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Entropy label for seamless MPLS
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Abstract

This document describes certain optimizations to how entropy labels can be used for load balancing in a seamless MPLS architecture, as enabled by LSP concatenation and LSP hierarchies.

The definition of the control plane and data plane behavior at LSP concatenation points; and at the ingress of an LSP in a hierarchy of LSPs, as described in this document, brings the benefits of entropy labels to certain deployment scenarios that may not have had such benefits as specified in [[EL-RFC](#)].

This document, if approved, updates [RFC 6790](#).

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1 Introduction

[EL-RFC] specifies a way to implement load-balancing in an MPLS network such that sub-flows of an LSP may be identified and sent on different paths through the network. This is achieved by using entropy labels (ELs) to abstract out the flow-identifying information into the entropy label and inserting the entropy label underneath the LSP label. The transit LSRs perform the load-balancing hash-computation, on the label-stack alone, to effect a good load-balancing outcome without a need to parse inner headers.

The key feature of [EL-RFC] is that it defines the EL in the context of a given LSP. [EL-RFC] defines the signaling extensions by which entropy label capability might be signaled for LSPs setup by RSVP-TE, LDP or [LU-BGP]. While that works well for individual LSPs, there are additional issues to consider for the seamless MPLS architecture [S-MPLS].

The currently-under-definition framework for seamless MPLS proposes an architecture ([S-MPLS]) that shall enable the setting-up of MPLS LSPs from access nodes to access nodes using a medley of signaling protocols and statically configured LSPs...by essentially leveraging LSP concatenation and hierarchies to carry labeled traffic in larger portions of the network without essentially increasing control plane state. There are special EL-related considerations that need to be dealt with to make EL more suitable for seamless MPLS, on account of its reliance on LSP concatenation and hierarchies.

This document defines additional abstractions and rules for the use of entropy-label with LSP concatenation/hierarchy to enable the use of ELs for the seamless MPLS architecture. This document describes how entropy labels may be used when the LSP has been setup by concatenation LSP segments or by tunneling the LSP over other LSPs. It is conceivable that different signaling protocols are in use to create an e2e LSP.

LSP stitching is the process of connecting LSP segments in the data plane to form a single e2e data plane LSP. This is achieved by setting up LSP segments through signaling or through management action, and then setting-up an e2e LSP that "uses" these LSP segments as hops in its path. The term "LSP stitching" has potential to be ambiguous. In order to reduce the ambiguity, both meanings of the usage of the term "LSP stitching" are clarified below. One meaning of the term "LSP stitching" is as defined in [GMPLS-STITCHING].

An alternate use of "LSP stitching" as occurs for inter-AS scenarios described in [INTER-AS-VPNS]. When section 10 in [INTER-AS-VPNS]

refers to either of the two following statements it is essentially describing "LSP stitching" in the data plane:

- In "b)": "This procedure requires that there be a label switched path leading from a packet's ingress PE to its egress PE."
- In "c)": "Like the previous procedure, it requires that there be a label switched path leading from a packet's ingress PE to its egress PE."

Labeled data traffic flowing over e2e MPLS LSPs, that have been setup by stitching together segments, would benefit from having the entropy label be included in it. The specification of [\[EL-RFC\]](#) can be optimized for usage in such environments.

This document specifies optimizations for "LSP stitching" which are applicable to the latter meaning of the term "LSP stitching". For terminology sake, this document shall refer to that latter case as "LSP concatenation".

LSP hierarchy is defined in [\[MPLS-ARCH\]](#) and [\[GMPLS-HIER\]](#). Usage of entropy label in LSP hierarchies has some peculiar practical issues that will benefit from some additional flexibility in inserting ELs for a specific layer in an LSP hierarchy.

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 [RFC 2119](#) [\[RFC2119\]](#).

The following acronyms/terms are used:

e2e: End to end LSP that has been setup by concatenating together LSP segments

ECMP: Equal Cost Multi-Path

EL: Entropy Label

ELC: Entropy Label Capability or Entropy Label Capable

ELI: Entropy Label Indicator

Intrinsic ELC: Entropy label capability/capable as in [\[EL-RFC\]](#). In this document, an LSP is considered to be

"intrinsically" EL-capable when the:

- ingress of the LSP has the ability to compute and PUSH the EL before PUSHing the ELI before PUSHing the LSP label; and
- egress/PHR of the LSP-segment has the ability to POP the (ELI+EL) at the egress/PHR while POPping-transport-label/ELI-is-top-label respectively.

