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Entropy labels for source routed stacked tunnels
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Abstract

Source routed tunnel stacking is a technique that can be leveraged to provide a method to steer a packet through a controlled set of segments. This can be applied to the Multi Protocol Label Switching (MPLS) data plane. Entropy label (EL) is a technique used in MPLS to improve load balancing. This document examines and describes how ELs are to be applied to source routed stacked tunnels.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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Table of Contents

1. Introduction 2
1.1. Requirements Language 3
2. Abbreviations and Terminology 3
3. Use-case requiring multipath load balancing in source stacked tunnels 4
4. Recommended EL solution for SPRING 5
5. Options considered 6
5.1. Single EL at the bottom of the stack of tunnels 6
5.2. An EL per tunnel in the stack 7
5.3. A re-usable EL for a stack of tunnels 7
5.3.1. EL at top of stack 8
5.4. ELs at readable label stack depths 8
6. Acknowledgements 9
7. IANA Considerations 9
8. Security Considerations 9
9. References 9
9.1. Normative References 9
9.2. Informative References 10
Authors' Addresses 11

1. Introduction

The source routed stacked tunnels paradigm is leveraged by techniques such as Segment Routing (SR) [I-D.filsfils-spring-segment-routing] to steer a packet through a set of segments. This can be directly applied to the MPLS data plane, but it has implications on label stack depth.

Clarifying statements on label stack depth have been provided in [RFC7325] but they do not address the case of source routed stacked MPLS tunnels as described in [I-D.gredler-spring-mpls] or

[I-D.filsfils-spring-segment-routing] where deeper label stacks are more prevalent.

Entropy label (EL) [RFC6790] is a technique used in the MPLS data plane to provide entropy for load balancing. When using LSP hierarchies there are implications on how [RFC6790] should be applied. One such issue is addressed by [I-D.ravisingh-mpls-el-for-seamless-mpls] but that is when different levels of the hierarchy are created at different LSRs. The current document addresses the case where the hierarchy is created at a single LSR as required by source stacked tunnels.

A use-case requiring load balancing with source stacked tunnels is given in Section 3. A recommended solution is described in Section 4 keeping in consideration the limitations of implementations when applying [RFC6790] to deeper label stacks. Options that were considered to arrive at the recommended solution are documented for historical purposes in Section 5.

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

Although this document is not a protocol specification, the use of this language clarifies the instructions to protocol designers producing solutions that satisfy the requirements set out in this document.

