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MPLS Upstream Label Assignment for LDP

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Abstract

This document describes procedures for distributing upstream-assigned labels for Label Distribution Protocol (LDP). It also describes how these procedures can be used for avoiding branch Label Switching Router (LSR) traffic replication on a LAN for LDP point-to-multipoint (P2MP) Label Switched Paths (LSPs).

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1. Specification of requirements

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].

2. Introduction

This document describes procedures for distributing upstream-assigned labels [RFC5331] for Label Distribution Protocol (LDP) [RFC5036]. These procedures follow the architecture for MPLS Upstream Label Assignment described in [RFC5331].

This document describes extensions to LDP that a Label Switching Router (LSR) can use to advertise to its neighboring LSRs whether the LSR supports upstream label assignment.

This document also describes extensions to LDP to distribute upstream-assigned labels.

The usage of MPLS upstream label assignment using LDP for avoiding branch LSR traffic replication on a LAN for LDP point-to-multipoint (P2MP) Label Switched Paths (LSPs) [MLDP] is also described.

3. LDP Upstream Label Assignment Capability

According to [RFC5331], upstream-assigned label bindings MUST NOT be used unless it is known that a downstream LSR supports them. This implies that there MUST be a mechanism to enable an LSR to advertise to its LDP neighbor LSR(s) its support of upstream-assigned labels.

A new Capability Parameter, the LDP Upstream Label Assignment Capability, is introduced to allow an LDP peer to exchange with its peers, its support of upstream label assignment. This parameter follows the format and procedures for exchanging Capability Parameters defined in [RFC5561].

Following is the format of the LDP Upstream Label Assignment 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| Upstream Lbl Ass Cap(IANA)|      Length (= 1)             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|1| Reserved    |
+-+-+-+-+-+-+-+-+
```

If an LSR includes the Upstream Label Assignment Capability in LDP Initialization Messages it implies that the LSR is capable of both distributing upstream-assigned label bindings and receiving upstream-assigned label bindings. The reserved bits MUST be set to zero on transmission and ignored on receipt. The Upstream Label Assignment Capability Parameter MUST be carried only in LDP initialization messages and MUST be ignored if received in LDP Capability messages.

4. Distributing Upstream-Assigned Labels in LDP

An optional LDP TLV, Upstream-Assigned Label Request TLV, is introduced. To request an upstream-assigned label an LDP peer MUST include this TLV in a Label Request message.

```
    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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |0|0| Upstream Ass Lbl Req (TBD)|      Length                   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                       Reserved                                |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

