      MPLS Upstream Label Assignment and Context-Specific Label Space

Status of This Memo

   This document specifies an Internet standards track protocol for the
   Internet community, and requests discussion and suggestions for
   improvements. Please refer to the current edition of the "Internet
   Official Protocol Standards" (STD 1) for the standardization state
   and status of this protocol. Distribution of this memo is unlimited.

Abstract

   RFC 3031 limits the MPLS architecture to downstream-assigned MPLS
   labels. This document introduces the notion of upstream-assigned
   MPLS labels. It describes the procedures for upstream MPLS label
   assignment and introduces the concept of a "Context-Specific Label
   Space".

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1. Introduction

   RFC 3031 [RFC3031] limits the MPLS architecture to downstream-
   assigned MPLS labels. To quote from RFC 3031:

   "In the MPLS architecture, the decision to bind a particular label L
   to a particular Forwarding Equivalence Class (FEC) F is made by the
   Label Switching Router (LSR) which is DOWNSTREAM with respect to that
   binding. The downstream LSR then informs the upstream LSR of the
   binding. Thus labels are "downstream-assigned", and label bindings
   are distributed in the "downstream to upstream" direction."

   This document introduces the notion of upstream-assigned MPLS labels
   to the MPLS architecture. The procedures for upstream assignment of
   MPLS labels are described.

   RFC 3031 describes per-platform and per-interface label space. This
   document generalizes the latter to a "Context-Specific Label Space"
   and describes a "Neighbor Label Space" as an example of this.
   Upstream-assigned labels are always looked up in a context-specific
   label space.

2. 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].

3. Context-Specific Label Space

   RFC 3031 describes per-platform and per-interface label spaces. This
   document introduces the more general concept of a "Context-Specific
   Label Space". An LSR may maintain one or more context-specific label
   spaces. In general, labels MUST be looked up in the per-platform
   label space unless something about the context determines that a
   label be looked up in a particular context-specific label space.

   One example of a context-specific label space is the per-interface
   label space discussed in RFC 3031. When an MPLS packet is received
   over a particular interface, the top label of the packet may need to
   be looked up in the receiving interface's per-interface label space.
   In this case, the receiving interface is the context of the packet.
   Whether MPLS packets received over a particular interface need to
   have their top labels looked up in a per-interface label space
   depends on some characteristic or configuration of the interface.

Per-interface label space [RFC3031] is an example of a context-
specific label space used for downstream-assigned labels. Context-
specific label spaces can also be used for upstream-assigned labels,
as described below.

When MPLS labels are upstream-assigned, the context of an MPLS label
L is provided by the LSR that assigns the label and binds the label
to a FEC F for a Label Switched Path (LSP) LSP1. The LSR that
assigns the label distributes the binding and context to an LSR Lr
that then receives MPLS packets on LSP1 with label L. When Lr
receives an MPLS packet on LSP1, it MUST be able to determine the
context of this packet.

An example of such a context is a tunnel over which MPLS packets on
LSP1 may be received. In this case, the top label of the MPLS
packet, after tunnel decapsulation, is looked up in a label space
that is specific to the root of the tunnel. This does imply that Lr
be able to determine the tunnel over which the packet was received.
Therefore, if the tunnel is an MPLS tunnel, penultimate-hop-popping
(PHP) MUST be disabled for the tunnel.

Another example of such a context is the neighbor from which MPLS
packets on LSP1 may be received. In this case, the top label of the
MPLS packet, transmitted by the neighbor on LSP1, is looked up in a
"Neighbor-Specific Label Space".

The above two examples are further described in Section 7.

There may be other sorts of contexts as well. For instance, we
define the notion of an MPLS label being used to establish a context,
i.e., identify a label space. A "context label" is one that
identifies a label table in which the label immediately below the
context label should be looked up. A context label carried as an
outermost label over a particular multi-access subnet/tunnel MUST be
unique within the scope of that subnet/tunnel.

