

Network Working Group
Internet-Draft
Intended status: Standards Track
Expires: November 19, 2022

P. Psenak, Ed.
Cisco Systems
S. Hegde
Juniper Networks, Inc.
C. Filsfils
Cisco Systems, Inc.
K. Talaulikar
Arrcus, Inc
A. Gulko
Edward Jones
May 18, 2022

IGP Flexible Algorithm
draft-ietf-lsr-flex-algo-20

Abstract

IGP protocols traditionally compute best paths over the network based on the IGP metric assigned to the links. Many network deployments use RSVP-TE based or Segment Routing based Traffic Engineering to steer traffic over a path that is computed using different metrics or constraints than the shortest IGP path. This document proposes a solution that allows IGP's themselves to compute constraint-based paths over the network. This document also specifies a way of using Segment Routing (SR) Prefix-SIDs and SRv6 locators to steer packets along the constraint-based paths.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of [BCP 78](#) and [BCP 79](#).

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at <https://datatracker.ietf.org/drafts/current/>.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on November 19, 2022.

Copyright Notice

Copyright (c) 2022 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to [BCP 78](https://trustee.ietf.org/license-info) and the IETF Trust's Legal Provisions Relating to IETF Documents (<https://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

Table of Contents

1.	Introduction	3
2.	Requirements Language	4
3.	Terminology	4
4.	Flexible Algorithm	5
5.	Flexible Algorithm Definition Advertisement	6
5.1.	IS-IS Flexible Algorithm Definition Sub-TLV	6
5.2.	OSPF Flexible Algorithm Definition TLV	8
5.3.	Common Handling of Flexible Algorithm Definition TLV	9
6.	Sub-TLVs of IS-IS FAD Sub-TLV	10
6.1.	IS-IS Flexible Algorithm Exclude Admin Group Sub-TLV	11
6.2.	IS-IS Flexible Algorithm Include-Any Admin Group Sub-TLV	12
6.3.	IS-IS Flexible Algorithm Include-All Admin Group Sub-TLV	12
6.4.	IS-IS Flexible Algorithm Definition Flags Sub-TLV	13
6.5.	IS-IS Flexible Algorithm Exclude SRLG Sub-TLV	14
7.	Sub-TLVs of OSPF FAD TLV	15
7.1.	OSPF Flexible Algorithm Exclude Admin Group Sub-TLV	15
7.2.	OSPF Flexible Algorithm Include-Any Admin Group Sub-TLV	16
7.3.	OSPF Flexible Algorithm Include-All Admin Group Sub-TLV	16
7.4.	OSPF Flexible Algorithm Definition Flags Sub-TLV	16
7.5.	OSPF Flexible Algorithm Exclude SRLG Sub-TLV	17
8.	IS-IS Flexible Algorithm Prefix Metric Sub-TLV	18
9.	OSPF Flexible Algorithm Prefix Metric Sub-TLV	19
10.	OSPF Flexible Algorithm ASBR Reachability Advertisement	21
10.1.	OSPFv2 Extended Inter-Area ASBR LSA	21
10.1.1.	OSPFv2 Extended Inter-Area ASBR TLV	23
10.2.	OSPF Flexible Algorithm ASBR Metric Sub-TLV	23
11.	Advertisement of Node Participation in a Flex-Algorithm	25
11.1.	Advertisement of Node Participation for Segment Routing	26
11.2.	Advertisement of Node Participation for Other Data-planes	26
12.	Advertisement of Link Attributes for Flex-Algorithm	26

13.	Calculation of Flexible Algorithm Paths	27
13.1.	Multi-area and Multi-domain Considerations	29
14.	Flex-Algorithm and Forwarding Plane	32
14.1.	Segment Routing MPLS Forwarding for Flex-Algorithm . . .	32
14.2.	SRv6 Forwarding for Flex-Algorithm	32
14.3.	Other Data-planes' Forwarding for Flex-Algorithm	33
15.	Operational Considerations	34
15.1.	Inter-area Considerations	34
15.2.	Usage of SRLG Exclude Rule with Flex-Algorithm	34
15.3.	Max-metric consideration	35
16.	Backward Compatibility	35
17.	Security Considerations	36
18.	IANA Considerations	36
18.1.	IGP IANA Considerations	36
18.1.1.	IGP Algorithm Types Registry	36
18.1.2.	IGP Metric-Type Registry	36
18.2.	Flexible Algorithm Definition Flags Registry	37
18.3.	IS-IS IANA Considerations	37
18.3.1.	Sub TLVs for Type 242	37
18.3.2.	Sub TLVs for for TLVs 135, 235, 236, and 237	38
18.3.3.	Sub-Sub-TLVs for Flexible Algorithm Definition Sub-TLV	38
18.4.	OSPF IANA Considerations	39
18.4.1.	OSPF Router Information (RI) TLVs Registry	39
18.4.2.	OSPFv2 Extended Prefix TLV Sub-TLVs	39
18.4.3.	OSPFv3 Extended-LSA Sub-TLVs	39
18.4.4.	OSPF Flex-Algorithm Prefix Metric Bits	40
18.4.5.	OSPF Opaque LSA Option Types	40
18.4.6.	OSPFv2 Externded Inter-Area ASBR TLVs	40
18.4.7.	OSPFv2 Inter-Area ASBR Sub-TLVs	40
18.4.8.	OSPF Flexible Algorithm Definition TLV Sub-TLV Registry	41
18.4.9.	Link Attribute Applications Registry	42
19.	Acknowledgements	42
20.	References	43
20.1.	Normative References	43
20.2.	Informative References	45
	Authors' Addresses	46

1. Introduction

An IGP-computed path based on the shortest IGP metric is often be replaced by a traffic-engineered path due to the traffic requirements which are not reflected by the IGP metric. Some networks engineer the IGP metric assignments in a way that the IGP metric reflects the link bandwidth or delay. If, for example, the IGP metric is reflecting the bandwidth on the link and the user traffic is delay

sensitive, the best IGP path may not reflect the best path from such users' perspective.

To overcome this limitation, various sorts of traffic engineering have been deployed, including RSVP-TE and SR-TE, in which case the TE component is responsible for computing paths based on additional metrics and/or constraints. Such paths need to be installed in the forwarding tables in addition to, or as a replacement for, the original paths computed by IGPs. Tunnels are often used to represent the engineered paths and mechanisms like one described in [\[RFC3906\]](#) are used to replace the native IGP paths with such tunnel paths.

This document specifies a set of extensions to IS-IS, OSPFv2, and OSPFv3 that enable a router to advertise TLVs that (a) identify calculation-type, (b) specify a metric-type, and (c) describe a set of constraints on the topology, that are to be used to compute the best paths along the constrained topology. A given combination of calculation-type, metric-type, and constraints is known as a "Flexible Algorithm Definition". A router that sends such a set of TLVs also assigns a Flex-Algorithm value to the specified combination of calculation-type, metric-type, and constraints.