2. Abbreviations and Terminology

EL - Entropy Label

ELI - Entropy Label Identifier

ELC - Entropy Label Capability

SR - Segment Routing

ECMP - Equal Cost Multi Paths

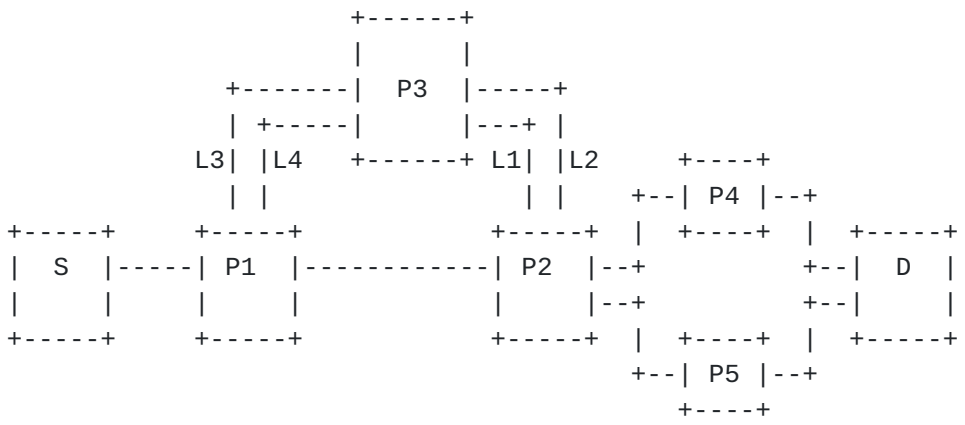
MPLS - Multiprotocol Label Switching

SID - Segment Identifier

RLD - Readable Label Depth

OAM - Operation, Administration and Maintenance

3. Use-case requiring multipath load balancing in source stacked tunnels



S=Source LSR, D=Destination LSR, P1,P2,P3,P4,P5=Transit LSRs,
L1,L2,L3,L4=Links

Figure 1: Traffic engineering use-case

Traffic-engineering (TE) is one of the applications of MPLS and is also a requirement for source stacked tunnels. Consider the topology shown in Figure 1. Lets say the LSR P1 has a limitation that it can only look four labels deep in the stack to do multipath decisions. All other transit LSRs in the figure can read deep label stacks and the LSR S can insert as many <ELI, EL> pairs as needed. The LSR S requires data to be sent to LSR D along a traffic-engineered path that goes over the link L1. Good load balancing is also required across equal cost paths (including parallel links). To engineer traffic along a path that takes link L1, the label stack that LSR S creates consists of a label to the node SID of LSR P3, stacked over the label for the adjacency SID of link L1 and that in turn is stacked over the label to the node SID of LSR D. For simplicity lets assume that all LSRs use the same label space for source stacked tunnels. Lets L_N-P denote the label to be used to reach the node SID of LSR P. Let L_A-Ln denote the label used for the adjacency SID for link Ln. The LSR S must use the label stack <L_N-P3, L_A-L1, L_N-D> for traffic-engineering. However to achieve good load balancing over the equal cost paths P2-P4-D, P2-P5-D and the parallel links L3, L4, a mechanism such as Entropy labels [RFC6790] should be adapted for source stacked tunnels. Multiple ways to apply entropy labels were considered and are documented in Section 5 along with their tradeoffs. A recommended solution is described in Section 4.

4. Recommended EL solution for SPRING

The solution described in this section follows [RFC6790].

An LSR may have a limitation in its ability to read and process the label stack in order to do multipath load balancing. This limitation expressed in terms of the number of label stack entries that the LSR can read is henceforth referred to as the Readable Label Depth (RLD) capability of that LSR. If an EL does not occur within the RLD of an LSR in the label stack of the MPLS packet that it receives, then it would lead to poor load balancing at that LSR. The RLD of an LSR is a characteristic of the forwarding plane of that LSR's implementation and determining it is outside the scope of this document.

In order for the EL to occur within the RLD of LSRs along the path corresponding to a label stack, multiple <ELI, EL> pairs MAY be inserted in the label stack as long as the tunnel's label below which they are inserted are advertised with entropy label capability enabled. The LSR that inserts <ELI, EL> pairs MAY have limitations on the number of such pairs that it can insert and also the depth at which it can insert them. If due to any limitation, the inserted ELs are at positions such that an LSR along the path receives an MPLS packet without an EL in the label stack within that LSR's RLD, then the load balancing performed by that LSR would be poor. Special attention should be paid when a forwarding adjacency LSP (FA-LSP) [RFC4206] is used as a link along the path of a source stacked LSP, since the labels of the FA-LSP would additionally count towards the depth of the label stack when calculating the appropriate positions to insert the ELs. The recommendations for inserting <ELI, EL> pairs are:

- An LSR that is limited in the number of <ELI, EL> pairs that it can insert SHOULD insert such pairs deeper in the stack.

- An LSR SHOULD try to insert <ELI, EL> pairs at positions so that for the maximum number of transit LSRs, the EL occurs within the RLD of the incoming packet to that LSR.

- An LSR SHOULD try to insert the minimum number of such pairs while trying to satisfy the above criteria.

A sample algorithm to insert ELs is shown below. Implementations can choose any algorithm as long as it follows the above recommendations.

```
Initialize the current EL insertion point to the
  bottommost label in the stack that is EL-capable
while (local-node can push more <ELI,EL> pairs OR
          insertion point is not above label stack) {
    insert an <ELI,EL> pair below current insertion point
    move new insertion point up from current insertion point until
        ((last inserted EL is below the RLD) AND (RLD > 2)
                        AND
         (new insertion point is EL-capable))
    set current insertion point to new insertion point
}
```

Figure 2: Algorithm to insert <ELI, EL> pairs in a label stack

When this algorithm is applied to the example described in Section 3 it will result in ELs being inserted in two positions, one below the label L_N-D and another below L_N-P3. Thus the resulting label stack would be <L_N-P3, ELI, EL, L_A-L1, L_N-D, ELI, EL>

The RLD can be advertised via protocols and those extensions would be described in separate documents [I-D.xu-isis-mpls-elc] and [I-D.xu-ospf-mpls-elc].

The recommendations above are not expected to bring any additional OAM considerations beyond those described in section 6 of [RFC6790]. However, the OAM requirements and solutions for source stacked tunnels are still under discussion and future revisions of this document will address those if needed.

5. Options considered

5.1. Single EL at the bottom of the stack of tunnels

In this option a single EL is used for the entire label stack. The source LSR S encodes the entropy label (EL) below the labels of all the stacked tunnels. In the example described in Section 3 it will result in the label stack at LSR S to look like <L_N-P3, L_A-L1, L_N-D, ELI, EL> <remaining packet header>. Note that the notation in [RFC6790] is used to describe the label stack. An issue with this approach is that as the label stack grows due an increase in the number of SIDs, the EL goes correspondingly deeper in the label stack. Hence transit LSRs have to access a larger number of bytes in the packet header when making forwarding decisions. In the example described in Section 3 the LSR P1 would poorly load-balance traffic on the parallel links L3, L4 since the EL is below the RLD of the packet received by P1. A load balanced network design using this approach must ensure that all intermediate LSRs have the capability

to traverse the maximum label stack depth as required for that application that uses source routed stacking.