LAG: Link Aggregation Group

LER: Label Edge Router

LSP: Label Switched Path

LSR: Label Switching Router

Notional ingress: Ingress LER for an LSP segment that is inserting the (ELI+EL) on data traffic going over an e2e LSP

Notional egress: egress LER for an LSP segment that is removing the (ELI+EL) from data traffic going over an e2e LSP

Notional LSP segment: the portion of the e2e LSP between a notional ingress and a notional egress

PHP: Penultimate Hop Popping

PHR: Penultimate Hop Router

UHP: Ultimate Hop Popping

NOTE: this document references the (ELI+EL) pair simply as EL when the presence of the ELI is of no significance for the issue being described. The presence of ELI is mandatory as per [\[EL-RFC\]](#) when EL is in use.

3. Key attributes of the entropy label solution: Summary from [\[EL-RFC\]](#)

- Transport-label-PUSHing router inserts (ELI+EL)
The (ELI+EL) insertion is done, if at all, by a router that is PUSHing the transport LSP's label.
- Ingress-LER (transport-label-PUSHing-router) inserts (ELI+EL) only if the PHR/egress has signaled ability to strip it off.
- Transport-label-POPping router POPs (ELI+EL) PHR/egress of the

LSP is responsible for POPping off the (ELI+EL) after it has been exposed as the top label on the packet due to POPping the transport label. The removal of the (ELI+EL) is done either when the ELI is the top label; or when the ELI is next label below the top label being POPed.

- Max-payload size for the LSP gets reduced by 8 bytes after the insertion of the (ELI+EL).

4. Problems and Motivation

[EL-RFC] defines EL signaling/usage suitable for single-segment LSPs.

[EL-RFC] does not explicitly specify the EL-signaling-interaction between concatenated LSP segments. Similarly, peculiarities in the data-plane related to LSP concatenation need further specification. Likewise, the signaling and data-plane peculiarities for using EL over LSP hierarchies could be further specified.

It is desirable to get the benefits of EL even for concatenated LSPs.

Certain aspects peculiar to concatenated LSPs need additional handling to increase the applicability of [EL-RFC]. [EL-RFC] needs to be extended to define the behavior for LSP concatenation and LSP hierarchies (tunneling) when using EL.

The sub-sections below list the specific additional requirements for making entropy label more deployable when used with LSP concatenation, and LSP hierarchy.

4.1 EL applicability for seamless MPLS

The seamless MPLS architecture relies on the use of LSP concatenation and hierarchy to signal an e2e LSP between access-nodes, such that the e2e LSP is going over aggregation/transport/cores nodes.

The signaling of such e2e LSPs is enabled by using the concatenation/hierarchy mechanisms that exist, using [LU-BGP]/LDP/RSVP.

The rules of [section 5](#) provide a general-purpose way for the use of ELs across e2e LSPs by defining:

- the rules of ELC propagation at concatenation points;
- the data-plane guidelines for the concatenation point LSR; and

- the data-plane guidelines for LSP hierarchies for inserting (ELI+EL) at ingress LER of an LSP in an LSP hierarchy.

4.2 EL for LSP concatenation

A concatenated e2e LSP might be stitched from greater than 2 segment LSPs (along the length of the e2e LSP), with 2 LSPs forming the stitch at each concatenation point.

An LSP segment is considered to be intrinsically EL capable when it supports the attributes summarized in [section 3](#).

Some of the segment LSPs in the e2e LSP may intrinsically support EL and some may not. So, the e2e LSP may not intrinsically support EL from end to end. However, to obtain the benefits of EL for concatenated LSPs, it is important that an EL should be present on the data packets traversing as many segments of the e2e LSP as is possible within data plane abilities of the routers on the way.

In using EL with LSP concatenation, the aims are BOTH of the following:

- a. Get EL benefits wherever possible: on all segments where possible. Just because a given segment does not support EL is not a reason to deny EL benefits to other segments of the e2e LSP.
 - b. Not run into data-plane problems where an intermediate-segment whose ingress LER can not look deeper to remove EL when the subsequent segment does not support EL.
- Independent setup of LSP segments:

LSP concatenation typically relies on LSP segments that have been independently setup. In an e2e LSP (made of concatenated segments), it is unlikely that all of the concatenation points (i.e., segment LSP end points) as well as the ultimate ingress and ultimate egress support EL as defined in [section 3](#).