This document also specifies a way for a router to use IGPs to associate one or more SR Prefix-SIDs or SRv6 locators with a particular Flex-Algorithm. Each such Prefix-SID or SRv6 locator then represents a path that is computed according to the identified Flex-Algorithm.

2. 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.

3. Terminology

This section defines terms that are often used in this document.

Flexible Algorithm Definition (FAD) - the set consisting of (a) calculation-type, (b) metric-type, and (c) a set of constraints.

Flexible Algorithm - a numeric identifier in the range 128-255 that is associated via configuration with the Flexible-Algorithm Definition.

Local Flexible Algorithm Definition - Flexible Algorithm Definition defined locally on the node.

Remote Flexible Algorithm Definition - Flexible Algorithm Definition received from other nodes via IGP flooding.

Flexible Algorithm Participation - per data-plane configuration state that expresses whether the node is participating in a particular Flexible Algorithm.

IGP Algorithm - value from the the "IGP Algorithm Types" registry defined under "Interior Gateway Protocol (IGP) Parameters" IANA registries. IGP Algorithms represents the triplet (Calculation Type, Metric, Constraints), where the second and third elements of the triple MAY be unspecified.

ABR - Area Border Router. In IS-IS terminology it is also known as L1/L2 router.

ASBR - Autonomous System Border Router.

4. Flexible Algorithm

Many possible constraints may be used to compute a path over a network. Some networks are deployed as multiple planes. A simple form of constraint may be to use a particular plane. A more sophisticated form of constraint can include some extended metric as described in [\[RFC8570\]](#). Constraints which restrict paths to links with specific affinities or avoid links with specific affinities are also possible. Combinations of these are also possible.

To provide maximum flexibility, we want to provide a mechanism that allows a router to (a) identify a particular calculation-type, (b) metric-type, (c) describe a particular set of constraints, and (d) assign a numeric identifier, referred to as Flex-Algorithm, to the combination of that calculation-type, metric-type, and those constraints. We want the mapping between the Flex-Algorithm and its meaning to be flexible and defined by the user. As long as all routers in the domain have a common understanding as to what a particular Flex-Algorithm represents, the resulting routing computation is consistent and traffic is not subject to any looping.

The set consisting of (a) calculation-type, (b) metric-type, and (c) a set of constraints is referred to as a Flexible-Algorithm Definition.

Flexible-Algorithm is a numeric identifier in the range 128-255 that is associated via configuratin with the Flexible-Algorithm Definition.

IANA "IGP Algorithm Types" registry defines the set of values for IGP Algorithms. We propose to allocate the following values for Flex-Algorithms from this registry:

128-255 - Flex-Algorithms

5. Flexible Algorithm Definition Advertisement

To guarantee the loop-free forwarding for paths computed for a particular Flex-Algorithm, all routers that (a) are configured to participate in a particular Flex-Algorithm, and (b) are in the same Flex-Algorithm definition advertisement scope MUST agree on the definition of the Flex-Algorithm.

5.1. IS-IS Flexible Algorithm Definition Sub-TLV

The IS-IS Flexible Algorithm Definition Sub-TLV (FAD Sub-TLV) is used to advertise the definition of the Flex-Algorithm.

The IS-IS FAD Sub-TLV is advertised as a Sub-TLV of the IS-IS Router Capability TLV-242 that is defined in [[RFC7981](#)].

IS-IS FAD Sub-TLV has the following 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
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|      Type      |      Length      |Flex-Algorithm |  Metric-Type  |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|  Calc-Type  |      Priority  |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     Sub-TLVs                                     |
+                                                                                   +
|                                     ...                                     |
|                                                                                   |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

where:

Type: 26

Length: variable, dependent on the included Sub-TLVs

Flex-Algorithm: Single octet value between 128 and 255 inclusive.

Metric-Type: Type of metric to be used during the calculation.
Following values are defined:

0: IGP Metric

1: Min Unidirectional Link Delay as defined in [\[RFC8570\]](#),
[section 4.2](#), encoded as application specific link attribute as
specified in [\[RFC8919\]](#) and [Section 12](#) of this document.

2: Traffic Engineering Default Metric as defined in [\[RFC5305\]](#),
[section 3.7](#), encoded as application specific link attribute as
specified in [\[RFC8919\]](#) and [Section 12](#) of this document.

Calc-Type: value from 0 to 127 inclusive from the "IGP Algorithm Types" registry defined under "Interior Gateway Protocol (IGP) Parameters" IANA registries. IGP algorithms in the range of 0-127 have a defined triplet (Calculation Type, Metric, Constraints). When used to specify the Calc-Type in the FAD Sub-TLV, only the Calculation Type defined for the specified IGP Algorithm is used. The Metric/Constraints MUST NOT be inherited. If the required calculation type is Shortest Path First, the value 0 SHOULD appear in this field.

Priority: Value between 0 and 255 inclusive that specifies the priority of the advertisement.

Sub-TLVs - optional sub-TLVs.

The IS-IS FAD Sub-TLV MAY be advertised in an LSP of any number. IS-IS router MAY advertise more than one IS-IS FAD Sub-TLV for a given Flexible-Algorithm (see [Section 6](#)).

The IS-IS FAD Sub-TLV has an area scope. The Router Capability TLV in which the FAD Sub-TLV is present MUST have the S-bit clear.

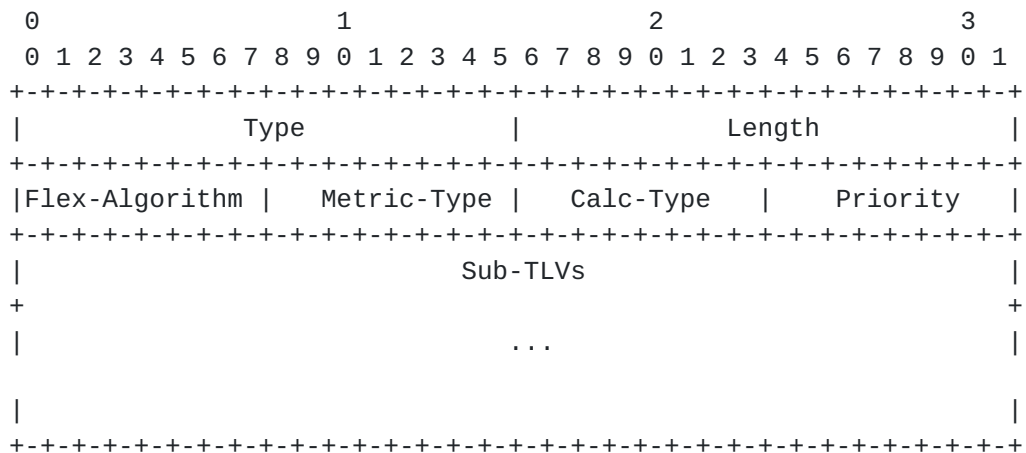
IS-IS L1/L2 router MAY be configured to re-generate the winning FAD from level 2, without any modification to it, to level 1 area. The re-generation of the FAD Sub-TLV from level 2 to level 1 is determined by the L1/L2 router, not by the originator of the FAD advertisement in the level 2. In such case, the re-generated FAD Sub-TLV will be advertised in the level 1 Router Capability TLV originated by the L1/L2 router.

