

MPLS Working Group  
Internet-Draft  
Intended status: Standards Track  
Expires: 22 April 2026

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19 October 2025

LSP Ping/Traceroute for Prefix SID in Multi-Algorithm/Multi-Topology  
Networks  
draft-ali-mpls-algo-mt-oam-01

## Abstract

[RFC8287] defines the extensions to MPLS LSP Ping and Traceroute for Segment Routing IGP-Prefix and IGP-Adjacency Segment Identifier (SIDs) with an MPLS data plane. The machinery defined in [RFC8287] works well in single topology, single algorithm deployments where each Prefix SID is only associated with a single IP prefix. In multi-topology networks, or networks deploying multiple algorithms for the same IP Prefix, MPLS echo request needs to carry additional information in the Target FEC Stack sub-TLVs to properly validate IGP Prefix SID.

This document updates [RFC8287] by modifying IPv4 and IPv6 IGP-Prefix Segment ID FEC sub-TLVs to also include algorithm identification while maintaining backwards compatibility. This document also introduces new Target FEC Stack sub-TLVs for Prefix SID validation in multi-topology networks.

## Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

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## 1. Introduction

[RFC8287] defines the extensions to MPLS LSP Ping and Traceroute for Segment Routing IGP-Prefix SID and IGP-Adjacency SID with an MPLS data plane. [RFC8287] proposes 3 Target FEC Stack Sub-TLVs to carry this information. [RFC9350] introduces the concept of Flexible Algorithm that allows IGPs (ISIS, OSPFv2 and OSPFv3) to compute constraint-based path over an MPLS network. The constraint-based paths enables the IGP of a router to associate one or more Segment Routing Prefix-SID with a particular Flexible Algorithm, and steer packets along the constraint-based paths. Multiple Flexible Algorithms are assigned to the same IPv4/IPv6 Prefix while each utilizing a different MPLS Prefix SID label. Similarly, operators may deploy same IP prefix across multiple topologies in the network using IGP Multi-topology ID (MT-ID). As Flexible-Algorithm based deployments in particular, and multi-topology networks in general, become more common, existing OAM machinery requires updates to correctly diagnose network faults.

Segment Routing architecture [RFC8402] defines the context for IGP Prefix SID as a unique tuple comprised of prefix, topology, and algorithm>. Existing MPLS Ping/Traceroute machinery for SR Prefix SIDs, defined in [RFC8287], carries prefix, prefix length, and IGP protocol. To correctly identify and validate a Prefix-SID, the validating device also requires algorithm and topology identification to be supplied in the FEC Stack sub-TLV. This document extends SR-IGP IPv4 and IPv6 Prefix SID FECs to validate a particular algorithm in a single-topology network, while maintaining backwards compatibility with existing implementations of [RFC8287]. It also introduces new Target FEC Stack sub-TLVs to perform MPLS Ping and Traceroute for IGP Prefix SIDs in multi-topology, multi-algorithm deployments.

## 2. Conventions

The key words "MUST", "SHALL", "SHOULD", etc., are to be interpreted as described in RFC 2119 [RFC2119].

### 3. Motivation

In presence of multiple algorithms, a single IGP Prefix may be associated with zero or more IGP Prefix SIDs in addition to the default (Shortest Path First) Prefix SID. Each Prefix SID will have a distinct Prefix SID label and may possibly have a distinct set of next-hops based on associated constraint-based path calculation criteria. This means that to reach the same destination, a non-default algorithm IGP-Prefix SID may take a different path than default IGP Prefix SID algorithm.

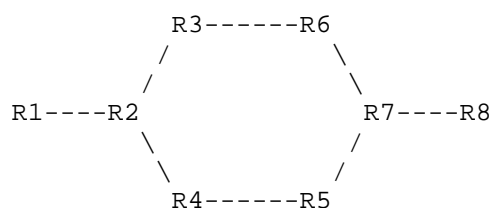


Figure 1 Reference Topology

Figure above, which is a simplification of the diagram used in [RFC8287] illustrates this point through an example. Node Segment IDs for R1, R2, R3, R4, R5, R6, R7, and R8 for the default algorithm are 5001, 5002, 5003, 5004, 5005, 5006, 5007, and 5008, respectively. Nodes R1, R2, R4, R5, R7, and R8 also participate in Flexible Algorithm 128. Their corresponding Node Segment IDs for the algorithm are 5801, 5802, 5804, 5805, 5807, and 5808, respectively.

