Note: I’ve removed comments that I think is resolved and accepted changes that I agree to.

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 LDP Extensions for Hub & Spoke Multipoint Label Switched Path

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Abstract

 This draft introduces a hub & spoke multipoint LSP (or HSMP

 LSP for short), which allows traffic both from root to leaf through P2MP LSP

 and also leaf to root along the co-routed reverse path. That means

 traffic entering the HSMP LSP from application/customer at the root

 node travels downstream to each leaf node, exactly as if it was travelling downstream

 along a P2MP LSP to each leaf node. And upstream traffic entering the HSMP LSP

 at any leaf node travels upstream along the tree to the root, as if it

 is unicast to the root, and strictly follows the downstream path of the tree

 rather than routing protocol based unicast path to the root.

Requirements Language

 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 RFC2119 [RFC2119].

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1. Introduction

 The point-to-multipoint LSP defined in [RFC6388] allows traffic to

 transmit from root to several leaf nodes, and multipoint-to-

 multipoint LSP allows traffic from every node to transmit to every

 other node. This draft introduces a hub & spoke multipoint LSP

 (or HSMP LSP for short), which allows traffic both from root to leaf

 through P2MP LSP and also leaf to root along the co-routed reverse

 path. That means traffic entering the HSMP LSP at the root node

 travels downstream, exactly as if it was travelling downstream along a

 P2MP LSP, and traffic entering the HSMP LSP at any other node travels

 upstream along the tree to the root. A packet travelling upstream

 should be thought of as being unicast to the root, except that it

 follows the path of the tree rather than routing protocol based unicast path to the

 root. The combination of upstream LSPs initiated from all leaf nodes forms a multipoint-to-point LSP.

2. Terminology

 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 [RFC2119].

 This document uses some terms and acronyms as follows:

 HSMP LSP: hub & spoke multipoint LSP. An LSP allows traffic both

 from root to leaf through P2MP LSP and also leaf to root along the

 co-routed reverse path.

 mLDP: Multipoint extensions for LDP

 MP2MP LSP: An LSP that connects a set of nodes, such that traffic

 sent by any node in the LSP is delivered to all others.

 PTP: The timing and synchronization protocol used by IEEE1588

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

 LSRs.

3. Applications

 In some cases, the P2MP LSP may not have a reply path for the OAM

 messages (e.g, LSP echo request). If P2MP LSP is provided by HSMP LSP instead, then

 the upstream path could be used as the OAM message reply

 path. This is especially useful in the case of P2MP LSP fault

 detection, performance measurement, root node redundancy and etc.

 There are several other applications that could take advantage of

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 a LDP based HSMP LSP as described below.

3.1. Time synchronization scenario

 [IEEE1588] over MPLS is defined in [I-D.ietf-tictoc-1588overmpls].

 It is required that the LSP used to transport PTP event message

 between a Master Clock and a Slave Clock, and the LSP between the

 same Slave Clock and Master Clock must be co-routed. Using point-

 to-multipoint technology to transmit PTP event messages from Master

 Clock at root side to Slave Clock at leaf side will greatly improve

 the bandwidth usage. Unfortunately current point-to-multipoint LSP

 only provides unidirectional path from root to leaf, which cannot

 provide a co-routed reverse path for the PTP event messages. LDP

 based HSMP LSP described in this draft provides unidirectional point-

 to-multipoint LSP from root to leaf and co-routed reverse path from

 leaf to root.

3.2. Virtual Private Multicast Service scenario

 Point to multipoint PW described in [I-D.ietf-pwe3-p2mp-pw] requires

 to setup reverse path from leaf node (referred as egress PE) to root

 node (referred as ingress PE), if HSMP LSP is used to multiplex P2MP

 PW, the reverse path can also be multiplexed to HSMP upstream path to

 avoid setup independent reverse path. In that case, the operational

 cost will be reduced for maintaining only one HSMP LSP, instead of

 P2MP LSP and n (number of leaf nodes) P2P reverse LSPs.

 The VPMS defined in [I-D.ietf-l2vpn-vpms-frmwk-requirements] requires

 reverse path from leaf to root node. The P2MP PW multiplexed to HSMP

 LSP can provide VPMS with reverse path, without introducing

 independent reverse path from each leaf to root.

3.3. Internet Protocol television (IPTV) scenario

 The mLDP based HSMP LSP can also be applied in a typical IPTV

 scenario. There is usually only one location with senders but there

 are many receiver locations. If IGMP is used for signalling between

 senders as IGMP querier[RFC3376] and receivers, the IGMP messages from the

 receivers are travelling only from the leaves to the root (and from

 root towards leaves) but not from leaf to leaf. In addition traffic

 from the root is only replicated towards the leaves. Then leaf node

 receiving IGMP report message (for source specific multicast case) will join HSMP LSP(reuse mechanism in [RFC6826] section 2), and then

 send IGMP report message upstream to root along HSMP upstream LSP. Note that in

 above case, there is no node redundancy for IGMP querier. And the

 node redundancy for IGMP querier[RFC3376] could be provided by two independent

 VPMS instances with HSMP applied.