L1/L2 router MUST NOT re-generate any FAD Sub-TLV from level 1 to level 2.

5.2. OSPF Flexible Algorithm Definition TLV

OSPF FAD TLV is advertised as a top-level TLV of the RI LSA that is defined in [\[RFC7770\]](#).

OSPF FAD TLV has the following format:



where:

Type: 16

Length: variable, dependent on the included Sub-TLVs

Flex-Algorithm:: Flex-Algorithm number. Value between 128 and 255 inclusive.

Metric-Type: Type of metric to be used during the calculation.
Following values are defined:

0: IGP Metric

1: Min Unidirectional Link Delay as defined in [\[RFC7471\]](#), [section 4.2](#), encoded as application specific link attribute as specified in [\[RFC8920\]](#) and [Section 12](#) of this document.

2: Traffic Engineering metric as defined in [\[RFC3630\]](#), [section 2.5.5](#), encoded as application specific link attribute as specified in [\[RFC8920\]](#) and [Section 12](#) of this document.

Calc-Type: as described in [Section 5.1](#)

Priority: as described in [Section 5.1](#)

Sub-TLVs - optional sub-TLVs.

When multiple OSPF FAD TLVs, for the same Flexible-Algorithm, are received from a given router, the receiver MUST use the first occurrence of the TLV in the Router Information LSA. If the OSPF FAD TLV, for the same Flex-Algorithm, appears in multiple Router Information LSAs that have different flooding scopes, the OSPF FAD TLV in the Router Information LSA with the area-scoped flooding scope MUST be used. If the OSPF FAD TLV, for the same algorithm, appears in multiple Router Information LSAs that have the same flooding scope, the OSPF FAD TLV in the Router Information (RI) LSA with the numerically smallest Instance ID MUST be used and subsequent instances of the OSPF FAD TLV MUST be ignored.

The RI LSA can be advertised at any of the defined opaque flooding scopes (link, area, or Autonomous System (AS)). For the purpose of OSPF FAD TLV advertisement, area-scoped flooding is REQUIRED. The Autonomous System flooding scope SHOULD NOT be used by default unless local configuration policy on the originating router indicates domain wide flooding.

5.3. Common Handling of Flexible Algorithm Definition TLV

This section describes the protocol-independent handling of the FAD TLV (OSPF) or FAD Sub-TLV (IS-IS). We will refer to it as FAD TLV in this section, even though in the case of IS-IS it is a Sub-TLV.

The value of the Flex-Algorithm MUST be between 128 and 255 inclusive. If it is not, the FAD TLV MUST be ignored.

Only a subset of the routers participating in the particular Flex-Algorithm need to advertise the definition of the Flex-Algorithm.

Every router, that is configured to participate in a particular Flex-Algorithm, MUST select the Flex-Algorithm definition based on the following ordered rules. This allows for the consistent Flex-Algorithm definition selection in cases where different routers advertise different definitions for a given Flex-Algorithm:

1. From the advertisements of the FAD in the area (including both locally generated advertisements and received advertisements) select the one(s) with the highest priority value.
2. If there are multiple advertisements of the FAD with the same highest priority, select the one that is originated from the router with the highest System-ID, in the case of IS-IS, or Router ID, in the case of OSPFv2 and OSPFv3. For IS-IS, the System-ID is

described in [[ISO10589](#)]. For OSPFv2 and OSPFv3, standard Router ID is described in [[RFC2328](#)] and [[RFC5340](#)] respectively.

A router that is not configured to participate in a particular Flex-Algorithm MUST ignore FAD Sub-TLVs advertisements for such Flex-Algorithm.

A router that is not participating in a particular Flex-Algorithm is allowed to advertise FAD for such Flex-Algorithm. Receiving routers MUST consider FAD advertisement regardless of the Flex-Algorithm participation of the FAD originator.

Any change in the Flex-Algorithm definition may result in temporary disruption of traffic that is forwarded based on such Flex-Algorithm paths. The impact is similar to any other event that requires network-wide convergence.

If a node is configured to participate in a particular Flexible-Algorithm, but there is no valid Flex-Algorithm definition available for it, or the selected Flex-Algorithm definition includes calculation-type, metric-type, constraint, flag, or Sub-TLV that is not supported by the node, it MUST stop participating in such Flexible-Algorithm. That implies that it MUST NOT announce participation for such Flexible-Algorithm as specified in [Section 11](#) and it MUST remove any forwarding state associated with it.

Flex-Algorithm definition is topology independent. It applies to all topologies that a router participates in.

6. Sub-TLVs of IS-IS FAD Sub-TLV

One of the limitations of IS-IS [[ISO10589](#)] is that the length of a TLV/sub-TLV is limited to a maximum of 255 octets. For the FAD sub-TLV, there are a number of sub-sub-TLVs (defined below) which are supported. For a given Flex-Algorithm, it is possible that the total number of octets required to completely define a FAD exceeds the maximum length supported by a single FAD sub-TLV. In such cases, the FAD may be split into multiple such sub-TLVs and the content of the multiple FAD sub-TLVs combined to provide a complete FAD for the Flex-Algorithm. In such case, the fixed portion of the FAD (see [Section 5.1](#)) MUST be identical in all FAD sub-TLVs for a given Flex-Algorithm from a given IS. In case the fixed portion of such FAD Sub-TLVs differ, the values in the fixed portion in the FAD sub-TLV in the first occurrence in the lowest numbered LSP from a given IS MUST be used.

Any specification that introduces a new ISIS FAD sub-sub-TLV MUST specify whether the FAD sub-TLV may appear multiple times in the set

of FAD sub-TLVs for a given Flex-Algorithm from a given IS and how to handle them if multiple are allowed.

6.1. IS-IS Flexible Algorithm Exclude Admin Group Sub-TLV

The Flexible Algorithm definition can specify 'colors' that are used by the operator to exclude links during the Flex-Algorithm path computation.

The IS-IS Flexible Algorithm Exclude Admin Group Sub-TLV is used to advertise the exclude rule that is used during the Flex-Algorithm path calculation as specified in [Section 13](#).

The IS-IS Flexible Algorithm Exclude Admin Group Sub-TLV (FAEAG Sub-TLV) is a Sub-TLV of the IS-IS FAD Sub-TLV. It has the following 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
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|      Type      |      Length      |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     Extended Admin Group                                     |
+-+-----+
|                                     ...                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

where:

Type: 1

Length: variable, dependent on the size of the Extended Admin Group. MUST be a multiple of 4 octets.

Extended Administrative Group: Extended Administrative Group as defined in [\[RFC7308\]](#).

The IS-IS FAEAG Sub-TLV MUST NOT appear more than once in a single IS-IS FAD Sub-TLV. If it appears more than once, the IS-IS FAD Sub-TLV MUST be ignored by the receiver.