4. Upstream Label Assignment

When two MPLS LSRs are adjacent in an MPLS Label Switched Path (LSP),
one of them can be termed an "upstream LSR" and the other a
"downstream LSR" [RFC3031]. Consider two LSRs, Ru and Rd, that have
agreed to bind Label L to a FEC F for packets sent from Ru to Rd.
Then, with respect to this binding, Ru is the "upstream LSR", and Rd
is the "downstream LSR.""

If the binding between L and F was made by Rd and advertised to Ru,
then the label binding is known as "downstream-assigned". RFC 3031
only discusses downstream-assigned label bindings.

If the binding between L and F was made by Ru and advertised to Rd,
then the label binding is known as "upstream-assigned".

If the binding between L and F was made by a third party, say R3, and
then advertised to both Ru and Rd, we also refer to the label binding
as "upstream-assigned".

An important observation about upstream-assigned labels is the
following. When an upstream-assigned label L is at the top of the
label stack, it must be looked up by an LSR that is not the LSR that
assigned and distributed the label binding for L. Therefore, an
upstream-assigned label MUST always be looked up in a context-
specific label space, as described in Section 7.

We do not require any coordination between the upstream label
assignments and the downstream label assignments; a particular label
value may be upstream-assigned to one FEC and downstream-assigned to
a different FEC.

The ability to use upstream-assigned labels is an OPTIONAL feature.
Upstream-assigned labels MUST NOT be used unless it is known that the
downstream LSR supports them.

One use case of upstream-assigned labels is MPLS multicast, and an
example of this is provided in Section 9.

4.1. Upstream-Assigned and Downstream-Assigned Labels

It is possible that some LSRs on an LSP for FEC F distribute
downstream-assigned label bindings for FEC F, while other LSRs
distribute upstream-assigned label bindings. It is possible for an
LSR to distribute a downstream-assigned label binding for FEC F to
its upstream adjacent LSR AND distribute an upstream-assigned label
binding for FEC F to its downstream adjacent LSR. When two LSRs, Ru
and Rd, are adjacent on an LSP for FEC F (with Ru being the upstream
neighbor and Rd the downstream neighbor), either Ru distributes an
upstream-assigned label binding for F to Rd, or else Rd distributes a
downstream-assigned label binding to Ru, but NOT both. Whether
upstream-assigned or downstream-assigned labels are to be used for a
particular FEC depends on the application using the LSP.

Any application that requires the use of upstream-assigned labels
MUST specify that explicitly, or else it is to be assumed that
downstream-assigned labels are used. An application on an LSR uses a
label distribution protocol to indicate to its peer LSRs whether a
particular label binding distributed by the LSR uses upstream-
assigned or downstream-assigned label. Details of such procedures
are outside the scope of this document. In some cases, the decision

as to which is used for a particular application may be made by a
configuration option.

5. Assigning Upstream-Assigned Labels

The only requirement on an upstream LSR assigning upstream-assigned
labels is that an upstream-assigned label must be unambiguous in the
context-specific label space in which the downstream LSR will look it
up. An upstream LSR that is the headend of multiple tunnels SHOULD,
by default, assign the upstream-assigned labels, for all the LSPs
carried over these tunnels, from a single label space, which is
common to all those tunnels. Further, an upstream LSR that is the
head of multiple tunnels SHOULD use the same IP address as the head
identifier of these tunnels, provided that the head identifier of
these tunnels includes an IP address. The LSR could assign the same
label value to both a downstream-assigned and an upstream-assigned
label. The downstream LSR always looks up upstream-assigned MPLS
labels in a context-specific label space as described in Section 7.

An entry for the upstream-assigned labels is not created in the
Incoming Label Map (ILM) [RFC3031] at the upstream LSR as these
labels are not incoming labels. Instead, an upstream label is an
outgoing label, with respect to the upstream LSR, for MPLS packets
transmitted on the MPLS LSP in which the upstream LSR is adjacent to
the downstream LSR. Hence, an upstream label is part of a Next Hop
Label Forwarding Entry (NHLFE) at the upstream LSR.