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4. Setting up HSMP LSP with LDP

 HSMP LSP is similar with MP2MP LSP described in [RFC6388], with the

 difference that the leaf LSRs can only send traffic to root node

 along the same path of traffic from root node to leaf node.

 HSMP LSP consists of a downstream path and upstream path. The

 downstream path is same as MP2MP LSP, while the upstream path is only

 from leaf to root node, without communication between leaf and leaf

 nodes. The transmission of packets from the root node of a HSMP LSP

 to the receivers is identical to that of a P2MP LSP. Traffic from a

 leaf node follows the upstream path toward the root node, along the

 a path that traverse the same nodes as the downstream node, but in reverse order.

 For setting up the upstream path of a HSMP LSP, ordered mode MUST be

 used which is same as MP2MP. Ordered mode can guarantee a leaf to

 start sending packets to root immediately after the upstream path is

 installed, without being dropped due to an incomplete LSP.

 Due to much of similar behavior between HSMP LSP and MP2MP LSP, the

 following sections only describe the difference between the two

 entities.

4.1. Support for HSMP LSP setup with LDP

 HSMP LSP requires the LDP capabilities [RFC5561] for nodes to indicate that they support setup of HSMP LSPs. An implementation supporting

 the HSMP LSP procedures specified in this document MUST implement the

 procedures for Capability Parameters in Initialization Messages.

 Advertisement of the HSMP LSP Capability indicates support of the

 procedures for HSMP LSP setup.

 A new Capability Parameter TLV is defined, the HSMP LSP Capability Parameter.

 Following is the format of the HSMP LSP Capability Parameter.

 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

 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

 |1|0| HSMP LSP Cap(TBD IANA) | Length |

 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

 |S| Reserved |

 +-+-+-+-+-+-+-+-+

 Figure 1. HSMP LSP Capability Parameter encoding

The length SHOULD be 1, and the S bit and reserved bits are defined in [RFC5561] section 3.

 The HSMP LSP capability Parameter type is to be assigned by IANA.

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4.2. HSMP FEC Elements

 Similar as MP2MP LSP, we define two new protocol entities, the HSMP

 Downstream FEC Element and Upstream FEC Element. If a FEC TLV contains one of the

 HSMP FEC Elements, the HSMP FEC Element MUST be the only FEC Element

 in the FEC TLV. The structure, encoding and error handling for the

 HSMP Downstream FEC Element and Upstream FEC Element are the same as for the

 MP2MP FEC Element described in [RFC6388] Section 4.2. The difference

 is that two additional new FEC types are defined: HSMP Downstream FEC

 (TBD, IANA) and HSMP Upstream FEC(TBD, IANA).

4.3. Using the HSMP FEC Elements

 In order to describe the message processing clearly, the entries in the list below

 define the processing of the HSMP FEC Elements, which are inherited

 from [RFC6388] section 4.3.

 1. HSMP downstream LSP <X, Y> (or simply downstream <X, Y>): a HSMP

 LSP downstream path with root node address X and opaque value Y.

 2. HSMP upstream LSP <X, Y> (or simply upstream <X, Y>): a HSMP LSP

 upstream path for root node address X and opaque value Y which will

 be used by any of downstream node to send traffic upstream to root

 node.

 3. HSMP downstream FEC Element <X, Y>: a FEC Element with root node

 address X and opaque value Y used for a downstream HSMP LSP.

 4. HSMP upstream FEC Element <X, Y>: a FEC Element with root node

 address X and opaque value Y used for an upstream HSMP LSP.

 5. HSMP-D Label Mapping <X, Y, L>: A Label Mapping message with a single

 HSMP downstream FEC Element <X, Y> and label TLV with label L. Label

 L MUST be allocated from the per-platform label space of the LSR

 sending the Label Mapping Message.

 6. HSMP-U Label Mapping <X, Y, Lu>: A Label Mapping message with a single

 HSMP upstream FEC Element <X, Y> and label TLV with label Lu. Label

 Lu MUST be allocated from the per-platform label space of the LSR

 sending the Label Mapping Message.

4.3.1. HSMP LSP Label Mapping

 This section specifies the procedures for originating HSMP Label Mapping

 messages and processing received HSMP label mapping messages for a

 particular HSMP LSP. The procedure of downstream HSMP LSP is same as

 that of downstream MP2MP LSP described in [RFC6388]. When LDP operates in Ordered Label Distribution Control mode [RFC5036], the upstream LSP will be setup by sending

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 HSMP LSP LDP Label Mapping message with a label which is allocated by upstream

 LSR to its downstream LSR hop by hop from root to leaf node,

 installing the upstream forwarding table by every node along the LSP.