In the case where the hardware is capable of pushing a single <ELI, EL> pair at any depth, this option is the same as the recommended solution in Section 4.

This option was discounted since there exist a number of hardware implementations which have a low maximum readable label depth. Choosing this option can lead to a loss of load-balancing using EL in a significant part of the network but that is a critical requirement in a service provider network.

5.2. An EL per tunnel in the stack

In this option each tunnel in the stack can be given its own EL. The source LSR pushes an <ELI, EL> before pushing a tunnel label when load balancing is required to direct traffic on that tunnel. In the example described in Section 3, the source LSR S encoded label stack would be <L_N-P3, ELI, EL, L_A-L1, L_N-D, ELI, EL> where all the ELs can be the same. Accessing the EL at an intermediate LSR is independent of the depth of the label stack and hence independent of the specific application that uses source stacking on that network. A drawback is that the depth of the label stack grows significantly, almost 3 times as the number of labels in the label stack. The network design should ensure that source LSRs should have the capability to push such a deep label stack. Also, the bandwidth overhead and potential MTU issues of deep label stacks should be accounted for in the network design.

In the case where the RLD is the minimum value (3) for all LSRs, all LSRs are EL capable and the LSR that is inserting <ELI, EL> pairs has no limit on how many it can insert then this option is the same as the recommended solution in Section 4.

This option was discounted due to the existence of hardware implementations that can push a limited number of labels on the label stack. Choosing this option would result in a hardware requirement to push two additional labels per tunnel label. Hence it would restrict the number of tunnels that can form a LSP and constrain the types of LSPs that can be created. This was considered unacceptable.

5.3. A re-usable EL for a stack of tunnels

In this option an LSR that terminates a tunnel re-uses the EL of the terminated tunnel for the next inner tunnel. It does this by storing the EL from the outer tunnel when that tunnel is terminated and re-inserting it below the next inner tunnel label during the label swap

operation. The LSR that stacks tunnels SHOULD insert an EL below the outermost tunnel. It SHOULD NOT insert ELs for any inner tunnels. Also, the penultimate hop LSR of a segment MUST NOT pop the ELI and EL even though they are exposed as the top labels since the terminating LSR of that segment would re-use the EL for the next segment.

In Section 3 above, the source LSR S encoded label stack would be <L_N-P3, ELI, EL, L_A-L1, L_N-D>. At P1 the outgoing label stack would be <L_N-P3, ELI, EL, L_A-L1, L_N-D> after it has load balanced to one of the links L3 or L4. At P3 the outgoing label stack would be <L_N-D, ELI, EL>. At P2 the outgoing label stack would be <L_N-D, ELI, EL> and it would load balance to one of the nexthop LSRs P4 or P5. Accessing the EL at an intermediate LSR (e.g. P1) is independent of the depth of the label stack and hence independent of the specific use-case to which the stacked tunnels are applied.

This option was discounted due to the significant change in label swap operations that would be required for existing hardware.

5.3.1. EL at top of stack

A slight variant of the re-usable EL option is to keep the EL at the top of the stack rather than below the tunnel label. In this case each LSR that is not terminating a segment should continue to keep the received EL at the top of the stack when forwarding the packet along the segment. An LSR that terminates a segment should use the EL from the terminated segment at the top of the stack when forwarding onto the next segment.

This option was discounted due to the significant change in label swap operations that would be required for existing hardware.

5.4. ELs at readable label stack depths

In this option the source LSR inserts ELs for tunnels in the label stack at depths such that each LSR along the path that must load balance is able to access at least one EL. Note that the source LSR may have to insert multiple ELs in the label stack at different depths for this to work since intermediate LSRs may have differing capabilities in accessing the depth of a label stack. The label stack depth access value of intermediate LSRs must be known to create such a label stack. How this value is determined is outside the scope of this document. This value can be advertised using a protocol such as an IGP. For the same Section 3 above, if LSR P1 needs to have the EL within a depth of 4, then the source LSR S encoded label stack would be <L_N-P3, ELI, EL, L_A-L1, L_N-D, ELI, EL> where all the ELs would typically have the same value.

In the case where the RLD has different values along the path and the LSR that is inserting <ELI, EL> pairs has no limit on how many pairs it can insert, and it knows the appropriate positions in the stack where they should be inserted, then this option is the same as the recommended solution in Section 4.

A variant of this solution was selected which balances the number of labels that need to be pushed against the requirement for entropy.

6. Acknowledgements

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7. IANA Considerations

This memo includes no request to IANA.

8. Security Considerations

This document does not introduce any new security considerations beyond those already listed in [RFC6790].

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