When Ru advertises a binding of label L for FEC F to Rd, it creates a
NHLFE entry corresponding to L. This NHLFE entry results in imposing
the label L on the MPLS label stack of the packet forwarded using the
NHLFE entry. If Ru is a transit router on the LSP for FEC F, it
binds the ILM for the LSP to this NHLFE. If Ru is an ingress router
on the LSP for FEC F, it binds the FEC to the NHLFE entry.

6. Distributing Upstream-Assigned Labels

Upstream-assigned label bindings MUST NOT be used unless it is known
that the downstream LSR supports them. How this is known is outside
the scope of this document.

MPLS upstream label assignment requires a label distribution protocol
to distribute the binding from the upstream LSR to the downstream
LSR. Considerations that pertain to a label distribution protocol
that are described in [RFC3031] apply.

The distribution of the upstream-assigned labels is similar to either
the ordered LSP control or independent LSP control of the downstream-
assigned labels. In the former case, an LSR distributes an upstream-

assigned label binding for a FEC F if it is either (a) the ingress
LSR for FEC F, or (b) if it has already received an upstream label
binding for that FEC from its adjacent upstream LSR for FEC F, or (c)
if it has received a request for a downstream label binding from its
upstream adjacent LSR. In the latter case, each LSR, upon noting
that it recognizes a particular FEC, makes an independent decision to
bind an upstream-assigned label to that FEC and to distribute that
binding to its label distribution peers.

7. Upstream Neighbor Label Space

   If the top label of an MPLS packet being processed by LSR Rd is
   upstream-assigned, the label is looked up in a context-specific label
   space, not in a per-platform label space.

   Rd uses a context-specific label space that it maintains for Ru to
   "reserve" MPLS labels assigned by Ru. Hence, if Ru distributes an
   upstream-assigned label binding L for FEC F to Rd, then Rd reserves L
   in the separate ILM for Ru's context-specific label space. This is
   the ILM that Rd uses to look up an MPLS label that is upstream-
   assigned by Ru. This label may be the top label on the label stack
   of a packet received from Ru or it may be exposed as the top label on
   the label stack, as a result of Rd popping one or more labels off the
   label stack, from such a packet.

   This implies that Rd MUST be able to determine whether the top label
   of an MPLS packet being processed is upstream-assigned and, if yes,
   the "context" of this packet. How this determination is made depends
   on the mechanism that is used by Ru to transmit the MPLS packet with
   an upstream-assigned top label L to Rd.

   If Ru transmits this packet by encapsulating it in an IP or MPLS
   tunnel, then the fact that L is upstream-assigned is determined by Rd
   by the tunnel on which the packet is received. Whether a given
   tunnel can be used for transmitting MPLS packets with either
   downstream-assigned or upstream-assigned MPLS labels, or both,
   depends on the tunnel type and is described in [RFC5332]. When Rd
   receives MPLS packets with a top label L on such a tunnel, it
   determines the "context" of this packet based on 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. Such a
   mechanism will be provided by the label distribution protocol between
   Ru and Rd and will likely require extensions to existing label
   distribution protocols. The description of such a mechanism is
   outside the scope of this document.

Rd maintains an "Upstream Neighbor Label Space" for upstream-assigned
labels, assigned by Ru. When Ru transmits MPLS packets the top label
of which is upstream-assigned over IP or MPLS tunnels, then Rd MUST
be able to determine the root of these IP/MPLS tunnels. Rd MUST then
use a separate label space for each unique root.

The root is identified by the head-end IP address of the tunnel. If
the same upstream router, Ru, uses different head-end IP addresses
for different tunnels, then the downstream router, Rd, MUST maintain
a different Upstream Neighbor Label Space for each such head-end IP
address.

Consider the following conditions:

   1) Ru is the "root" of two tunnels, call them A and B.

   2) IP address X is an IP address of Ru.

   3) The signaling protocol used to set up tunnel A identified A's
      root node as IP address X.