The IS-IS FAEAG Sub-TLV MUST NOT appear more than once in the set of FAD sub-TLVs for a given Flex-Algorithm from a given IS. If it appears more than once in such set, the IS-IS FAEAG Sub-TLV in the first occurrence in the lowest numbered LSP from a given IS MUST be used and any other occurrences MUST be ignored.

6.2. IS-IS Flexible Algorithm Include-Any Admin Group Sub-TLV

The Flexible Algorithm definition can specify 'colors' that are used by the operator to include links during the Flex-Algorithm path computation.

The IS-IS Flexible Algorithm Include-Any Admin Group Sub-TLV is used to advertise include-any rule that is used during the Flex-Algorithm path calculation as specified in [Section 13](#).

The format of the IS-IS Flexible Algorithm Include-Any Admin Group Sub-TLV is identical to the format of the FAEAG Sub-TLV in [Section 6.1](#).

The IS-IS Flexible Algorithm Include-Any Admin Group Sub-TLV Type is 2.

The IS-IS Flexible Algorithm Include-Any Admin Group Sub-TLV MUST NOT appear more than once in a single IS-IS FAD Sub-TLV. If it appears more than once, the IS-IS FAD Sub-TLV MUST be ignored by the receiver.

The IS-IS Flexible Algorithm Include-Any Admin Group Sub-TLV MUST NOT appear more than once in the set of FAD sub-TLVs for a given Flex-Algorithm from a given IS. If it appears more than once in such set, the IS-IS Flexible Algorithm Include-Any Admin Group Sub-TLV in the first occurrence in the lowest numbered LSP from a given IS MUST be used and any other occurrences MUST be ignored.

6.3. IS-IS Flexible Algorithm Include-All Admin Group Sub-TLV

The Flexible Algorithm definition can specify 'colors' that are used by the operator to include link during the Flex-Algorithm path computation.

The IS-IS Flexible Algorithm Include-All Admin Group Sub-TLV is used to advertise include-all rule that is used during the Flex-Algorithm path calculation as specified in [Section 13](#).

The format of the IS-IS Flexible Algorithm Include-All Admin Group Sub-TLV is identical to the format of the FAEAG Sub-TLV in [Section 6.1](#).

The IS-IS Flexible Algorithm Include-All Admin Group Sub-TLV Type is 3.

The IS-IS Flexible Algorithm Include-All Admin Group Sub-TLV MUST NOT appear more than once in a single IS-IS FAD Sub-TLV. If it appears

more than once, the IS-IS FAD Sub-TLV MUST be ignored by the receiver.

The IS-IS Flexible Algorithm Include-All Admin Group Sub-TLV MUST NOT appear more than once in the set of FAD sub-TLVs for a given Flex-Algorithm from a given IS. If it appears more than once in such set, the IS-IS Flexible Algorithm Include-All Admin Group Sub-TLV in the first occurrence in the lowest numbered LSP from a given IS MUST be used and any other occurrences MUST be ignored.

6.4. IS-IS Flexible Algorithm Definition Flags Sub-TLV

The IS-IS Flexible Algorithm Definition Flags Sub-TLV (FADF Sub-TLV) is a Sub-TLV of the IS-IS FAD Sub-TLV. It has the following 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
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|      Type      |      Length      |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     Flags                                     |
+-+-----+
|                                     ...                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

where:

Type: 4

Length: variable, non-zero number of octets of the Flags field

Flags:

```

      0 1 2 3 4 5 6 7...
+---+---+---+---+---+---+
|M| | | ...
+---+---+---+---+---+---+

```

M-flag: when set, the Flex-Algorithm specific prefix metric MUST be used for inter-area and external prefix calculation. This flag is not applicable to prefixes advertised as SRv6 locators.

Bits are defined/sent starting with Bit 0 defined above. Additional bit definitions that may be defined in the future SHOULD be assigned in ascending bit order so as to minimize the number of bits that will need to be transmitted.

Undefined bits MUST be transmitted as 0.

Bits that are NOT transmitted MUST be treated as if they are set to 0 on receipt.

The IS-IS FADF Sub-TLV MUST NOT appear more than once in a single IS-IS FAD Sub-TLV. If it appears more than once, the IS-IS FAD Sub-TLV MUST be ignored by the receiver.

The IS-IS FADF Sub-TLV MUST NOT appear more than once in the set of FAD sub-TLVs for a given Flex-Algorithm from a given IS. If it appears more than once in such set, the IS-IS FADF Sub-TLV in the first occurrence in the lowest numbered LSP from a given IS MUST be used and any other occurrences MUST be ignored.

If the IS-IS FADF Sub-TLV is not present inside the IS-IS FAD Sub-TLV, all the bits are assumed to be set to 0.

If a node is configured to participate in a particular Flexible-Algorithm, but the selected Flex-Algorithm definition includes a bit in the IS-IS FADF Sub-TLV that is not supported by the node, it MUST stop participating in such Flexible-Algorithm.

New flag bits may be defined in the future. Implementations MUST check all advertised flag bits in the received IS-IS FADF Sub-TLV - not just the subset currently defined.

6.5. IS-IS Flexible Algorithm Exclude SRLG Sub-TLV

The Flexible Algorithm definition can specify Shared Risk Link Groups (SRLGs) that the operator wants to exclude during the Flex-Algorithm path computation.

The IS-IS Flexible Algorithm Exclude SRLG Sub-TLV (FAESRLG) is used to advertise the exclude rule that is used during the Flex-Algorithm path calculation as specified in [Section 13](#).

The IS-IS FAESRLG Sub-TLV is a Sub-TLV of the IS-IS FAD Sub-TLV. It has the following 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
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|      Type      |      Length      |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     Shared Risk Link Group Value                                     |
+-+-----+
|                                     ...                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

where:

Type: 5

Length: variable, dependent on number of SRLG values. MUST be a multiple of 4 octets.

Shared Risk Link Group Value: SRLG value as defined in [\[RFC5307\]](#).

The IS-IS FAESRLG Sub-TLV MUST NOT appear more than once in a single IS-IS FAD Sub-TLV. If it appears more than once, the IS-IS FAD Sub-TLV MUST be ignored by the receiver.

The IS-IS FAESRLG Sub-TLV MAY appear more than once in the set of FAD sub-TLVs for a given Flex-Algorithm from a given IS. This may be necessary in cases where the total number of SRLG values which are specified cause the FAD sub-TLV to exceed the maximum length of a single FAD sub-TLV. In such case the receiver MUST use the union of all values across all IS-IS FAESRLG Sub-TLVs from such set.

7. Sub-TLVs of OSPF FAD TLV

7.1. OSPF Flexible Algorithm Exclude Admin Group Sub-TLV

The Flexible Algorithm Exclude Admin Group Sub-TLV (FAEAG Sub-TLV) is a Sub-TLV of the OSPF FAD TLV. It's usage is described in [Section 6.1](#). It has the following 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
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     |                                     |
|               Type                 |               Length                 |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     |                                     |
|               Extended Admin Group |                                     |
+-+-----+-----+-----+-----+-----+-----+-----+-----+
|                                     |                                     |
|               ...                   |                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

where:

Type: 1

Length: variable, dependent on the size of the Extended Admin Group. MUST be a multiple of 4 octets.

