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1. Introduction

Segment Routing, as described in [[I-D.ietf-spring-segment-routing](#)], can be used on top of the MPLS data plane without any modification as described in [[I-D.ietf-spring-segment-routing-mpls](#)].

Segment Routing control plane can co-exist with current label distribution protocols such as LDP ([[RFC5036](#)]).

This draft outlines the mechanisms through which SR interworks with LDP in cases where a mix of SR-capable and non-SR-capable routers co-exist within the same network and more precisely in the same routing domain.

[Section 2](#) describes the co-existence of SR with other MPLS Control Plane. [Section 3](#) documents a method to migrate from LDP to SR-based MPLS tunneling. [Section 4](#) documents the interworking between SR and LDP in the case of non-homogeneous deployment. [Section 5](#) describes how a partial SR deployment can be used to provide SR benefits to LDP-based traffic including a possible application of SR in the context of inter-domain MPLS use-cases.

2. SR/LDP Ship-in-the-night coexistence

We call "MPLS Control Plane Client (MCC)" any control plane protocol installing forwarding entries in the MPLS data plane. SR, LDP, RSVP-TE, BGP 3107, VPNv4, etc are examples of MCCs.

An MCC, operating at node N, must ensure that the incoming label it installs in the MPLS data plane of Node N has been uniquely allocated to himself.

Thanks to the defined segment allocation rule and specifically the notion of the Segment Routing Global Block (SRGB, as defined in [[I-D.ietf-spring-segment-routing](#)]), SR can co-exist with any other MCC.

This is clearly the case for the adjacency segment: it is a local label allocated by the label manager, as for any MCC.

This is clearly the case for the prefix segment: the label manager allocates the SRGB set of labels to the SR MCC client and the operator ensures the unique allocation of each global prefix segment/label within the allocated SRGB set.

Note that this static label allocation capability of the label manager exists for many years across several vendors and hence is not new. Furthermore, note that the label-manager ability to statically

allocate a range of labels to a specific application is not new either. This is required for MPLS-TP operation. In this case, the range is reserved by the label manager and it is the MPLS-TP ([RFC5960]) NMS (acting as an MCC) that ensures the unique allocation of any label within the allocated range and the creation of the related MPLS forwarding entry.

Let us illustrate an example of ship-in-the-night (SIN) coexistence.

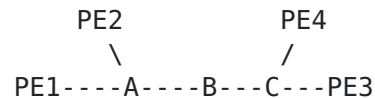


Figure 1: SIN coexistence

The EVEN VPN service is supported by PE2 and PE4 while the ODD VPN service is supported by PE1 and PE3. The operator wants to tunnel the ODD service via LDP and the EVEN service via SR.

This can be achieved in the following manner:

The operator configures PE1, PE2, PE3, PE4 with respective loopbacks 192.0.2.201/32, 192.0.2.202/32, 192.0.2.203/32, 192.0.2.204/32. These PE's advertised their VPN routes with next-hop set on their respective loopback address.

The operator configures A, B, C with respective loopbacks 192.0.2.1/32, 192.0.2.2/32, 192.0.2.3/32.

The operator configures PE2, A, B, C and PE4 with SRGB [100, 300].

The operator attach the respective Node Segment Identifiers (Node-SID's, as defined in [I-D.ietf-spring-segment-routing]): 202, 101, 102, 103 and 204 to the loopbacks of nodes PE2, A, B, C and PE4. The Node-SID's are configured to request penultimate-hop-popping.

PE1, A, B, C and PE3 are LDP capable.

PE1 and PE3 are not SR capable.

PE3 sends an ODD VPN route to PE1 with next-hop 192.0.2.203 and VPN label 10001.

From an LDP viewpoint: PE1 received an LDP label binding (1037) for FEC 192.0.2.203/32 from its nhop A. A received an LDP label binding (2048) for that FEC from its nhop B. B received an LDP label binding (3059) for that FEC from its nhop C. C received implicit-null LDP binding from its next-hop PE3.

As a result, PE1 sends its traffic to the ODD service route advertised by PE3 to next-hop A with two labels: the top label is 1037 and the bottom label is 10001. A swaps 1037 with 2048 and forwards to B. B swaps 2048 with 3059 and forwards to C. C pops 3059 and forwards to PE3.