   4) The signaling protocol used to set up tunnel B identified B's
      root node as IP address X.

   5) Packets sent through tunnels A and B may be carrying upstream-
      assigned labels.

   6) Ru is the LSR that assigned the upstream-assigned labels
      mentioned in condition 5.

If and only if these conditions hold, then Ru MUST use the same label
space when upstream-assigning labels for packets that travel through
tunnel A that it uses when upstream-assigning labels for packets that
travel through tunnel B.

Suppose that Rd is a node that belongs to tunnels A and B, but is not
the root node of either tunnel. Then Rd may assume that the same
upstream-assigned label space is used on both tunnels IF AND ONLY IF
the signaling protocol used to set up tunnel A identified the root
node as IP address X and the signaling protocol used to set up tunnel
B identified the root node as the same IP address X.

In addition, the protocol that is used for distributing the upstream-
assigned label to be used over a particular tunnel MUST identify the
"assigner" using the same IP address that is used by the protocol
that sets up the tunnel to identify the root node of the tunnel.
Implementors must take note of this, even if the tunnel setup

protocol is different from the protocol that is used for distributing
the upstream-assigned label to be used over the tunnel.

The precise set of procedures for identifying the IP address of the
root of the tunnel depend, of course, on the protocol used to set up
the tunnel. For Point-to-Point (P2P) tunnels, the intention is that
the headend of the tunnel is the "root". For Point-to-Multipoint
(P2MP) or Multipoint-to-Multipoint (MP2MP) tunnels, one can always
identify one node as being the "root" of the tunnel.

Some tunnels may be set up by configuration, rather than by
signaling. In these cases, the IP address of the root of the tunnel
must be configured.

Some tunnels may not even require configuration, e.g., a Generic
Routing Encapsulation (GRE) tunnel can be "created" just by
encapsulating packets and transmitting them. In such a case, the IP
address of the root is considered to be the IP source address of the
encapsulated packets.

If the tunnel on which Rd receives MPLS packets with a top label L is
an MPLS tunnel, then Rd determines a) that L is upstream-assigned and
b) the context for L, from the labels above L in the label stack.
Note that one or more of these labels may also be upstream-assigned
labels.

If the tunnel on which Rd receives MPLS packets with a top label L is
an IP/GRE tunnel, then Rd determines a) that L is upstream-assigned
[RFC5332] and b) the context for L, from the source address in the IP
header.

When Ru and Rd are adjacent to each other on a multi-access data link
media, if Ru would transmit the packet, with top label L, by
encapsulating it in a data link frame, then whether L is upstream-
assigned or downstream assigned can be determined by Rd, as described
in [RFC5332]. This is possible because if L is upstream-assigned,
then [RFC5332] uses a different ether type in the data link frame.
However, this is not sufficient for Rd to determine the context of
this packet. In order for Rd to determine the context of this
packet, Ru encapsulates the packet in a one-hop MPLS tunnel. This
tunnel uses an MPLS context label that is assigned by Ru. Section 8
describes how the context label is assigned. Rd maintains a separate
"Upstream Neighbor Label Space" for Ru. The "context" of this
packet, i.e., Ru's upstream neighbor label space, in which L was
reserved, is determined by Rd from the top context label and the
interface on which the packet is received. The ether type in the
data link frame is set to indicate that the top label is upstream-
assigned. The second label in the stack is L.

8. Context Label on LANs

   For a labeled packet with an ether type of "upstream label
   assignment", the top label is used as the context. The context label
   value is assigned by the upstream LSR and advertised to the
   downstream LSRs. Mechanisms for advertising the context label will
   be provided by the label distribution protocol between the upstream
   and downstream LSRs. The description of such a mechanism is outside
   the scope of this document.

   The context label assigned by an LSR for use on a particular LAN
   interface MUST be unique across all the context labels assigned by
   other LSRs for use on the same LAN. When a labeled packet is
   received from the LAN, the context label MUST be looked up in the
   context of the LAN interface on which the packet is received.