Extended Administrative Group: Extended Administrative Group as defined in [\[RFC7308\]](#).

The OSPF FAEAG Sub-TLV MUST NOT appear more than once in an OSPF FAD TLV. If it appears more than once, the OSPF FAD TLV MUST be ignored by the receiver.

7.2. OSPF Flexible Algorithm Include-Any Admin Group Sub-TLV

The usage of this Sub-TLVs is described in [Section 6.2](#).

The format of the OSPF Flexible Algorithm Include-Any Admin Group Sub-TLV is identical to the format of the OSPF FAEAG Sub-TLV in [Section 7.1](#).

The OSPF Flexible Algorithm Include-Any Admin Group Sub-TLV Type is 2.

The OSPF Flexible Algorithm Include-Any Admin Group Sub-TLV MUST NOT appear more than once in an OSPF FAD TLV. If it appears more than once, the OSPF FAD TLV MUST be ignored by the receiver.

7.3. OSPF Flexible Algorithm Include-All Admin Group Sub-TLV

The usage of this Sub-TLVs is described in [Section 6.3](#).

The format of the OSPF Flexible Algorithm Include-All Admin Group Sub-TLV is identical to the format of the OSPF FAEAG Sub-TLV in [Section 7.1](#).

The OSPF Flexible Algorithm Include-All Admin Group Sub-TLV Type is 3.

The OSPF Flexible Algorithm Include-All Admin Group Sub-TLV MUST NOT appear more than once in an OSPF FAD TLV. If it appears more than once, the OSPF FAD TLV MUST be ignored by the receiver.

7.4. OSPF Flexible Algorithm Definition Flags Sub-TLV

The OSPF Flexible Algorithm Definition Flags Sub-TLV (FADF Sub-TLV) is a Sub-TLV of the OSPF FAD TLV. It has the following 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
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     |                                     |
|                               Type   |                               Length   |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     |                                     |
|                               Flags   |                                     |
+-+-----+-----+-----+-----+-----+-----+-----+-----+
|                                     |                                     |
|                               ...     |                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

where:

Type: 4

Length: variable, dependent on the size of the Flags field. MUST be a multiple of 4 octets.

Flags:

```

    0 1 2 3 4 5 6 7...
+-+--+--+--+--+--+...
|M| | |           ...
+-+--+--+--+--+--+...

```

M-flag: when set, the Flex-Algorithm specific prefix and ASBR metric MUST be used for inter-area and external prefix calculation. This flag is not applicable to prefixes advertised as SRv6 locators.

Bits are defined/sent starting with Bit 0 defined above. Additional bit definitions that may be defined in the future SHOULD be assigned in ascending bit order so as to minimize the number of bits that will need to be transmitted.

Undefined bits MUST be transmitted as 0.

Bits that are NOT transmitted MUST be treated as if they are set to 0 on receipt.

The OSPF FADF Sub-TLV MUST NOT appear more than once in an OSPF FAD TLV. If it appears more than once, the OSPF FAD TLV MUST be ignored by the receiver.

If the OSPF FADF Sub-TLV is not present inside the OSPF FAD TLV, all the bits are assumed to be set to 0.

If a node is configured to participate in a particular Flexible-Algorithm, but the selected Flex-Algorithm definition includes a bit in the OSPF FADF Sub-TLV that is not supported by the node, it MUST stop participating in such Flexible-Algorithm.

New flag bits may be defined in the future. Implementations MUST check all advertised flag bits in the received OSPF FADF Sub-TLV - not just the subset currently defined.

7.5. OSPF Flexible Algorithm Exclude SRLG Sub-TLV

The OSPF Flexible Algorithm Exclude SRLG Sub-TLV (FAESRLG Sub-TLV) is a Sub-TLV of the OSPF FAD TLV. Its usage is described in [Section 6.5](#). It has the following 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
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                               Type                               |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                               Shared Risk Link Group Value        |
+-+-----+
|                               ...                                  |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
where:

```

Type: 5

Length: variable, dependent on the number of SRLGs. MUST be a multiple of 4 octets.

Shared Risk Link Group Value: SRLG value as defined in [\[RFC4203\]](#).

The OSPF FAESRLG Sub-TLV MUST NOT appear more than once in an OSPF FAD TLV. If it appears more than once, the OSPF FAD TLV MUST be ignored by the receiver.

8. IS-IS Flexible Algorithm Prefix Metric Sub-TLV

The IS-IS Flexible Algorithm Prefix Metric (FAPM) Sub-TLV supports the advertisement of a Flex-Algorithm specific prefix metric associated with a given prefix advertisement.

The IS-IS FAPM Sub-TLV is a sub-TLV of TLVs 135, 235, 236, and 237 and has the following 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
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|      Type      |      Length      |Flex-Algorithm |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                               Metric                               |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
where:

```

Type: 6

Length: 5 octets

Flex-Algorithm: Single octet value between 128 and 255 inclusive.

Metric: 4 octets of metric information

The IS-IS FAPM Sub-TLV MAY appear multiple times in its parent TLV. If it appears more than once with the same Flex-Algorithm value, the first instance MUST be used and any subsequent instances MUST be ignored.

If a prefix is advertised with a Flex-Algorithm prefix metric larger than MAX_PATH_METRIC as defined in [\[RFC5305\]](#) this prefix MUST NOT be considered during the Flexible-Algorithm computation.

The usage of the Flex-Algorithm prefix metric is described in [Section 13](#).

The IS-IS FAPM Sub-TLV MUST NOT be advertised as a sub-TLV of the IS-IS SRv6 Locator TLV [[I-D.ietf-lsr-isis-srv6-extensions](#)]. The IS-IS SRv6 Locator TLV includes the Algorithm and Metric fields which MUST be used instead. If the FAPM Sub-TLV is present as a sub-TLV of the IS-IS SRv6 Locator TLV in the received LSP, such FAPM Sub-TLV MUST be ignored.

9. OSPF Flexible Algorithm Prefix Metric Sub-TLV

The OSPF Flexible Algorithm Prefix Metric (FAPM) Sub-TLV supports the advertisement of a Flex-Algorithm specific prefix metric associated with a given prefix advertisement.

The OSPF Flex-Algorithm Prefix Metric (FAPM) Sub-TLV is a Sub-TLV of the:

- OSPFv2 Extended Prefix TLV [[RFC7684](#)]
- Following OSPFv3 TLVs as defined in [[RFC8362](#)]:

Inter-Area Prefix TLV

External Prefix TLV

OSPF FAPM Sub-TLV has the following 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
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                               |                               |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|Flex-Algorithm|      Flags      |      Reserved      |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                               |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

where:

Type: 3 for OSPFv2, 26 for OSPFv3

Length: 8 octets

Flex-Algorithm: Single octet value between 128 and 255 inclusive.