However, there would be individual LSP segments that would completely satisfy the requirements of [section 2](#) (i.e. are intrinsically EL capable). This document describes how EL may be used for (portions of) the e2e LSP while still working within the framework for [EL-RFC].

S---A---B---C---D

In the above topology, for an e2e LSP from S to D, the segments AB

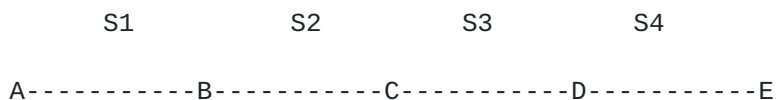
and CD could be intrinsically EL capable while the segments SA, & BC may not be. For data traffic going over the LSP from S to D, using EL on the segments AB and CD would be beneficial for load-balancing over LAGs/ECMP.

- Dealing with different protocols being used to setup the segments of the e2e LSP.

4.2.1 Spectrum of EL usage behaviors required to be supported for concatenated LSPs

To cater for an incremental deployment of intrinsically-ELC routers in a network, the multiple different modes for EL use with LSP concatenation need to be supported.

The spectrum of supported behaviors are listed below by referencing the following diagram.



LSP segments S1, S2, S3, S4 are between LERs A/B/C/D/E. There may or may not be other routers between the per-segment ingress<->egress LERs.

Transport LSP signaling protocol: could be any: LDP/RSVP/([[LU-BGP](#)] tunneled over RSVP/LDP).

4.2.1.1 Entropy label for per-segment LSP

Each of the segments will have their independent EL capability based on BOTH the:

- Per-segment ingress having the ability to insert the EL.
- Per-segment egress (or PH router) having the ability to strip the EL.

This is very similar to [[EL-RFC](#)] with the additional data-plane rule of [section 5.2.2.1](#) "A. Rationalizing EL for the outgoing LSP segment:".

Reasoning for why per-segment EL may be attractive for certain use scenarios:

Opportunity to get benefits on those segments where EL benefits are available. Even though the e2e LSP may not support ELC, this allows

the EL benefits on those segments that are EL-capable.

4.2.1.2 Entropy label for notional-segment-LSP(s)

In the case of concatenated LSPs, it is useful to:

- Insert EL at first per-segment ingress LER (per-segment ingress LER closest to the e2e ingress LER) that has the ability to insert EL.
- Carry the EL on the data packets as far along the concatenated LSP

as the last per-segment egress LER that ability to strip the EL on a series of contiguous EL-supporting segments.

The above is enabled by the rules of section "5.2.1.1 Signaling ELC at concatenation points (Translation rules)".

The benefit of using EL with notional-segment LSPs:

An operator might be able to use EL for the MPLS traffic on its path to a concatenation point even though the concatenation-point router (or its PHR) itself may not have the data-plane capabilities required as in [[EL-RFC](#)].

Additionally, even if the concatenation-point (or its PHR) do have the data-plane capabilities of [[EL-RFC](#)], it is just more efficient to forward the data packets without having to strip the EL and then reinsert the EL when the downstream segment is also intrinsically ELC.

4.2.1.3 Entropy label for e2e LSP

This correspond to having the notional-LSP and the e2e LSP being the same.

This is covered by the rules of [section 5.2.1.1](#) "Signaling ELC at concatenation points (Translation rules):" with the additional requirement that the data-plane be exactly the same as [[EL-RFC](#)], i.e.

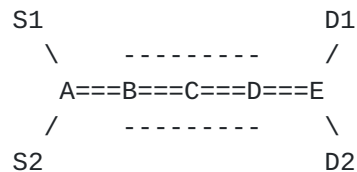
- the (ELI+EL) insertion is done by a label PUSHing router,
- the (ELI+EL) POP is done by the PHR/egress for the e2e LSP.

4.3 EL for LSP hierarchy

For the purpose of highlighting the problem to be addressed and the resultant requirements to be met, the following diagram is presented

as an example.

