, but the LSP is still forwarding packets. That happens when links come up or routing metrics are changed. In that case it would like to build the new LSP before it breaks the old LSP to minimize the traffic interruption. The approuch described below deals with both scenarios and does not require LDP to know which of the events above caused the upstream

router to change. The approuch below is an optional extention to the MP LSP building procedures described in this draft.

7.1. Protocol event

An approach is to use additional signaling in LDP. Suppose a downstream LSR-D is changing to a new upstream LSR-U for FEC-A, this LSR-U may already be forwarding packets for this FEC-A. Based on the existence of state for FEC-A, LSR-U will send a notification to the LSR-D to initiate the switchover. The assumption is that if our upstream LSR-U has state for the FEC-A and it has received a notification from its upstream router, then this LSR is forwarding packets for this FEC-A and it can send a notification back to initiate the switchover. You could say there is an explicit notification to tell the LSR it became part of the tree identified by FEC-A. LSR-D can be in 3 different states.

1. There no state for a given FEC-A.

2. State for FEC-A has just been created and is waiting for notification.

3. State for FEC-A exists and notification was received.

Suppose LSR-D sends a label mapping for FEC-A to LSR-U. LSR-U must only reply with a notification to LSR-D if it is in state #3 as described above. If LSR-U is in state 1 or 2, it should remember it has received a label mapping from LSR-D which is waiting for a notification. As soon as LSR-U received a notification from its upstream LSR it can move to state #3 and trigger notifications to its downstream LSR's that requested it. More details will be added in the next revision of the draft.

8. Security Considerations

The same security considerations apply as for the base LDP specification, as described in [1].

9. IANA considerations

This document creates a new name space (the LDP MP Opaque Value Element type) that is to be managed by IANA. Also, this document requires allocation of three new LDP FEC element types: the P2MP type, the MP2MP-up and the MP2MP-down types.

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