An optional LDP TLV, Upstream-Assigned Label TLV is introduced to signal an upstream-assigned label. Upstream-Assigned Label TLVs are carried by the messages used to advertise, release and withdraw upstream assigned label mappings.

```
    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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |0|0| Upstream Ass Label (TBD)  |      Length                   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                         Reserved                              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                   Label                                       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The Label field is a 20-bit label value as specified in [RFC3032] represented as a 20-bit number in a 4 octet field as specified in section 3.4.2.1 of RFC5036 [RFC5036].

4.1. Procedures

Procedures for Label Mapping, Label Request, Label Abort, Label Withdraw and Label Release follow [RFC5036] other than the modifications pointed out in this section.

A LDP LSR MUST NOT distribute the Upstream Assigned Label TLV to a neighboring LSR if the neighboring LSR had not previously advertised the Upstream Label Assignment Capability in its LDP Initialization messages. A LDP LSR MUST NOT send the Upstream Assigned Label Request TLV to a neighboring LSR if the neighboring LSR had not previously advertised the Upstream Label Assignment Capability in its LDP Initialization messages.

As described in [RFC5331] the distribution of upstream-assigned labels is similar to either ordered LSP control or independent LSP control of the downstream assigned labels.

When the label distributed in a Label Mapping message is an upstream-assigned label, the Upstream Assigned Label TLV MUST be included in the Label Mapping message. When an LSR receives a Label Mapping message with an Upstream Assigned Label TLV and it does not recognize the TLV, it MUST generate a Notification message with a status code of "Unknown TLV" [RFC5036]. If it does recognize the TLV but is unable to process the upstream label, it MUST generate a Notification message with a status code of "No Label Resources". If the Label Mapping message was generated in response to a Label Request message, the Label Request message MUST contain an Upstream Assigned Label Request TLV. A LSR that generates an upstream assigned label request to a neighbor LSR, for a given FEC, MUST NOT send a downstream label mapping to the neighbor LSR for that FEC unless it withdraws the upstream-assigned label binding. Similarly if an LSR generates a downstream assigned label request to a neighbor LSR, for a given FEC, it MUST NOT send an upstream label mapping to that LSR for that FEC, unless it aborts the downstream assigned label request.

The Upstream Assigned Label TLV may be optionally included in Label Withdraw and Label Release messages that withdraw/release a particular upstream assigned label binding.

5. LDP Tunnel Identifier Exchange

As described in [RFC5331] an upstream LSR Ru MAY transmit an MPLS packet, the top label of which (L) is upstream-assigned, to a downstream LSR Rd, by encapsulating it in an IP or MPLS tunnel. In this case the fact that L is upstream-assigned is determined by Rd by the tunnel on which the packet is received. There must be a mechanism for Ru to inform Rd that a particular tunnel from Ru to Rd will be used by Ru for transmitting MPLS packets with upstream-assigned MPLS labels.

When LDP is used for upstream label assignment, the Interface ID TLV [RFC3472] is used for signaling the Tunnel Identifier. If Ru uses an IP or MPLS tunnel to transmit MPLS packets with upstream assigned labels to Rd, Ru MUST include the Interface ID TLV in the Label Mapping messages along with the Upstream Assigned Label TLV. The IPv4/v6 Next/Previous Hop Address and the Logical Interface ID fields in the Interface ID TLV SHOULD be set to 0 by the sender and ignored by the receiver. The Length field indicates the total length of the TLV, i.e., 4 + the length of the value field in octets. A value field whose length is not a multiple of four MUST be zero-padded so

that the TLV is four- octet aligned.

Hence the IPv4 Interface ID TLV has the following format:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|0|0|     Type (0x082d)         |             Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 IPv4 Next/Previous Hop Address (0)            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Logical Interface ID (0)                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Sub-TLVs                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The IPv6 Interface ID TLV has the following format:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|0|0|     Type (0x082e)         |             Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 IPv6 Next/Previous Hop Address (0)            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Logical Interface ID (0)                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Sub-TLVs                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

As shown in the above figures the Interface ID TLV carries sub-TLVs. Four new Interface ID sub-TLVs are introduced to support RSVP-TE P2MP LSPs, LDP P2MP LSPs, IP Multicast Tunnels and context labels. The sub-TLV value in the sub-TLV acts as the tunnel identifier.

Following are the sub-TLVs that are introduced:

1. RSVP-TE P2MP LSP TLV. Type = 28 (To be assigned by IANA). Value of the TLV is the RSVP-TE P2MP LSP SESSION Object [RFC4875].

Below is the RSVP-TE P2MP LSP TLV format when carried in the IPv4 Interface ID TLV:

```
     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
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |    Type (0x1c)                |  16                           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                          P2MP ID                              |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |  MUST be zero                 |      Tunnel ID                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Extended Tunnel ID                        |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Below is the RSVP-TE P2MP LSP TLV format when carried in the IPv6 Interface ID TLV:

```
     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
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |    Type (0x1c)                |  28                           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                          P2MP ID                              |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |  MUST be zero                 |      Tunnel ID                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Extended Tunnel ID                        |
    |                                                               |
    |                            .......                            |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

This TLV identifies the RSVP-TE P2MP LSP. It allows Ru to tunnel an "inner" LDP P2MP LSP, the label for which is upstream assigned, over an "outer" RSVP-TE P2MP LSP that has leaves <Rd1...Rdn>. The RSVP-TE P2MP LSP IF_ID TLV allows Ru to signal to <Rd1...Rdn> the binding of the inner LDP P2MP LSP to the outer RSVP-TE P2MP LSP. The control plane signaling between Ru and <Rd1...Rdn> for the inner P2MP LSP uses targeted LDP signaling messages

2. LDP P2MP LSP TLV. Type = 29 (To be assigned by IANA). Value of the TLV is the LDP P2MP FEC as defined in [MLDP] and has to be set as per the procedures in [MLDP]. Here is the format of the LDP P2MP FEC as defined in [MLDP]:

```
     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
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
|P2MP Type      |        Address Family         | Address Length|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~                       Root Node Address                       ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Opaque Length              |    Opaque Value ...           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               +
~                                                               ~
|                                                               |
|                               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The Address Family MUST be set to IPv4, the Address Length MUST be set to 4 and the Root Node Address MUST be set to an IPv4 address when the LDP P2MP LSP TLV is carried in the IPv4 Interface ID TLV. The Address Family MUST be set to IPv6, the Address Length MUST be set to 16 and the Root Node Address MUST be set to an IPv6 address when the LDP P2MP LSP TLV is carried in the IPv6 Interface ID TLV.

The TLV value identifies the LDP P2MP LSP. It allows Ru to tunnel an "inner" LDP P2MP LSP, the label for which is upstream assigned, over an "outer" LDP P2MP LSP that has leaves <Rd1...Rdn>. The LDP P2MP LSP IF_ID TLV allows Ru to signal to <Rd1...Rdn> the binding of the inner LDP P2MP LSP to the outer LDP- P2MP LSP. The control plane signaling between Ru and <Rd1...Rdn> for the inner P2MP LSP uses targeted LDP signaling messages

3. IP Multicast Tunnel TLV. Type = 30 (To be assigned by IANA) In this case the TLV value is a <Source Address, Multicast Group Address> tuple. Source Address is the IP address of the root of the tunnel i.e. Ru, and Multicast Group Address is the Multicast Group Address used by the tunnel. The addresses MUST be IPv4 addresses when the IP Multicast Tunnel TLV is included in the IPv4 Interface ID TLV. The addresses MUST be IPv6 addresses when the IP Multicast Tunnel TLV is included in the IPv6 Interface ID TLV.

4. MPLS Context Label TLV. Type = 31 (To be assigned by IANA). In this case the TLV value is a <Source Address, MPLS Context Label> tuple. The Source Address belongs to Ru and the MPLS Context Label is an upstream assigned label, assigned by Ru. The Source Address MUST be set to an IPv4 address when the MPLS Context Label TLV is carried in the IPv4 Interface ID TLV. The Source Address MUST be set to an IPv6 address when the MPLS Context Label TLV is carried in the IPv6 Interface ID TLV. This allows Ru to tunnel an "inner" LDP P2MP LSP, the label of which is upstream assigned, over an "outer" one-hop MPLS LSP, where the outer one-hop LSP has the following property:

+ The label pushed by Ru for the outer MPLS LSP is an upstream assigned context label, assigned by Ru. When <Rd1...Rdn> perform an MPLS label lookup on this label a combination of this label and the incoming interface MUST be sufficient for <Rd1...Rdn> to uniquely determine Ru's context specific label space to lookup the next label on the stack in. <Rd1...Rdn> MUST receive the data sent by Ru with the context specific label assigned by Ru being the top label on the label stack.

Currently the usage of the context label TLV is limited only to LDP P2MP LSPs on a LAN as specified in the next section. The context label TLV MUST NOT be used for any other purposes.

Note that when the outer P2MP LSP is signaled with RSVP-TE or MLDP the above procedures assume that Ru has a priori knowledge of all the <Rd1, ... Rdn>. In the scenario where the outer P2MP LSP is signaled using RSVP-TE, Ru can obtain this information from RSVP-TE. However, in the scenario where the outer P2MP LSP is signaled using MLDP, MLDP does not provide this information to Ru. In this scenario the procedures by which Ru could acquire this information are outside the scope of this document.

6. LDP Point-to-Multipoint LSPs on a LAN

This section describes one application of upstream label assignment using LDP. Further applications are to be described in separate documents.

[MLDP] describes how to setup P2MP LSPs using LDP. On a LAN the solution relies on "ingress replication". A LSR on a LAN, that is a branch LSR for a P2MP LSP, (say Ru) sends a separate copy of a packet that it receives on the P2MP LSP to each of the downstream LSRs on the LAN (say <Rd1...Rdn> that are adjacent to it in the P2MP LSP.

It is desirable for Ru to send a single copy of the packet for the LDP P2MP LSP on the LAN, when there are multiple downstream routers on the LAN that are adjacent to Ru in that LDP P2MP LSP. This requires that each of <Rd1...Rdn> must be able to associate the label L, used by Ru to transmit packets for the P2MP LSP on the LAN, with that P2MP LSP. It is possible to achieve this using LDP upstream-assigned labels with the following procedures.