Let there be an LSP hierarchy with the ingress for the different levels of LSP hierarchy being at different routers, such that each LSP in the hierarchy is intrinsically EL capable. The individual LSPs in the hierarchy could be a single-segment LSP or a concatenated e2e LSP.



In the above topology, let there be the following LSPs:

- L1: B->D
- L2: A->E, tunneled through LSP L1
- L3: S1->D1, tunneled through LSP L2
- L4: S2->D2, tunneled through LSP L2

All of the LSPs above are assumed to be intrinsically EL capable.

4.3.1 Possibility of unnecessary reduction of max-payload of the LSP:

Even though the aim of using EL is to get better load-balancing support, in some cases the insertion of (ELI+EL) may unnecessarily reduce the effective payload of an LSP.

In above diagram, as per [\[EL-RFC\]](#) for a data packet on LSP L3, the insertion of (ELI+EL) for each of the 3 LSPs: L1, L2 and L3 is not explicitly prohibited. As a result it is possible that the packet on LSP L3, might end up with 3 (ELI+EL)s (one for each LSP level in the hierarchy) thus reducing the effective payload of the LSP L3. Likewise for L4. The presence of the (ELI+EL) for the outer LSPs L1 and L2 is not strictly useful for load-balancing the data traffic on the LSPs L3 and L4.

The solution for this issue is presented in [section 5.3.2](#): it relies on inserting the (ELI+EL) in the context of only 1 LSP in a hierarchy.

This issues results in the following requirement for EL usage in the presence of LSP hierarchies:

- Desirability of having a single (ELI+EL) on data packets over an LSP hierarchy: The LSP for which the (ELI+EL) is inserted, is preferably the innermost intrinsically EL-capable LSP, as the

notion of a user-flow is more specifically indicated by fields deeper inside the packet headers. Having an EL be present deeper in the packet provides load-balancing benefits of EL for the traversal of the packet across a longer stretch of the network.

If there is to be only 1 (ELI+EL) in the label stack, it imposes an additional data plane requirement on the ingress LER as described in [section 5.3.2](#).

[4.3.2](#) Possibility of EL being non-usable for load-balancing: Even though the aim of using EL is to get better load-balancing, in some cases the insertion of (ELI+EL) may actually offer no load-balancing benefits at all. Whether the presence of an EL offers load-balancing benefits on a given transit router, depends on:

- whether the transit router has a LAG or an ECMP as an outgoing interface for the LSP, AND
- whether the forwarding ASICs of the transit routers have the ability to include the EL (appearing at a specific position in the label stack) in the hash computation, either by:
 - + looking up the ELI and then picking the EL, or
 - + computing the hash on the maximum number of labels that it can pick from the label-stack for hash-computation which happens to also include the EL.

When the EL on a packet is outside the portion-of-the-label-stack that the ASIC of a transit router can use for hash computation, the forwarding hardware may include only the top few labels or the bottom few labels in the hash computation. This may prevent the inclusion of EL for hash-computation.

In the above diagram, for a data packet going over LSP L3 let the issue of [section 4.3.1](#) have been resolved by the router S1 inserting the (ELI+EL) underneath the label for LSP L3 and none of the other routers inserting the (ELI+EL). When this data packet arrives at router C, its label stack looks thus:

Label-LSP1		Label-LSP2		Label-LSP3		ELI		EL
Top-label				->				Bottom label

Let's say that the router C is able to include only the top 4 labels in a label stack for the hash-computation due to the ability of its forwarding ASICs.

So, the router C is not able to get the benefit of the presence of the EL in the data packet. If the only ECMP/LAG in this network is the link between C&D, then the presence of the EL serves no purpose

for the above network example and it ends up reducing the payload capacity of the LSPs L3 and L4 by 8 bytes.

This example could be further generalized in the case of seamless MPLS, where there may be deeper LSP hierarchies.

A transit router that has the ability to hash on an EL (based on its depth in the label stack) does not have multiple paths; while another router that has multiple paths and the ability hash on the EL (appearing at a specific depth in the label stack) is unable to do so as the EL appears outside the depth of the label stack that may be included in the hash. In neither of the foregoing cases is the presence of an EL helpful.