Flags: single octet value

```

      0 1 2 3 4 5 6 7
+---+---+---+---+---+
|E|                               |
+---+---+---+---+---+

```

E bit : position 0: The type of external metric. If bit is set, the metric specified is a Type 2 external metric. This bit is applicable only to OSPF External and NSSA external prefixes. This is semantically the same as E bit in section A.4.5 of [\[RFC2328\]](#) and section A.4.7 of [\[RFC5340\]](#) for OSPFv2 and OSPFv3 respectively.

Bits 1 through 7: MUST be cleared by sender and ignored by receiver.

Reserved: Must be set to 0, ignored at reception.

Metric: 4 octets of metric information

The OSPF FAPM Sub-TLV MAY appear multiple times in its parent TLV. If it appears more than once with the same Flex-Algorithm value, the first instance MUST be used and any subsequent instances MUST be ignored.

The usage of the Flex-Algorithm prefix metric is described in [Section 13](#).

10. OSPF Flexible Algorithm ASBR Reachability Advertisement

An OSPF ABR advertises the reachability of ASBRs in its attached areas to enable routers within those areas to perform route calculations for external prefixes advertised by the ASBRs. OSPF extensions for advertisement of Flex-Algorithm specific reachability and metric for ASBRs is similarly required for Flex-Algorithm external prefix computations as described further in [Section 13.1](#).

10.1. OSPFv2 Extended Inter-Area ASBR LSA

The OSPFv2 Extended Inter-Area ASBR (EIA-ASBR) LSA is an OSPF Opaque LSA [[RFC5250](#)] that is used to advertise additional attributes related to the reachability of the OSPFv2 ASBR that is external to the area yet internal to the OSPF domain. Semantically, the OSPFv2 EIA-ASBR LSA is equivalent to the fixed format Type 4 Summary LSA [[RFC2328](#)]. Unlike the Type 4 Summary LSA, the LSID of the EIA-ASBR LSA does not carry the ASBR Router-ID - the ASBR Router-ID is carried in the body of the LSA. OSPFv2 EIA-ASBR LSA is advertised by an OSPFv2 ABR and its flooding is defined to be area-scoped only.

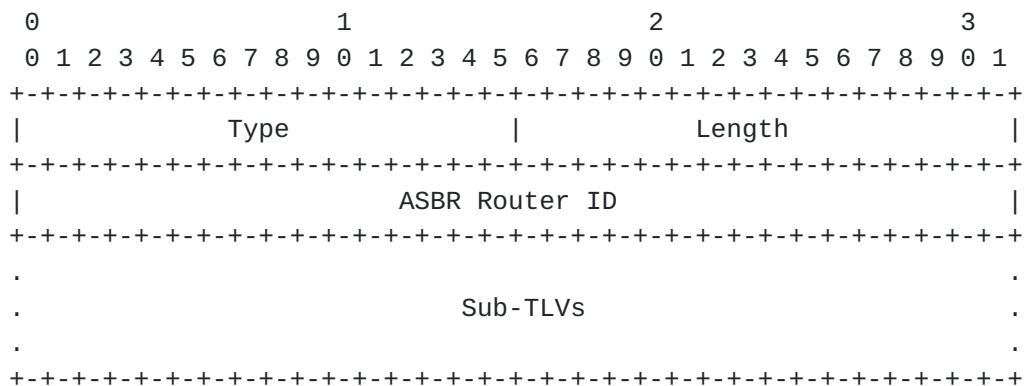
An OSPFv2 ABR generates the EIA-ASBR LSA for an ASBR when it is advertising the Type-4 Summary LSA for it and has the need for advertising additional attributes for that ASBR beyond what is conveyed in the fixed format Type-4 Summary LSA. An OSPFv2 ABR MUST NOT advertise the EIA-ASBR LSA for an ASBR for which it is not advertising the Type 4 Summary LSA. This ensures that the ABR does not generate the EIA-ASBR LSA for an ASBR to which it does not have reachability in the base OSPFv2 topology calculation. The OSPFv2 ABR SHOULD NOT advertise the EIA-ASBR LSA for an ASBR when it does not have additional attributes to advertise for that ASBR.

The OSPFv2 EIA-ASBR LSA has the following format:

10.1.1. OSPFv2 Extended Inter-Area ASBR TLV

The OSPFv2 Extended Inter-Area ASBR (EIA-ASBR) TLV is a top-level TLV of the OSPFv2 EIA-ASBR LSA and is used to advertise additional attributes associated with the reachability of an ASBR.

The OSPFv2 EIA-ASBR TLV has the following format:



where:

Type: 1

Length: variable

ASBR Router ID: four octets carrying the OSPF Router ID of the ASBR whose information is being carried.

Sub-TLVs : variable

Only a single OSPFv2 EIA-ASBR TLV MUST be advertised in each OSPFv2 EIA-ASBR LSA and the receiver MUST ignore all instances of this TLV other than the first one in an LSA.

OSPFv2 EIA-ASBR TLV MUST be present inside an OSPFv2 EIA-ASBR LSA with at least a single sub-TLV included, otherwise the OSPFv2 EIA-ASBR LSA MUST be ignored by the receiver.

10.2. OSPF Flexible Algorithm ASBR Metric Sub-TLV

The OSPF Flexible Algorithm ASBR Metric (FAAM) Sub-TLV supports the advertisement of a Flex-Algorithm specific metric associated with a given ASBR reachability advertisement by an ABR.

The OSPF Flex-Algorithm ASBR Metric (FAAM) Sub-TLV is a Sub-TLV of the:

An OSPF ABR MUST NOT include the OSPF FAAM Sub-TLV with a specific Flex-Algorithm in its reachability advertisement for an ASBR between

areas unless that ASBR is reachable for it in the context of that specific Flex-Algorithm.

An OSPF ABR MUST include the OSPF FAAM Sub-TLVs as part of the ASBR reachability advertisement between areas for the Flex-Algorithm for which the winning FAD includes the M-flag and the ASBR is reachable in the context of that specific Flex-Algorithm.

OSPF routers MUST use the OSPF FAAM Sub-TLV to calculate the reachability of the ASBRs if the winning FAD for the specific Flex-Algorithm includes the M-flag. OSPF routers MUST NOT use the OSPF FAAM Sub-TLV to calculate the reachability of the ASBRs for the specific Flex-Algorithm if the winning FAD for such Flex-Algorithm does not include the M-flag. Instead, the OSPFv2 Type 4 Summary LSAs or the OSPFv3 Inter-Area-Router-LSAs MUST be used instead as specified in [section 16.2 of \[RFC2328\]](#) and [section 4.8.5 of \[RFC5340\]](#) for OSPFv2 and OSPFv3 respectively.

The processing of the new or changed OSPF FAAM Sub-TLV triggers the processing of the External routes similar to what is described in [section 16.5](#) of the [\[RFC2328\]](#) for OSPFv2 and [section 4.8.5 of \[RFC5340\]](#) for OSPFv3 for the specific Flex-Algorithm. The External and NSSA External route calculation should be limited to Flex-Algorithm(s) for which the winning FAD(s) includes the M-flag.