PE4 sends an EVEN VPN route to PE2 with next-hop 192.0.2.204 and VPN label 10002.

From an SR viewpoint: PE2 maps the IGP route 192.0.2.204/32 onto Node-SID 204; A swaps 204 with 204 and forwards to B; B swaps 204 with 204 and forwards to C; C pops 204 and forwards to PE4.

As a result, PE2 sends its traffic to the VPN service route advertised by PE4 to next-hop A with two labels: the top label is 204 and the bottom label is 10002. A swaps 204 with 204 and forwards to B. B swaps 204 with 204 and forwards to C. C pops 204 and forwards to PE4.

The two modes of MPLS tunneling co-exist.

The ODD service is tunneled from PE1 to PE3 through a continuous LDP LSP traversing A, B and C.

The EVEN service is tunneled from PE2 to PE4 through a continuous SR node segment traversing A, B and C.

2.1. MPLS2MPLS co-existence

We want to highlight that several MPLS2MPLS entries can be installed in the data plane for the same prefix.

Let us examine A's MPLS forwarding table as an example:

Incoming label: 1037

- outgoing label: 2048
- outgoing nhop: B

Note: this entry is programmed by LDP for 192.0.2.203/32

Incoming label: 203

- outgoing label: 203
- outgoing nhop: B

Note: this entry is programmed by SR for 192.0.2.203/32

These two entries can co-exist because their incoming label is unique. The uniqueness is guaranteed by the label manager allocation rules.

The same applies for the MPLS2IP forwarding entries.

2.2. IP2MPLS co-existence

By default, if both LDP and SR propose an IP to MPLS entry (IP2MPLS) for the same IP prefix, then the LDP route SHOULD be selected.

A local policy on a router MUST allow to prefer the SR-provided IP2MPLS entry.

Note that this policy may be locally defined. There is no requirement that all routers use the same policy.

3. Migration from LDP to SR

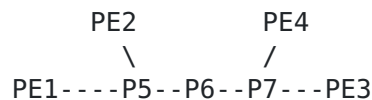


Figure 2: Migration

Several migration techniques are possible. We describe one technique inspired by the commonly used method to migrate from one IGP to another.

At time T0, all the routers run LDP. Any service is tunneled from an ingress PE to an egress PE over a continuous LDP LSP.

At time T1, all the routers are upgraded to SR. They are configured with the SRGB range [100, 300]. PE1, PE2, PE3, PE4, P5, P6 and P7 are respectively configured with the node segments 101, 102, 103, 104, 105, 106 and 107 (attached to their service-recurring loopback).

At this time, the service traffic is still tunneled over LDP LSP. For example, PE1 has an SR node segment to PE3 and an LDP LSP to PE3 but by default, as seen earlier, the LDP IP2MPLS encapsulation is preferred. However, it has to be noted that the SR infrastructure is usable, e.g. for Fast Reroute (FRR) or IGP Loop Free Convergence to protect existing IP and LDP traffic. FRR mechanisms are described in [\[I-D.francois-rtgwg-segment-routing-ti-lfa\]](#).

At time T2, the operator enables the local policy at PE1 to prefer SR IP2MPLS encapsulation over LDP IP2MPLS.

The service from PE1 to any other PE is now riding over SR. All other service traffic is still transported over LDP LSP.

At time T3, gradually, the operator enables the preference for SR IP2MPLS encapsulation across all the edge routers.

All the service traffic is now transported over SR. LDP is still operational and services could be reverted to LDP.

However, any traffic switched through LDP entries will still suffer from LDP-IGP synchronization.

At time T4, LDP is unconfigured from all routers.

4. SR and LDP Interworking

In this section, we analyze the case where SR is available in one part of the network and LDP is available in another part. We describe how a continuous MPLS tunnel can be built throughout the network.

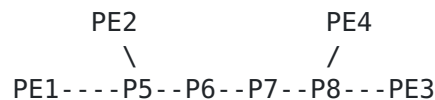


Figure 3: SR and LDP Interworking

Let us analyze the following example:

P6, P7, P8, PE4 and PE3 are LDP capable.