Now consider an MPLS LSP Traceroute request to validate the path to reach node R8 through Flexible Algorithm 128. The TTL of the first echo request packet expires at node R2 with incoming label 5808. Node R2 attempts to validate IGP-Prefix SID Target FEC stack sub-TLV from the echo request. However, this TFS sub-TLV does not contain information identifying the algorithm. As a result, R2 will attempt validation with default algorithm which expects the echo packet to arrive with Prefix SID label 5008. The validation will fail, and node R2 responds as per the procedure defined in [RFC8029].

Carrying algorithm identification in the Target FEC Stack sub-TLV of MPLS echo request will help avoid such false negatives. It will also help detect forwarding deviations such as when the packet for a particular destination is incorrectly forwarded to a device that is participating in the default algo but does not participate in a given Flexible Algorithm.

The above problem statement can also be extended to apply in Multi-Topology networks. In such networks, the Target FEC Stack sub-TLV MUST carry Multi-Topology ID (MT-ID) in addition to prefix, its length, IGP identification, and algorithm.

#### 4. Algorithm Identification for IGP-Prefix SID Sub-TLVs

Section 5 of [RFC8287] defines 3 different Segment ID Sub-TLVs that will be included in Target FEC Stack TLV defined in [RFC8029]. This section updates IPv4 IGP-Prefix Segment ID Sub-TLV and IPv6 IGP-Prefix Segment ID Sub-TLV to also include an additional field identifying the algorithm.

##### 4.1. IPv4 IGP-Prefix Segment ID Sub-TLV

The Sub-TLV format for IPv4 IGP-Prefix Segment ID MUST be set as shown in the below TLV format:

```

      0               1               2               3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+
|                                     IPv4 prefix                                     |
+-----+-----+-----+-----+-----+-----+-----+-----+
|Prefix Length |   Protocol   |   Algo   |   Reserved   |
+-----+-----+-----+-----+-----+-----+-----+

```

Algo field MUST be set to 0 if the default algorithm is used. Algo field is set to 1 if Strict Shortest Path First (Strict-SPF) algorithm is used. For Flex-Algo, the Algo field MUST be set with the algorithm value (values can be 128-255).

##### 4.2. Algorithm Identification for IGP-Prefix SID Sub-TLVs

The Sub-TLV format for IPv6 IGP-Prefix Segment ID MUST be set as shown in the below TLV format:

```

      0               1               2               3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+
|                                     IPv6 prefix                                     |
+-----+-----+-----+-----+-----+-----+-----+-----+
|Prefix Length |   Protocol   |   Algo   |   Reserved   |
+-----+-----+-----+-----+-----+-----+-----+

```

Algo field MUST be set to 0 if the default algorithm is used. Algo field is set to 1 if Strict Shortest Path First (Strict-SPF) algorithm is used. For Flex-Algo, the Algo field MUST be set with the algorithm value (values can be 128-255).

## 5. Multi-topology Support for IGP Prefix SID

IGP Prefix SID TLVs defined above assume a single-topology network for path validation. For Multi-Topology networks, this section introduces new Multi-Topology IGP IPv4 Prefix SID and Multi-Topology IGP IPv6 Prefix SID sub-TLVs in the Target FEC Stack TLV of MPLS echo request. These sub-TLVs carry MT-ID for OSPF and IS-IS protocols as specified in [RFC4915] and [RFC5120] respectively.