Processing of the OSPF FAAM Sub-TLV does not require the existence of the equivalent OSPFv2 Type 4 Summary LSA or the OSPFv3 Inter-Area-Router-LSA that is advertised by the same ABR inside the area. When the OSPFv2 EIA-ASBR LSA or the OSPFv3 E-Inter-Area-Router-LSA are advertised along with the OSPF FAAM Sub-TLV by the ABR for a specific ASBR, it is expected that the same ABR would advertise the reachability of the same ASBR in the equivalent base LSAs - i.e., the OSPFv2 Type 4 Summary LSA or the OSPFv3 Inter-Area-Router-LSA. The presence of the base LSA is not mandatory for the usage of the extended LSA with the OSPF FAAM Sub-TLV. This means that the order in which these LSAs are received is not significant.

11. Advertisement of Node Participation in a Flex-Algorithm

When a router is configured to support a particular Flex-Algorithm, we say it is participating in that Flex-Algorithm.

Paths for various data-planes MAY be computed for a specific Flex-Algorithm. Each data-plane uses its own specific forwarding over such Flex-Algorithm paths. To guarantee the presence of the data-plane specific forwarding, associated with a particular Flex-Algorithm, a router MUST advertise its participation for a particular

Flex-Algorithm for each data-plane. Some data-planes may share a common participation advertisement (e.g. SR MPLS and SRv6).

11.1. Advertisement of Node Participation for Segment Routing

[[RFC8667](#)], [[RFC8665](#)], and [[RFC8666](#)] (IGP Segment Routing extensions) describe how the SR-Algorithm is used to compute the IGP best path.

Routers advertise the support for the SR-Algorithm as a node capability as described in the above mentioned IGP Segment Routing extensions. To advertise participation for a particular Flex-Algorithm for Segment Routing, including both SR MPLS and SRv6, the Flex-Algorithm value MUST be advertised in the SR-Algorithm TLV (OSPF) or sub-TLV (IS-IS).

Segment Routing Flex-Algorithm participation advertisement is topology independent. When a router advertises participation in an SR-Algorithm, the participation applies to all topologies in which the advertising node participates.

11.2. Advertisement of Node Participation for Other Data-planes

This section describes considerations related to how other data-planes can advertise their participation in a specific Flex-Algorithm.

Data-plane specific Flex-Algorithm participation advertisements MAY be topology specific or MAY be topology independent, depending on the data-plane itself.

Data-plane specific advertisement for Flex-Algorithm participation MUST be defined for each data-plane and is outside of the scope of this document.

12. Advertisement of Link Attributes for Flex-Algorithm

Various link attributes may be used during the Flex-Algorithm path calculation. For example, include or exclude rules based on link affinities can be part of the Flex-Algorithm definition as defined in [Section 6](#) and [Section 7](#).

Application-specific link attributes, as specified in [[RFC8919](#)] or [[RFC8920](#)], that are to be used during Flex-Algorithm calculation MUST use the Application-Specific Link Attribute (ASLA) advertisements defined in [[RFC8919](#)] or [[RFC8920](#)], unless, in the case of IS-IS, the L-Flag is set in the ASLA advertisement. When the L-Flag is set, then legacy advertisements are to be used, subject to the procedures and constraints defined in [[RFC8919](#)] [Section 4.2](#) and [Section 6](#).

The mandatory use of ASLA advertisements applies to link attributes specifically mentioned in this document (Min Unidirectional Link Delay, TE Default Metric, Administrative Group, Extended Administrative Group and Shared Risk Link Group) and any other link attributes that may be used in support of Flex-Algorithm in the future.

A new Application Identifier Bit is defined to indicate that the ASLA advertisement is associated with the Flex-Algorithm application. This bit is set in the Standard Application Bit Mask (SABM) defined in [\[RFC8919\]](#) or [\[RFC8920\]](#):

Bit-3: Flexible Algorithm (X-bit)

ASLA Admin Group Advertisements to be used by the Flexible Algorithm application MAY use either the Administrative Group or Extended Administrative Group encodings. If the Administrative Group encoding is used, then the first 32 bits of the corresponding FAD sub-TLVs are mapped to the link attribute advertisements as specified in [RFC 7308](#).

A receiver supporting this specification MUST accept both ASLA Administrative Group and Extended Administrative Group TLVs as defined in [\[RFC8919\]](#) or [\[RFC8920\]](#). In the case of ISIS, if the L-Flag is set in ASLA advertisement, as defined in [\[RFC8919\]](#) [Section 4.2](#), then the receiver MUST be able to accept both Administrative Group TLV as defined in [\[RFC5305\]](#) and Extended Administrative Group TLV as defined in [\[RFC7308\]](#).

13. Calculation of Flexible Algorithm Paths

A router MUST be configured to participate in a given Flex-Algorithm K and MUST select the FAD based on the rules defined in [Section 5.3](#) before it can compute any path for that Flex-Algorithm.

No specific two way connectivity check is performed during the Flex-Algorithm path computation. The result of the existing, Flex-Algorithm agnostic, two way connectivity check is used during the Flex-Algorithm path computation.

As described in [Section 11](#), participation for any particular Flex-Algorithm MUST be advertised on a per data-plane basis. Calculation of the paths for any particular Flex-Algorithm MUST be data-plane specific.

Multiple data-planes MAY use the same Flex-Algorithm value at the same time, and as such, share the FAD for it. Traffic for each data-plane will be forwarded based on the data-plane specific forwarding entries.

Flex-Algorithm definition is data-plane independent and is used by all Flex-Algorithm data-planes.

The way various data-planes handle nodes that do not participate in Flexible-Algorithm is data-plane specific. If the data-plane only wants to consider participating nodes during the Flex-Algorithm calculation, then when computing paths for a given Flex-Algorithm, all nodes that do not advertise participation for that Flex-Algorithm in their data-plane specific advertisements **MUST** be pruned from the topology. Segment Routing, including both SR MPLS and SRv6, are data-planes that **MUST** use such pruning when computing Flex-Algorithm paths.

When computing the path for a given Flex-Algorithm, the metric-type that is part of the Flex-Algorithm definition ([Section 5](#)) **MUST** be used.

When computing the path for a given Flex-Algorithm, the calculation-type that is part of the Flex-Algorithm definition ([Section 5](#)) **MUST** be used.

Various link include or exclude rules can be part of the Flex-Algorithm definition. To refer to a particular bit within an AG or EAG we use the term 'color'.

Rules, in the order as specified below, **MUST** be used to prune links from the topology during the Flex-Algorithm computation.

For all links in the topology:

1. Check if any exclude AG rule is part of the Flex-Algorithm definition. If such exclude rule exists, check if any color that is part of the exclude rule is also set on the link. If such a color is set, the link **MUST** be pruned from the computation.
2. Check if any exclude SRLG rule is part of the Flex-Algorithm definition. If such exclude rule exists, check if the link is part of any SRLG that is also part of the SRLG exclude rule. If the link is part of such SRLG, the link **MUST** be pruned from the computation.
3. Check if any include-any AG rule is part of the Flex-Algorithm definition. If such include-any rule exists, check if any color that is part of the include-any rule is also set on the link. If no such color is set, the link **MUST** be pruned from the computation.