PE1, PE2, P5 and P6 are SR capable. PE1, PE2, P5 and P6 are configured with SRGB (100, 200) and respectively with node segments 101, 102, 105 and 106.

A service flow must be tunneled from PE1 to PE3 over a continuous MPLS tunnel encapsulation. We need SR and LDP to interwork.

4.1. LDP to SR

In this section, we analyze a right-to-left traffic flow.

PE3 has learned a service route whose nhop is PE1. PE3 has an LDP label binding from the nhop P8 for the FEC "PE1". Hence PE3 sends its service packet to P8 as per classic LDP behavior.

P8 has an LDP label binding from its nhop P7 for the FEC "PE1" and hence P8 forwards to P7 as per classic LDP behavior.

P7 has an LDP label binding from its nhop P6 for the FEC "PE1" and hence P7 forwards to P6 as per classic LDP behavior.

P6 does not have an LDP binding from its nhop P5 for the FEC "PE1". However P6 has an SR node segment to the IGP route "PE1". Hence, P6 forwards the packet to P5 and swaps its local LDP-label for FEC "PE1" by the equivalent node segment (i.e. 101).

P5 pops 101 (assuming PE1 advertised its node segment 101 with the penultimate-pop flag set) and forwards to PE1.

PE1 receives the tunneled packet and processes the service label.

The end-to-end MPLS tunnel is built from an LDP LSP from PE3 to P6 and the related node segment from P6 to PE1.

4.1.1. LDP to SR Behavior

It has to be noted that no additional signaling or state is required in order to provide interworking in the direction LDP to SR.

A SR node having LDP neighbors MUST create LDP bindings for each Prefix-SID and Node-SID learned in the SR domain and, for each FEC, stitch the incoming LDP label to the outgoing SR label. This has to be done in both LDP independent and ordered label distribution control modes as defined in [[RFC5036](#)].

If the SR/LDP node operates in LDP ordered label distribution control mode (as defined in [[RFC5036](#)], then the SR/DLP node MUST consider SR learned labels as if they were learned through an LDP neighbor and create LDP bindings for each Prefix-SID and Node-SID learned in the SR domain.

4.2. SR to LDP

In this section, we analyze the left-to-right traffic flow.

We assume that the operator configures P5 to act as a Segment Routing Mapping Server (SRMS) and advertises the following mappings: (P7, 107), (P8, 108), (PE3, 103) and (PE4, 104).

These mappings are advertised as Remote-Binding SID as described in [[I-D.ietf-isis-segment-routing-extensions](#)].

The mappings advertised by one or more SR mapping servers result from local policy information configured by the operator.

If PE3 had been SR capable, the operator would have configured PE3 with node segment 103. Instead, as PE3 is not SR capable, the operator configures that policy at the SRMS and it is the latter which advertises the mapping.

The mapping server advertisements are only understood by the SR capable routers. The SR capable routers install the related node segments in the MPLS data plane exactly like if the node segments had been advertised by the nodes themselves.

For example, PE1 installs the node segment 103 with nhop P5 exactly as if PE3 had advertised node segment 103.

PE1 has a service route whose nhop is PE3. PE1 has a node segment for that IGP route: 103 with nhop P5. Hence PE1 sends its service packet to P5 with two labels: the bottom label is the service label and the top label is 103.

P5 swaps 103 for 103 and forwards to P6.

P6's next-hop for the IGP route "PE3" is not SR capable (P7 does not advertise the SR capability). However, P6 has an LDP label binding from that next-hop for the same FEC (e.g. LDP label 1037). Hence, P6 swaps 103 for 1037 and forwards to P7.

P7 swaps this label with the LDP-label received from P8 and forwards to P8.

P8 pops the LDP label and forwards to PE3.

PE3 receives the tunneled packet and processes the service label.

The end-to-end MPLS tunnel is built from an SR node segment from PE1 to P6 and an LDP LSP from P6 to PE3.

Note: SR mappings advertisements cannot set Penultimate Hop Popping. In the previous example, P6 requires the presence of the segment 103 such as to map it to the LDP label 1037. For that reason, the P flag available in the Prefix-SID is not available in the Remote-Binding SID.