### 5.1. Multi-topology IPv4 IGP-Prefix Segment ID Sub-TLV

The Sub-TLV format for Multi-topology IPv4 IGP-Prefix Segment ID MUST be set as shown in the below TLV format:

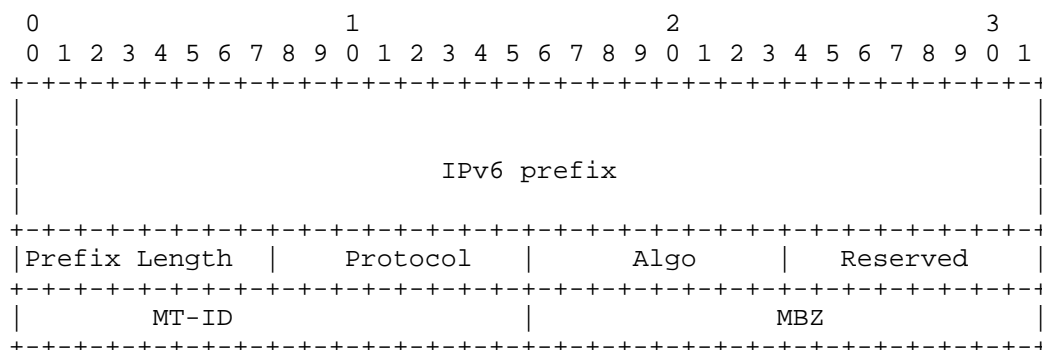
0										1										2										3																			
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1																		
										IPv4 prefix																																							
Prefix Length										Protocol										Algo										Reserved																			
										MT-ID																				MBZ																			

MT-ID identifies the Multi-Topology ID associated with the Prefix SID. MT-ID is set in trailing 12 bits of the field when the Protocol is set to IS-IS. Leading 4-bits of the MT-ID MUST be all zeroes for IS-IS. MT-ID is set to trailing 8 bits when the protocol is specified as OSPF. The leading octet MUST be set to all zeroes for OSPF. MBZ MUST be set to all zeroes.

The Protocol field MUST be set 1 if the responder MUST perform FEC validation using OSPF as the IGP protocol and MT-ID is an OSPF Multi-Topology ID. Protocol is set to 2 if the responder MUST perform FEC validation using IS-IS as the IGP protocol, and the MT-ID is IS-IS Multi-Topology ID. Protocol MUST not be set to 0 when using Multi-Topology IPv4 IGP Prefix SID sub-TLV.

## 5.2. Multi-topology Support for IGP Prefix SID

The Sub-TLV format for IPv6 IGP-Prefix Segment ID MUST be set as shown in the below TLV format:



MT-ID identifies the Multi-Topology ID associated with the Prefix SID. MT-ID is set in trailing 12 bits of the field when the Protocol is set to IS-IS. Leading 4-bits of the MT-ID MUST be all zeroes for IS-IS. MT-ID is trailing 8 bits when the protocol is specified as OSPF. The leading octet MUST be set to all zeroes for OSPF. MBZ MUST be set to all zeroes.

The Protocol field MUST be set 1 if the responder MUST perform FEC validation using OSPF as the IGP protocol and MT-ID is an OSPF Multi-Topology ID. Protocol is set to 2 if the responder MUST perform FEC validation using IS-IS as the IGP protocol, and the MT-ID is IS-IS Multi-Topology ID. Protocol MUST not be set to 0 when using Multi-Topology IPv6 IGP Prefix SID sub-TLV.

## 6. Procedures

The below section describes LSP Ping and Traceroute procedures beyond the text specified in LSP

### 6.1. Single-Topology Networks

An array of network operators may deploy flexible algorithms in their network for constraint-based shortest paths, without deploying multi-topology. The updated FEC definitions for IGP Prefix SID allows operator to achieve LSP Ping and Traceroute in these networks while maintaining backwards compatibility with existing devices in the network. Below text highlights the handling procedures and initiator and responder for the updated FEC definitions.

#### 6.1.1. Initiator Node Procedures

A node initiating LSP echo request packet for the Node Segment ID MUST identify and include the algorithm associated with the IGP Prefix SID in the Target FEC Stack sub-TLV. If the initiating node is not aware of the algorithm, the default algorithm (id 0) of Shortest Path First is assumed.