 The detail procedure of setting up upstream HSMP LSP is different with that of

 upstream MP2MP LSP, and is specified in below section.

 All labels discussed here are downstream-assigned [RFC5332] except

 those which are assigned using the procedures described in section 5.

 Determining the upstream LSR for the HSMP LSP <X, Y> follows the

 procedure for a MP2MP LSP described in [RFC6388] Section 4.3.1.1.

 Determining one's downstream HSMP LSR procedure is much same as

 defined in [RFC6388] section 4.3.1.2. An Upstream LDP peer which receives a

 Label Mapping with HSMP downstream FEC Element from a LDP peer D will treat D as downstream HSMP

 LDP peer.

 Determining the forwarding interface to an LSR follows the same procedure as

 defined in [RFC6388] section 2.4.1.2.

4.3.1.1. HSMP LSP leaf node operation

 The leaf node operation is same as the operation of MP2MP LSP defined

 in [RFC6388] section 4.3.1.4. The only is that different FEC elements are

 and as specified below.

 A leaf node Z will send a HSMP-D Label Mapping <X, Y, L> to U, instead of

 MP2MP-D Label Mapping <X, Y, L>. and expects a HSMP-U Label Mapping <X, Y,

 Lu> from node U and checks whether it already has forwarding state

 for upstream <X, Y>. The created forwarding state on leaf node Z is

 same as the leaf node of MP2MP LSP. Z will push label Lu onto the

 traffic that Z wants to forward over the HSMP LSP.

4.3.1.2. HSMP LSP transit node operation

 Suppose node Z receives a HSMP-D Label Mapping <X, Y, L> from LSR D, the

 procedure is same as processing MP2MP-D Label Mapping message defined

 in [RFC6388] section 4.3.1.5, and the processing protocol entity is

 HSMP-D Label Mapping message. The different procedure is specified

 below.

 Node Z checks if upstream LSR U already has assigned a label Lu to

 upstream <X, Y>. If not, transit node Z waits until it receives a

 HSMP-U Label Mapping <X, Y, Lu> from LSR U. Once the HSMP-U Label Mapping is

 received from LSR U, node Z checks whether it already has forwarding

 state upstream <X, Y> with incoming label Lu' and outgoing label Lu.

 If it does, Z sends a HSMP-U Label Mapping <X, Y, Lu'> to downstream

 node. If it does not, it allocates a label Lu' and creates a new

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 label swap for Lu' with Label Lu over interface Iu. Interface Iu is

 determined via the procedures in Section 4.3.1. Node Z determines

 the downstream HSMP LSR as per Section 4.3.1, and sends a HSMP-U

 Label Mapping <X, Y, Lu'> to node D.

 Since a packet from any downstream node is forwarded only to the

 upstream node, the same label (representing the upstream path) can be

 distributed to all downstream nodes. This differs from the

 procedures for MPMP LSPs [RFC6388], where a distinct label must be

 distributed to each downstream node. The forwarding state upstream

 <X, Y> on node Z will be like this {<Lu'>, <Iu Lu>}. Iu means the

 upstream interface over which Z receives HSMP-U Label Map <X, Y, Lu>

 from LSR U. Packets from any downstream interface over which Z send

 HSMP-U Label Map <X, Y, Lu'> with label Lu' will be forwarded to Iu

 with label Lu' swap to Lu.

4.3.1.3. HSMP LSP root node operation

 Suppose root node Z receives a HSMP-D Label Mapping <X, Y, L> from node

 D, the procedure is much same as processing MP2MP-D Label Mapping

 message defined in [RFC6388] section 4.3.1.6, and the processing

 protocol entity is HSMP-D Label Mapping message. The different

 procedure is specified below.

 Node Z checks if it has forwarding state for upstream <X, Y>. If

 not, Z creates a forwarding state for incoming label Lu' that

 indicates that Z is the LSP egress. E.g., the forwarding state might

 specify that the label stack is popped and the packet passed to some

 specific application. Node Z determines the downstream HSMP LSR as

 per section 4.3.1, and sends a HSMP-U Label Map <X, Y, Lu'> to node

 D.

 Since Z is the root of the tree, Z will not send a HSMP-D Label Map

 and will not receive a HSMP-U Label Mapping.

4.3.2. HSMP LSP Label Withdraw

 The HSMP Label Withdraw procedure is much same as MP2MP leaf

 operation defined in [RFC6388] section 4.3.2, and the processing

 protocol entities are HSMP FECs. The only difference is process of

 HSMP-U Label Release message, which is specified below.