4.2.1. SR to LDP Behavior

SR to LDP interworking requires a SRMS as defined in [\[I-D.ietf-isis-segment-routing-extensions\]](#).

The SRMS MUST be configured by the operator in order to advertise Node-SIDs on behalf of non-SR nodes.

At least one SRMS MUST be present in the routing domain. Multiple SRMSs SHOULD be present for redundancy.

Each SR capable router installs in the MPLS data plane Node-SIDs learned from the SRMS exactly like if these SIDs had been advertised by the nodes themselves.

A SR node having LDP neighbors MUST create LDP bindings for each Prefix-SID and Node-SID learned in the SR domain and, for each FEC, stitch the incoming SR label to the outgoing LDP label. This has to be done in both LDP independent and ordered label distribution control modes as defined in [[RFC5036](#)].

If the SR/LDP node operates in LDP ordered label distribution control mode (as defined in [[RFC5036](#)], then the SR/LDP node MUST consider SR learned labels as if they were learned through an LDP neighbor and create LDP bindings for each Prefix-SID and Node-SID learned in the SR domain.

The encodings of the SRMS advertisements are specific to the routing protocol. See [[I-D.ietf-isis-segment-routing-extensions](#)], [[I-D.ietf-ospf-segment-routing-extensions](#)] and [[I-D.ietf-ospf-ospfv3-segment-routing-extensions](#)] for details of SRMS encodings. See also [[I-D.ietf-spring-conflict-resolution](#)] for the specific rules on SRMS advertisements.

It has to be noted, The SR to LDP behavior does not propagate the status of the LDP FEC which was signaled if LDP was configured to use the ordered mode.

It has to be noted that in the case of SR to LDP, the label binding is equivalent to the LDP Label Distribution Control Mode ([[RFC5036](#)]) where a label is bound to a FEC independently from the received binding for the same FEC.

5. SR/LDP Interworking Use Cases

SR can be deployed such as to enhance LDP transport. The SR deployment can be limited to the network region where the SR benefits are most desired.

5.1. SR Protection of LDP-based Traffic

In Figure 4, let us assume:

All link costs are 10 except FG which is 30.

All routers are LDP capable.

X, Y and Z are PE's participating to an important service S.

The operator requires 50msec link-based Fast Reroute (FRR) for service S.

A, B, C, D, E, F and G are SR capable.

X, Y, Z are not SR capable, e.g. as part of a staged migration from LDP to SR, the operator deploys SR first in a sub-part of the network and then everywhere.

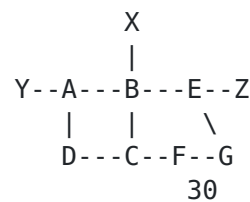


Figure 4: SR/LDP interworking example

The operator would like to resolve the following issues:

To protect the link BA along the shortest-path of the important flow XY, B requires a Remote LFA (RLFA, [\[RFC7490\]](#)) repair tunnel to D and hence a targeted LDP session from B to D. Typically, network operators prefer avoiding these dynamically established multi-hop LDP sessions in order to reduce the number of protocols running in the network and hence simplify network operations.

There is no LFA/RLFA solution to protect the link BE along the shortest path of the important flow XZ. The operator wants a guaranteed link-based FRR solution.

The operator can meet these objectives by deploying SR only on A, B, C, D, E, F and G:

The operator configures A, B, C, D, E, F and G with SRGB (100, 200) and respective node segments 101, 102, 103, 104, 105, 106 and 107.

The operator configures D as an SR Mapping Server with the following policy mapping: (X, 201), (Y, 202), (Z, 203).

Each SR node automatically advertises local adjacency segment for its IGP adjacencies. Specifically, F advertises adjacency segment 9001 for its adjacency FG.

A, B, C, D, E, F and G keep their LDP capability and hence the flows XY and XZ are transported over end-to-end LDP LSP's.