#### 6.1.2. Responder Node Procedures

This section updates the procedures defined in Section 7.4 of [RFC8287] for IPv4/IPv6 IGP Prefix SID FEC. If the algorithm is 0, the procedures from [RFC8287] do not require any change. For any other algorithm value, if the responding node is validating the FEC stack, it MUST also validate the IGP Prefix SID advertisement for the algorithm defined in Algo field.

If the responding node is including IGP Prefix SID FEC in the FEC stack due to FEC Stack Change operation, it MUST also include algorithm associated with the Prefix SID.

If the transit node does not support the IPv4/ Ipv6 IGP-Prefix Prefix SID FEC Sub-TLV defined in this document, it follows the procedure described in [RFC8287] in responding to the invoking MPLS OAM probe.

### 6.2. Multi-Topology Networks

In presence of Multi-Topology networks, the operators can use the new Multi-Topology IGP IPv4/IPv6 Prefix SID FEC definitions to achieve path validation and fault isolation. Below text describes handling procedures for Multi-Topology networks for initiator and responder. The procedures defined in [RFC8287] are still applicable and the text below updates them instead of replacing them.

#### 6.2.1. Initiator Node Procedures

A node initiating LSP echo request packet for Single-Topology network MAY use Multi-Topology IGP IPv4/IPv6 Prefix SID defined above. A node initiating LSP echo request for Multi-Topology networks MUST use Multi-Topology IGP IPv4/IPv6 Prefix SID defined above. The node MUST identify and include both the IGP MT-ID and the algorithm associated with the IGP prefix SID in addition to prefix, prefix length, and the protocol. If the initiating node is not aware of the algorithm, the default algorithm (id 0) of Shortest Path First is assumed. The protocol MUST be set to 1 if the responding node is running OSPF, and 2 if the responding node is running IS-IS.



### 6.2.2. Responding Node Procedures

This section updates the procedures defined in Section 7.4 of [RFC8287] for Multi-Topology IPv4/IPv6 IGP Prefix SID FEC. Upon reception of the sub-TLV, responding node MUST validate that Protocol field is not 0 to correctly parse MT-ID. In addition to procedures defined in [RFC8287], if responding node is validating the FEC Stack, it MUST validate the IGP Prefix SID advertisement for the algorithm and the MT-ID described in the incoming FEC sub-TLV.

If the responding node is including Multi-Topology IGP Prefix SID FEC in the FEC stack due to a FEC Stack Change operation, it MUST also include the algorithm and MT-ID associated with the Prefix SID, and set the Protocol to 1 or 2, based on the corresponding IGP.

If the transit node does not support the Multi-Topology IPv4/IPv6 IGP Prefix SID FEC sub-TLV defined in this document, it follows the procedure described in [RFC8287] in responding to the invoking MPLS OAM probe.

## 7. IANA Considerations

### 7.1. New Target FEC tack Sub-TLV

IANA is requested to assign four new Sub-TLVs from "Sub-TLVs for TLV Types 1, 16 and 21" sub-registry from the "Multi-Protocol Label Switching (MPLS) Label Switched Paths (LSPs) Ping Parameters" (IANA-MPLS-LSP-PING) registry.

Sub-Type	Sub-TLV Name	Reference
-----	-----	-----
TBD1	IPv4 IGP-Prefix Segment ID	This document
TBD2	IPv6 IGP-Prefix Segment ID	This document
TBD3	Multi-topology IPv4 IGP-Prefix Segment ID	This document
TBD4	Multi-topology IPv6 IGP-Prefix Segment ID	This document

### 7.2. Algorithm in the Segment ID Sub-TLV

IANA is requested to create a new "Algorithm in the Segment ID Sub-TLV" registry under the "Multi-Protocol Label Switching (MPLS) Label Switched Paths (LSPs) Ping Parameters" registry. The initial entries are requested as below:

Value	Meaning	Reference
-----	-----	-----
0	Default Algorithm	This document
1	Strict Shortest Path First (Strict-SPF)	This document
128-255	Flex-Algo algorithm value	This document

## 8. Security Considerations

This document updates [RFC8287] and does not introduce any security considerations.

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## 10. Acknowledgements

The authors would like to thank Nagendra Kumar, Faisal Iqbal for their contributions.

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