Consider an LSR Rd that receives the LDP P2MP FEC [MLDP] from its downstream LDP peer. Further the upstream interface to reach LSR Ru which is the next-hop to the P2MP LSP root address, Pr, in the LDP P2MP FEC, is a LAN interface, Li. Further Rd and Ru support upstream-assigned labels. In this case Rd instead of sending a Label Mapping

message as described in [MLDP] sends a Label Request message to Ru. This Label Request message MUST contain an Upstream Assigned Label Request TLV.

On receiving this message, Ru sends back a Label Mapping message to Rd with an upstream-assigned label. This message also contains an Interface ID TLV with a MPLS Context Label sub-TLV, as described in the previous section, with the value of the MPLS label set to a value assigned by Ru on inteface Li as specified in [RFC5331]. Processing of the Label Request and Label Mapping messages for LDP upstream-assigned labels is as described in section 4.1. If Ru receives a Label Request for an upstream assigned label for the same P2MP FEC from multiple downstream LSRs on the LAN, <Rd1...Rdn>, it MUST send the same upstream-assigned label to each of <Rd1...Rdn>.

Ru transmits the MPLS packet using the procedures defined in [RFC5331] and [RFC5332]. The MPLS packet transmitted by Ru contains as the top label the context label assigned by Ru on the LAN interface, Li. The bottom label is the upstream label assigned by Ru to the LDP P2MP LSP. The top label is looked up in the context of the LAN interface, Li, [RFC5331] by a downstream LSR on the LAN. This lookup enables the downstream LSR to determine the context specific label space to lookup the inner label in.

Note that <Rd1...Rdn> may have more than one equal cost next-hop on the LAN to reach Pr. It MAY be desirable for all of them to send the label request to the same upstream LSR and they 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. Opaque value is defined in [MLDP] and comprises the P2MP LSP identifier.

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. It is also to be noted that the procedures in this section can still be used by Rd and Ru if other LSRs on the LAN do not support upstream label assignment. Ingress replication and downstream label assignment will continue to be used for LSRs that do not support upstream label assignment.

7. IANA Considerations

7.1. LDP TLVs

IANA maintains a registry of LDP TLVs at the registry "Label Distribution Protocol" in the sub-registry called "TLV Type Name Space".

This document defines a new LDP Upstream Label Assignment Capability TLV (Section 3). IANA is requested to assign the value 0x0507 to this TLV.

This document defines a new LDP Upstream-Assigned Label TLV (Section 4). IANA is requested to assign the type value of 0x204 to this TLV.

This document defines a new LDP Upstream-Assigned Label Request TLV (Section 4). IANA is requested to assign the type value of 0x205 to this TLV.

7.2. Interface Type Identifiers

[RFC3472] defines the LDP Interface ID IPv4 and IPv6 TLV. These top-level TLVs can carry sub-TLVs dependent on the interface type. These sub-TLVs are assigned "Interface ID Types". IANA maintains a registry of Interface ID Types for use in GMPLS in the registry "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Parameters" and sub-registry "Interface_ID Types". IANA is requested to make corresponding allocations from this registry as follows:

- RSVP-TE P2MP LSP TLV (requested value 28)

- LDP P2MP LSP TLV (requested value 29)

- IP Multicast Tunnel TLV (requested value 30)

- MPLS Context Label TLV (requested value 31)

8. Security Considerations

The security considerations discussed in RFC 5036, RFC 5331 and RFC 5332 apply to this document.

More detailed discussion of security issues that are relevant in the context of MPLS and GMPLS, including security threats, related defensive techniques, and the mechanisms for detection and reporting, are discussed in "Security Framework for MPLS and GMPLS Networks

[MPLS-SEC].

9. Acknowledgements

Thanks to Yakov Rekhter for his contribution. Thanks to Ina Minei and Thomas Morin for their comments. The hashing algorithm used on LAN interfaces is taken from [MLDP]. Thanks to Loa Andersson, Adrian Farrel and Eric Rosen for their comments and review.

10. References

10.1. Normative References

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10.2. Informative References

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