For example, LDP at B installs the following MPLS data plane entries:

Incoming label: local LDB label bound by B for FEC Y
Outgoing label: LDP label bound by A for FEC Y
Outgoing nhop: A

Incoming label: local LDB label bound by B for FEC Z
Outgoing label: LDP label bound by E for FEC Z
Outgoing nhop: E

The novelty comes from how the backup chains are computed for these LDP-based entries. While LDP labels are used for the primary nhop and outgoing labels, SR information is used for the FRR construction. In steady state, the traffic is transported over LDP LSP. In transient FRR state, the traffic is backup thanks to the SR enhanced capabilities.

The RLFA paths are dynamically pre-computed as defined in [\[RFC7490\]](#). Typically, implementations allow to enable RLFA mechanism through a simple configuration command that triggers both the pre-computation and installation of the repair path. The details on how RLFA mechanisms are implemented and configured is outside the scope of this document and not relevant to the aspects of SR/LDP interwork explained in this document.

This helps meet the requirements of the operator:

Eliminate targeted LDP session.

Guaranteed FRR coverage.

Keep the traffic over LDP LSP in steady state.

Partial SR deployment only where needed.

[5.2.](#) Eliminating Targeted LDP Session

B's MPLS entry to Y becomes:

- Incoming label: local LDB label bound by B for FEC Y
Outgoing label: LDP label bound by A for FEC Y
Backup outgoing label: SR node segment for Y {202}
Outgoing nhop: A
Backup nhop: repair tunnel: node segment to D {104}
with outgoing nhop: C

It has to be noted that D is selected as Remote Free Alternate (R-LFA) as defined in [[RFC7490](#)].

In steady-state, X sends its Y-destined traffic to B with a top label which is the LDP label bound by B for FEC Y. B swaps that top label for the LDP label bound by A for FEC Y and forwards to A. A pops the LDP label and forwards to Y.

Upon failure of the link BA, B swaps the incoming top-label with the node segment for Y (202) and sends the packet onto a repair tunnel to D (node segment 104). Thus, B sends the packet to C with the label stack {104, 202}. C pops the node segment 104 and forwards to D. D swaps 202 for 202 and forwards to A. A's nhop to Y is not SR capable and hence A swaps the incoming node segment 202 to the LDP label announced by its next-hop (in this case, implicit null).

After IGP convergence, B's MPLS entry to Y will become:

- Incoming label: local LDB label bound by B for FEC Y
- Outgoing label: LDP label bound by C for FEC Y
- Outgoing nhop: C

And the traffic XY travels again over the LDP LSP.

Conclusion: the operator has eliminated the need for targeted LDP sessions (no longer required) and the steady-state traffic is still transported over LDP. The SR deployment is confined to the area where these benefits are required.

Despite that in general, an implementation would not require a manual configuration of LDP Targeted sessions however, it is always a gain if the operator is able to reduce the set of protocol sessions running on the network infrastructure.

5.3. Guaranteed FRR coverage

As mentioned in [Section 5.1](#) above, in the example topology described in Figure 4, there is no RLFA-based solution for protecting the traffic flow YZ against the failure of link BE because there is no intersection between the extended P-space and Q-space (see [[RFC7490](#)] for details). However:

- o G belongs to the Q space of Z.
- o G can be reached from B via a "repair SR path" {106, 9001} that is not affected by failure of link BE (The method by which G and the repair tunnel to it from B are identified are out of scope of this document.)

B's MPLS entry to Z becomes:

- Incoming label: local LDB label bound by B for FEC Z
Outgoing label: LDP label bound by E for FEC Z
Backup outgoing label: SR node segment for Z {203}
Outgoing nhop: E
Backup nhop: repair tunnel to G: {106, 9001}

G is reachable from B via the combination of a node segment to F {106} and an adjacency segment FG {9001}

Note that {106, 107} would have equally work. Indeed, in many case, P's shortest path to Q is over the link PQ. The adjacency segment from P to Q is required only in very rare topologies where the shortest-path from P to Q is not via the link PQ.

In steady-state, X sends its Z-destined traffic to B with a top label which is the LDP label bound by B for FEC Z. B swaps that top label for the LDP label bound by E for FEC Z and forwards to E. E pops the LDP label and forwards to Z.