This translates into a requirement for EL: Flexibility in choice of LSP tunnel for which EL is inserted:

There is a need to have a way by which to include an EL underneath a specific label in a label-hierarchy based on it serving the most useful purpose (i.e. taking into consideration location of multiple-forwarding-paths and stack-depth-concerns).

[EL-RFC] has no way of influencing the insertion of (ELI+EL) at a certain LSP level in the stack. Thus, there is a need for a mechanism by which one of the many intrinsically-EL-capable LSPs in an LSP hierarchy could be picked for inserting the (ELI+EL).

5. EL for LSP concatenation/hierarchy

5.1 Additional EL abstractions: specific to LSP concatenation/hierarchy

Given the previous sections, following additional abstractions need to be defined to make EL more useful for LSP concatenation and hierarchy.

5.2 New abstractions: EL applicability for LSP concatenation

5.2.1 Signaling

New abstractions need to be defined to handle the differences in the use of ELs for concatenated-LSPs as compared to their use for single-segment LSPs.

The differences are:

- Notion of ingress for EL insertion:
(ELI+EL) insertion might not necessarily be done by a label-PUSHing router. A concatenation point where the label is being swapped might do the (ELI+EL) insertion, and serves as a

"notional ingress".

- Notion of egress for EL:

"Notional-egress" might not be the segment egress for the segment of the notional-ingress.

Even though certain concatenation-points (segment LERs) might not support POPping (ELI+EL), it may be acceptable to let the (ELI+EL) continue to be on the packet since the egress of a subsequent segment has the capability to POP the (ELI+EL) (which may not necessarily be along with POPping the transport label). A

"notional-ingress and notional-egress" pair might actually be the segment-ingress and segment-egress for different LSP segments that are part of the same e2e LSP.

The portion of the concatenated e2e LSP, between a notional-ingress and a notional-egress is referred to as the "notional-LSP-segment" in this document.

As a packet traverses an e2e LSP, it may have an (ELI+EL) imposed on it and then removed at different routers.

It is desirable for there to not be more than one instance of an (ELI+EL) to appear on a packet at any given time. However, the insertion followed by removal of an (ELI+EL) may happen more than once as the packet traverses the e2e LSP. Each router doing the (ELI+EL) insertion is the notional-ingress and each router doing the (ELI+EL) removal is the notional-egress (or notion EL-stripping-PH-router).

Thus, there may be more than 1 "notional ingress" for EL insertion, and there may be more than 1 "notional egress" for EL removal.

For each notional "ingress ingress", there will be a "notional egress" with the "notional ingress"es and "notional egress"es alternating along the path of the e2e LSP when there are more than 1 notional ingress and egress for an e2e LSP.

In the simplest case, this boils down to the case of there being just one notional ingress and one notional egress; and the notional ingress coincides with the e2e ingress, and the notional-egress coincides with the e2e egress. That is the case that [\[EL-RFC\]](#) addresses.

Separation of control/data-plane implies that certain routers

- Might be running software that supports signaling ELC and understanding an egress' ELC.
- However, might not have the capability to insert (ELI+EL).

Such routers should not be allowed to play a spoil-sport in preventing EL benefits for traffic traversing over them via concatenated LSPs. In other words, such routers can not act as notional-ingress or notional-egress. However, the presence of such per-segment ingress/egress routers on the path of a notional segment-LSP should not prevent the notional segment-LSP from benefiting from the use of EL.

5.2.1.1 Signaling ELC at concatenation points (Translation rules)

The rules for propagating ELC, at concatenation points, from a downstream segment LSP to an upstream segment LSP are listed in this section.

The benefit in propagating ELC across concatenation points is to not have to re-compute the EL at different segment ingress for those segments that are EL capable, including when the LSP segments have been setup using different protocols.

Additionally, in certain cases it should be possible to get the benefits of (ELI+EL) on LSP segments that are not "intrinsically EL capable", where the lack of "intrinsic EL capability" is due to:

- The per-segment ingress does not support EL insertion.
- The per-segment PHR/egress does not support POP of the EL.

However, such a concatenation point might support ELC signaling.

At a concatenation point, when 2 LSP segments: L1 (incoming LSP) and L2 (the outgoing LSP) are being concatenated, the following rules should be followed by the concatenation point in signaling its ELC.