   This document provides two methods that an LSR can use to choose a
   context label to advertise on a particular LAN.

   The first method requires that each LSR be provisioned with a 20-bit
   context label for each LAN interface on which a context label is
   required. It is then left to the provisioning system to make sure
   that an assigned context label is unique across the corresponding
   LAN.

   The second method allows the context labels to be auto-generated, but
   is only applicable if each LSR on the LAN has an IPv4 address as its
   primary IP address for the corresponding LAN interface. (If the LAN
   contains LSRs that have only IPv6 addresses for the LAN interface,
   then the first method is used.)

   Suppose that each LAN interface is configured with a primary IPv4
   address that is unique on that LAN. The host part of the IPv4
   address, identified by the network mask, is unique. If the IPv4
   network mask is greater than 12 bits, it is possible to map the
   remaining 20 bits into a unique context label value. This enables
   the LSRs on the LAN to automatically generate a unique context label.
   To ensure that auto-generated context label values do not fall into
   the reserved label space range [RFC3032], the value of the host part
   of the IPv4 address is offset with 0x10, if this value is not greater
   than 0xFFFEF. Values of the host part of the IPv4 address greater
   than 0xFFFEF are not allowed to be used as context labels.

   Consider LSR Rm (downstream) connected to Ru1 (upstream) on a LAN
   interface and to Ru2 (upstream) on a different LAN interface. Rm
   could receive a context label value derived from the LAN interface
   from Ru1 and from Ru2. It is possible that the context label values
   used by Ru1 and Ru2 are the same. This would occur if the LAN

interfaces of both Ru1 and Ru2 are configured with a primary IPv4
address where the lowest 20 bits are equal. However, this does not
create any ambiguity, as it has already been stated that the context
label MUST be looked up in the context of the LAN interface on which
the packet is received.

9. Usage of Upstream-Assigned Labels

A typical use case of upstream-assigned labels is for MPLS multicast
and is described here for illustration. This use case arises when an
upstream LSR Ru is adjacent to several downstream LSRs <Rd1...Rdn> in
an LSP, LSP1 AND Ru is connected to <Rd1...Rdn> via a multi-access
media or tunnel, AND Ru wants to transmit a single copy of an MPLS
packet on the LSP to <Rd1...Rdn>. In the case of a tunnel, Ru can
distribute an upstream-assigned label L that is bound to the FEC for
LSP1, to <Rd1..Rdn> and transmit an MPLS packet, the top label of
which is L, on the tunnel. In the case of a multi-access media, Ru
can distribute an upstream-assigned label L that is bound to the FEC
for LSP1, to <Rd1..Rdn> and transmit an MPLS packet, the top label of
which is the context label that identifies Ru, and the label
immediately below is L, on the multi-access media. Each of
<Rd1..Rdn> will then interpret this MPLS packet in the context of Ru
and forward it appropriately. This implies that <Rd1..Rdn> MUST all
be able to support an Upstream Neighbor Label Space for Ru and Ru
MUST be able to determine this. The mechanisms for determining this
are specific to the application that is using upstream-assigned
labels and is outside the scope of this document.

10. Security Considerations

The security considerations that apply to upstream-assigned labels
and context labels are no different in kind than those that apply to
downstream-assigned labels.

Note that procedures for distributing upstream-assigned labels and/or
context labels are not within the scope of this document. Therefore,
the security considerations that may apply to such procedures are not
considered here.

Section 8 of this document describes a procedure that enables an LSR
to automatically generate a unique context label for a LAN. This
procedure assumes that the IP addresses of all the LSR interfaces on
the LAN will be unique in their low-order 20 bits. If two LSRs whose
IP addresses have the same low-order 20 bits are placed on the LAN,
other LSRs are likely to misroute packets transmitted to the LAN by
either of the two LSRs in question.

   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].

11. Acknowledgements

   Thanks to IJsbrand Wijnands's contribution, specifically for the text
   on which Section 8 is based.

12. References

12.1. Normative References

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