Upon failure of the link BE, B swaps the incoming top-label with the node segment for Z (203) and sends the packet onto a repair tunnel to G (node segment 106 followed by adjacency segment 9001). Thus, B sends the packet to C with the label stack {106, 9001, 203}. C pops the node segment 106 and forwards to F. F pops the adjacency segment 9001 and forwards to G. G swaps 203 for 203 and forwards to E. E's nhop to Z is not SR capable and hence E swaps the incoming node segment 203 for the LDP label announced by its next-hop (in this case, implicit null).

After IGP convergence, B's MPLS entry to Z will become:

- Incoming label: local LDB label bound by B for FEC Z
Outgoing label: LDP label bound by C for FEC Z
Outgoing nhop: C

And the traffic XZ travels again over the LDP LSP.

Conclusions:

- o the operator has eliminated its second problem: guaranteed FRR coverage is provided. The steady-state traffic is still transported over LDP. The SR deployment is confined to the area where these benefits are required.

- o FRR coverage has been achieved without any signaling for setting up the repair LSP and without setting up a targeted LDP session between B and G.

5.4. Inter-AS Option C, Carrier's Carrier

In inter-AS Option C, two interconnected ASes sets up inter-AS MPLS connectivity. SR may be independently deployed in each AS.

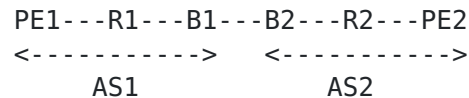


Figure 5: Inter-AS Option C

In Inter-AS Option C [[RFC4364](#)], B2 advertises to B1 a BGP3107 route for PE2 and B1 reflects it to its internal peers, such as PE1. PE1 learns from a service route reflector a service route whose nhop is PE2. PE1 resolves that service route on the BGP3107 route to PE2. That BGP3107 route to PE2 is itself resolved on the AS1 IGP route to B1.

If AS1 operates SR, then the tunnel from PE1 to B1 is provided by the node segment from PE1 to B1.

PE1 sends a service packet with three labels: the top one is the node segment to B1, the next-one is the BGP3107 label provided by B1 for the route "PE2" and the bottom one is the service label allocated by PE2.

6. IANA Considerations

This document does not introduce any new codepoint.

7. Manageability Considerations

7.1. SR and LDP co-existence

As illustrated in [Section 2.2](#), when both SR and LDP co-exist, the following applies:

- o If both SR and LDP propose an IP2MPLS entry for the same IP prefix, then by default the LDP route MUST be selected.
- o A local policy on a router MUST allow to prefer the SR-provided IP2MPLS entry.

- o Note that this policy may be locally defined. There is no requirement that all routers use the same policy.

7.2. SRMS Management

In the case of SR/LDP interoperability through the use of a SRMS, mappings are advertised by one or more SRMS.

SRMS function is implemented in the link-state protocol (such as IS-IS and OSPF). Link-state protocols allow propagation of updates across area boundaries and therefore SRMS advertisements are propagated through the usual inter-area advertisement procedures in link-state protocols.

Multiple SRMSs can be provisioned in a network for redundancy. Moreover, a preference mechanism may also be used among SRMSs so to deploy a primary/secondary SRMS scheme allowing controlled modification or migration of SIDs.

The content of SRMS advertisement (i.e.: mappings) are a matter of local policy determined by the operator. When multiple SRMSs are active, it is necessary that the information (mappings) advertised by the different SRMSs is aligned and consistent.

[[I-D.ietf-spring-conflict-resolution](#)] illustrates mechanisms through which such consistency is achieved.

When the SRMS advertise mappings, an implementation SHOULD provide a mechanism through which the operator determines which of the IP2MPLS mappings are preferred among the one advertised by the SRMS and the ones advertised by LDP.

7.3. Dataplane Verification

When Label switch paths (LSPs) are defined by stitching LDP LSPs with SR LSPs, it is necessary to have mechanisms allowing the verification of the LSP connectivity as well as validation of the path. These mechanisms are described in [\[I-D.ietf-mpls-spring-lsp-ping\]](#).

8. Security Considerations

This document does not introduce any change to the MPLS dataplane and therefore no additional security of the MPLS dataplane is required.

This document introduces another form of label binding advertisements. The security associated with these advertisement is part of the security applied to routing protocols such as IS-IS and OSPF which both make use of cryptographic authentication mechanisms.

9. Acknowledgements

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