A. Segment-egress:

1. A segment-egress signals ELC for an LSP-segment L1 when:
 - a. The segment-egress is intrinsically ELC, or
 - b. When it is not intrinsically-ELC, however segment-egress for LSP-segment L2 (downstream of L1)- for which this concatenation-point is segment-ingress - is signaling ELC.
[This handles the case: Support the signaling even though it may not support the data-plane behavior.]

B. Segment-ingress:

The following is relevant only for RSVP as defined in [[EL-RFC](#)]. When this router acting as segment-egress for an LSP L1 (that is concatenated to downstream LSP L2) is signaling ELC for L1, then this router must signal ELC in its Path messages using the

mechanism defined in [[EL-RFC](#)].

This is relevant only in the context of bidirectional LSPs.

[5.2.2](#) Data plane aspects

[5.2.2.1](#) LSP concatenation: Differing EL dispositions

At a concatenation point, when 2 LSP segments: L1 (incoming LSP) and L2 (the outgoing LSP) are being concatenated, the following rules should be followed by the concatenation point in its data-plane behavior.

A. Rationalizing EL for the outgoing LSP segment:

When the LSP segments L1 and L2 differ in their ELC, the concatenation point router needs to take the following data-plane actions depending on its role for the e2e LSP:

a. Notional egress behavior:

When L1 intrinsically supports ELC and L2 does not, then the concatenation-point router must remove the (ELI+EL), if present under top label, from the received data packets before effectively SWAPing the top label. In other words, in the presence of the ELI, the operations performed should be:

```
POP(IncomingLabel), POP(ELI+EL), PUSH(OutgoingLabel)
    or alternately:
POP, POP, SWAP(OutgoingLabel)
```

Translation rule "A 2" of [section 5.2.1.1](#) would have ensured that the above is doable at the concatenation point.

b. Notional ingress behavior:

When L1 does not intrinsically support ELC and L2 does, then the concatenation point router must POP the incoming label, insert (ELI+EL) before PUSHing the label for the LSP segment L2.

The label operations performed would be:

```
POP(IncomingLabel), PUSH(EL), PUSH(ELI), PUSH(OutgoingLabel),
    or
SWAP(EL), PUSH(ELI), PUSH(OutgoingLabel)
```

c. Implicit notional ingress behavior:

When L1 is intrinsically ELC and so is L2, the arriving data traffic should already have (ELI+EL) on it.

However, it is possible that due to local configuration on the notional-ingress, (ELI+EL) is not being inserted. In that

case, traffic arriving on L1 will not have (ELI+EL) on it.

In that case, this concatenation-point is the "implicit notional ingress" and it should insert (ELI+EL) just as if it were a "notional ingress".

B. Preventing multiple (ELI+EL) pairs underneath a given forwarding label in the stack:

A segment-ingress that is intrinsically-EL-capable should have the ability to inspect received data packets to check whether an (ELI+EL) already exists on the data packet underneath the top label.

Not causing multiple ELs on a data packet:

When both the LSP segments L1 and L2 support ELC, the concatenation point router SHOULD insert an (ELI+EL) only if the incoming packet does not contain an (ELI+EL) underneath the top label. In that case, the label operations are as below:

POP(IncomingLabel), PUSH(ELI+EL), PUSH(OutgoingLabel)

If the incoming packet already contains an (ELI+EL) underneath the top label, an additional (ELI+EL) MUST NOT be inserted on the packet underneath the top label that is being effectively SWAPed.

This prevents a segment ingress from inserting an (ELI+EL) when the notional ingress has already inserted an (ELI+EL).

C. Rationalizing EL insertion (at concatenation-point) for LSP hierarchy:

A concatenation point router that is intrinsically-EL-capable should have the ability to inspect received data packets to check whether an (ELI+EL) already exists, underneath any label in the label-stack.

If the router has such a ability, then this router MUST NOT insert an (ELI+EL) as in "A a" above.

This helps to prevent multiple (ELI+EL)s on the packet inserted (at a concatenation point) in the context of different transport labels in a label hierarchy.

D. Notional ingress role change at a router:

This role can change due to local configuration on the router or due to segment egress starting/stopping to signal ELC possibly due to a configuration change at the segment egress or due to a configuration change at this router.

When this router becomes a notional ingress, it reacts to the change as in "A b" above.