 When a transit node Z receives a HSMP-U Label Release message from

 downstream node D, Z should check if there are any incoming interface

 in forwarding state upstream <X, Y>. If all downstream nodes are

 released and there is no incoming interface, Z should delete the

 forwarding state upstream <X, Y> and send HSMP-U Label Release

 message to its upstream node.

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4.3.3. HSMP LSP upstream LSR change

 The procedure for changing the upstream LSR is the same as defined in

 [RFC6388] section 4.3.3, except it is applied to HSMP FECs.

5. HSMP LSP on a LAN

 The procedure to process P2MP LSP on a LAN has been described in

 [RFC6388]. When the LSR forwards a packet downstream on one of those

 LSPs, the packet's top label must be the "upstream LSR label", and

 the packet's second label is "LSP label".

 When establishing the downstream path of a HSMP LSP, as defined in

 [RFC6389], a Label Request for an LSP label is sent to the upstream

 LSR. The upstream LSR should send Label Mapping that contains the

 LSP label for the downstream HSMP FEC and the upstream LSR context

 label. At the same time, it must also send label mapping for

 upstream HSMP FEC to downstream node. Packets sent by the upstream

 router can be forwarded downstream using this forwarding state based

 on a two label lookup. Packets travelling upstream need to be

 forwarded in the direction of the root by using the label allocated

 by upstream LSR.

6. Redundancy considerations

 In some scenario, it is necessary to provide two root nodes for

 redundancy purpose. One way to implement this is to use two

 independent HSMP LSPs acting as active/standby. At one time, only

 one HSMP LSP will be active, and the other will be standby. After

 detecting the failure of active HSMP LSP, the root and leaf nodes

 will switch the traffic to the standby HSMP LSP which takes on the role as active HSMP LSP. The detail of redundancy mechanism will be

 for future study.

7. Co-routed path exceptions

 There are some exceptional cases when mLDP based HSMP LSP could not

 achieve co-routed path. One possible case is using static routing

 between LDP neighbors; another possible case is IGP cost asymmetric

 generated by physical link cost asymmetric, or TE-Tunnels used

 between LDP neighbors. The LSR/LER in HSMP LSP could detect if the

 path is co-routed or not, if not co-routed, an indication could be

 generated to the management system.

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8. Failure Detection of HSMP LSP

 The idea of LSP ping for HSMP LSPs could be expressed as an intention

 to test the LSP echo request packets that enter at the root along a particular

 downstream path of HSMP LSP, and end their MPLS path on the leaf.

 The leaf node then sends the LSP ping echo reply along the co-routed

 upstream path of HSMP LSP, and end on the root that are the

 (intended) root node.

 New sub-TLVs are required to be assigned by IANA in Target FEC Stack

 TLV to define the corresponding HSMP-upstream FEC type and HSMP-

 downstream FEC type. In order to ensure the leaf node to send the

 LSP ping response along the HSMP upstream path, the R bit (Validate

 Reverse Path) in Global Flags Field defined in [RFC6426] is reused

 here.

 The node processing mechanism of LSP echo request and reply for HSMP LSP is inherited

 from [RFC6425] and [RFC6426] section 3.4, except the following:

 1. The root node sending LSP echo request message for HSMP LSP MUST attach

 Target FEC Stack with HSMP downstream FEC, and set R bit to '1' in

 Global Flags Field.

 2. When the leaf node receiving the LSP echo request, it MUST send the LSP

 echo reply to the associated HSMP upstream path. The Reverse-path

 Target FEC Stack TLV attached by leaf node in echo reply message SHOULD

 contain the sub-TLV of associated HSMP upstream FEC.

9. Security Considerations

 The same security considerations apply as for the MP2MP LSP described

 in [RFC6388] and [RFC6425].

Although this document introduces new FEC Elements and corresponding procedures, the protocol does not bring any new security issues compared to [RFC6388] and [RFC6425].

10. IANA Considerations

 This document requires allocation of two new LDP FEC Element types

 from the "Label Distribution Protocol (LDP) Parameters registry" the

 "Forwarding Equivalence Class (FEC) Type Name Space":

 1. the HSMP-upstream FEC type - requested value TBD

 2. the HSMP-downstream FEC type - requested value TBD

 This document requires allocation of one new code points for the HSMP

 LSP capability TLV from "Label Distribution Protocol (LDP) Parameters

 registry" the "TLV Type Name Space":

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 HSMP LSP Capability Parameter - requested value TBD

 This document requires allocation of two new sub-TLV types for

 inclusion within the LSP ping [RFC4379] Target FEC Stack TLV (TLV

 type 1).

 1. the HSMP upstream LDP FEC Stack - requested value TBD

 2. the HSMP downstream LDP FEC Stack - requested value TBD

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