When this router stops being a notional ingress, this router stops inserting the (ELI+EL) underneath the top label that this router is

SWAPing(if this router is concatenation point), or
PUSHING (if this router is e2e ingress).

E. Notional egress role change at a router:

This role can change due to local configuration on the router or due the egress of a downstream concatenated LSP segment starting to signal ELC.

When this router becomes a notional egress, it reacts to the change as in "A a" above.

When this router stops being a notional egress, this router stops performing the label operation described in "A a" above. Instead this router now starts to simply SWAP the top label.

5.3 New abstractions: EL applicability for LSP hierarchy

5.3.1 Management plane:

Moving the (ELI+EL) underneath a different LSP's transport label:

There are 2 ways to handle the issue of [section 4.3.2](#):

- Configuration at the ingress LER: a configuration option should exist by which an operator can disable the insertion of (ELI+EL) on a per-LSP basis. The specific level in the LSP hierarchy for which to enable this configuration is based on operator knowledge based on:
 - * Knowledge of transit routers that need EL benefits : those routers that have a multi-path (LAG or LSP ECMP) as egress interface.
 - * The label hashing abilities of such routers: information about the specific number of labels in the label-stack that can be used in the hash computation; and any constraints about the position of the labels that can be used for computation when the label stack is larger than a certain ASIC-specific threshold.
- Configuration-based rewrite of the label stack at the ingress LER

of an intrinsically-EL-capable LSP:

An operator will know the forwarding characteristics (with regards to the number of labels that can be included in the hash computation) of the transit routers across the path of the e2e LSP that is part of an LSP hierarchy.

By making such a configuration, the operator can ensure that the EL will appear in the label stack such that all transit routers shall be able to include the as part of the hash computation.

The configuration would cause the label stack of the outgoing packet to have its extant (ELI+EL) removed, and an (ELI+EL) inserted just underneath the label of the LSP for which this ingress LER is setup to insert (ELI+EL).

5.3.2 Data plane aspects

Preventing insertion of multiple (ELI+EL)s:

At an ingress LER, the router SHOULD not insert an (ELI+EL) for an LSP if the packet already contains an ELI.

This ensures that for a data packet on a hierarchy of LSPs, there will be only 1 instance of an (ELI+EL). This helps to prevent the issue of [section 4.3.1](#).

This also ensures that when multiple LSPs in an LSP hierarchy are intrinsically-EL-capable, the (ELI+EL) will be inserted just underneath the transport label of the innermost LSP in the hierarchy. However, based on [section 5.3.1](#) there is a way by which to modify the level in the LSP hierarchy for which an (ELI+EL) is inserted.

A more specific case of this is already covered in section "5.2.2.1 C. Rationalizing EL insertion (at concatenation-point) for LSP hierarchy:".

6. Use-cases

In this document, the definition of LSP-concatenation refers to those cases where a label advertised by one label distribution protocol being:

- removed at one router (by PH POP) followed by a label PUSH for a

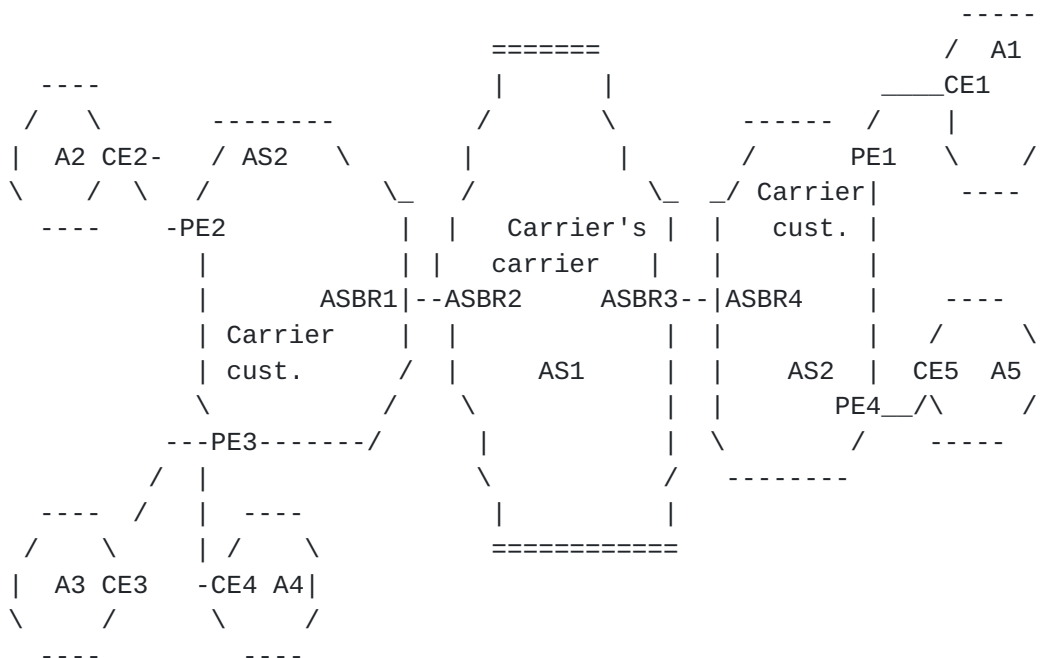
label distributed by another protocol at the router downstream of the PH router of the previous protocol's LSP. Such a router which is PUSHing a label for a subsequent protocol is referred to as a concatenation-point router in this document.

- SWAPed at a router for a label distributed by another protocol is also referred to as a concatenation-point in this document.

The list of use-cases of this draft stems from the following possible optimizations:

- A. Not having to insert/remove (ELI+EL) multiple times along an e2e labeled path, due to the EL capability not getting signaled e2e. In other words, not having to remove (ELI+EL) at a concatenation point only to re-insert it.
The lack of e2e EL capability signaling could be either due to lack of support; or due to a label advertised by one label distribution protocol being removed at one router (which also causes the removal of (ELI+EL)) and a label distributed by a subsequent router being PUSHed along with (ELI+EL) at that router.
- B. On an e2e labeled transport-LSP path, it may be possible to get the load-balancing benefits of EL on (segment of) the e2e LSP even though not every concatenation point router (as defined above) may intrinsically support EL for the LSP terminating at it.

6.1 Carrier of carrier L3VPN



A<n> = Customer site n

CE = Customer Edge Device

PE = Provider Edge Router

In the above figure, the "carrier's carrier" is providing L3VPN service to a carrier customer (carrier cust.) is itself an L3VPN provider.

Let the sites A<n> be the sites of the same L3VPN.

In order to provide L3VPN service to the sites A<n>, there is effectively an e2e LSP between each pair of PEs. For PEs in the same carrier customer site, the e2e LSP is an RSVP or LDP LSP. eg. Between PE2 and PE3.

For PEs that are across the carrier-customer's core, there is an e2e LSP created by advertising a BGP label for the remote PE's loopback address. The BGP label advertised from ASBR2 to ASBR1 rides-on top of the RSVP or LDP label in the carrier's-carrier core.

eg. For having an e2e LSP from PE1 to PE2, a BGP label is advertised for PE1's loopback into the carrier customer's site on the left. This label could be dealt with by ASBR1 in two ways:

- Advertising it into LDP in the carrier customer's site (on the left), or
- By advertising it over an iBGP session to PE2.

In the former case (LDP advertising a FEC for PE1), this document makes possible for ASBR1 to not have to remove the EL (inserted by PE2) and let it be removed by either a concatenation point (ASBR2 or ASBR3 or ASBR4) or the egress PE1. This is facilitated by the

translation rules of [section 5.2.1.1](#). The same also facilitates traffic with EL to be carried over concatenation points such that the EL is eventually removed by the last-EL-capable concatenation point or the EL capable e2e egress.

Each carrier (carrier's carrier; and carrier-customer) will have LAGs and LDP ECMP paths in its network.

[6.2](#) Inter-AS L3VPN: Option C

Option C is conceptually similar to CoC L3VPN from a point of view of setting up the e2e LSP. Therefore, similar EL use-cases also exist for Option C.

This applies for both L3VPN and also BGP-VPLS.

[7](#). Manageability

There are no new MPLS OAM issues opened up by this specification. Any MPLS manageability are the same as those inherited from [\[EL-RFC\]](#) and addressing those is outside the scope of this document.

[8](#). Security considerations

Security considerations as listed in section 9 of [\[EL-RFC\]](#) apply.

[9](#). Acknowledgments

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[10](#). IANA considerations

None.

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