4. Check if any include-all AG rule is part of the Flex-Algorithm definition. If such include-all rule exists, check if all colors that are part of the include-all rule are also set on the link. If all such colors are not set on the link, the link MUST be pruned from the computation.
5. If the Flex-Algorithm definition uses other than IGP metric ([Section 5](#)), and such metric is not advertised for the particular link in a topology for which the computation is done, such link MUST be pruned from the computation. A metric of value 0 MUST NOT be assumed in such case.

[13.1](#). Multi-area and Multi-domain Considerations

Any IGP Shortest Path Tree calculation is limited to a single area. This applies to Flex-Algorithm calculations as well. Given that the computing router does not have visibility of the topology of the next areas or domain, the Flex-Algorithm specific path to an inter-area or inter-domain prefix will be computed for the local area only. The egress L1/L2 router (ABR in OSPF), or ASBR for inter-domain case, will be selected based on the best path for the given Flex-Algorithm in the local area and such egress ABR or ASBR router will be responsible to compute the best Flex-Algorithm specific path over the next area or domain. This may produce an end-to-end path, which is sub-optimal based on Flex-Algorithm constraints. In cases where the ABR or ASBR has no reachability to a prefix for a given Flex-Algorithm in the next area or domain, the traffic may be dropped by the ABR/ASBR.

To allow the optimal end-to-end path for an inter-area or inter-domain prefix for any Flex-Algorithm to be computed, the FAPM has been defined in [Section 8](#) and [Section 9](#). For external route calculation for prefixes originated by ASBRs in remote areas in OSPF, the FAAM has been defined in [Section 10.2](#) for the ABR to indicate its ASBR reachability along with the metric for the specific Flex-Algorithm.

If the FAD selected based on the rules defined in [Section 5.3](#) includes the M-flag, an ABR or ASBR MUST include the FAPM ([Section 8](#), [Section 9](#)) when advertising the prefix, that is reachable in a given Flex-Algorithm, between areas or domains. Such metric will be equal to the metric to reach the prefix for that Flex-Algorithm in its source area or domain. This is similar in nature to how the metric is set when prefixes are advertised between areas or domains for the default algorithm. When a prefix is unreachable in its source area or domain in a specific Flex-Algorithm, then an ABR or ASBR MUST NOT include the FAPM for that Flex-Algorithm when advertising the prefix between areas or domains.

If the FAD selected based on the rules defined in [Section 5.3](#) includes the M-flag, the FAPM MUST be used during the calculation of prefix reachability for the inter-area and external prefixes. If the FAPM for the Flex-Algorithm is not advertised with the inter-area or external prefix reachability advertisement, the prefix MUST be considered as unreachable for that Flex-Algorithm. Similarly in the case of OSPF, for ASBRs in remote areas, if the FAAM is not advertised by the local ABR(s), the ASBR MUST be considered as unreachable for that Flex-Algorithm and the external prefix advertisements from such an ASBR are not considered for that Flex-Algorithm.

Flex-Algorithm prefix metrics and the OSPF Flex-Algorithm ASBR metrics MUST NOT be used during the Flex-Algorithm computation unless the FAD selected based on the rules defined in [Section 5.3](#) includes the M-Flag, as described in ([Section 6.4](#) or [Section 7.4](#)).

In the case of OSPF, when calculating external routes in a Flex-Algorithm (with FAD selected includes the M-Flag) where the advertising ASBR is in a remote area, the metric will be the sum of the following:

- o the FAPM for that Flex-Algorithm advertised with the external route by the ASBR
- o the metric to reach the ASBR for that Flex-Algorithm from the local ABR i.e., the FAAM for that Flex-Algorithm advertised by the ABR in the local area for that ASBR
- o the Flex-Algorithm specific metric to reach the local ABR

This is similar in nature to how the metric is calculated for routes learned from remote ASBRs in the default algorithm using the OSPFv2 Type 4 ASBR Summary LSA and the OSPFv3 Inter-Area-Router LSA.

If the FAD selected based on the rules defined in [Section 5.3](#) does not includes the M-flag, then the IGP metrics associated with the prefix reachability advertisements used by the base IS-IS and OSPF protocol MUST be used for the Flex-Algorithm route computation. Similarly, in the case of external route calculations in OSPF, the ASBR reachability is determined based on the base OSPFv2 Type 4 Summary LSA and the OSPFv3 Inter-Area-Router LSA.

It is NOT RECOMMENDED to use the Flex-Algorithm for inter-area or inter-domain prefix reachability without the M-flag set. The reason is that without the explicit Flex-Algorithm Prefix Metric advertisement (and the Flex-Algorithm ASBR metric advertisement in the case of OSPF external route calculation), it is not possible to

conclude whether the ABR or ASBR has reachability to the inter-area or inter-domain prefix for a given Flex-Algorithm in the next area or domain. Sending the Flex-Algorithm traffic for such prefix towards the ABR or ASBR may result in traffic looping or black-holing.

During the route computation, it is possible for the Flex-Algorithm specific metric to exceed the maximum value that can be stored in an unsigned 32-bit variable. In such scenarios, the value MUST be considered to be of value 4,294,967,295 during the computation and advertised as such.

The FAPM MUST NOT be advertised with IS-IS L1 or L2 intra-area, OSPFv2 intra-area, or OSPFv3 intra-area routes. If the FAPM is advertised for these route-types, it MUST be ignored during the prefix reachability calculation.

The M-flag in FAD is not applicable to prefixes advertised as SRv6 locators. The IS-IS SRv6 Locator TLV [[I-D.ietf-lsr-isis-srv6-extensions](#)] includes the Algorithm and Metric fields. When the SRv6 Locator is advertised between areas or domains, the metric field in the Locator TLV of IS-IS MUST be used irrespective of the M-flag in the FAD advertisement.

OSPF external and NSSA external prefix advertisements MAY include a non-zero forwarding address in the prefix advertisements in the base protocol. In such a scenario, the Flex-Algorithm specific reachability of the external prefix is determined by Flex-Algorithm specific reachability of the forwarding address.

In OSPF, the procedures for translation of NSSA external prefix advertisements into external prefix advertisements performed by an NSSA ABR [[RFC3101](#)] remain unchanged for Flex-Algorithm. An NSSA translator MUST include the OSPF FAPM Sub-TLVs for all Flex-Algorithms that are in the original NSSA external prefix advertisement from the NSSA ASBR in the translated external prefix advertisement generated by it regardless of its participation in those Flex-Algorithms or its having reachability to the NSSA ASBR in those Flex-Algorithms.

An area could become partitioned from the perspective of the Flex-Algorithm due to the constraints and/or metric being used for it, while maintaining the continuity in the algorithm 0. When that happens, some destinations inside that area could become unreachable in that Flex-Algorithm. These destinations will not be able to use an inter-area path. This is the consequence of the fact that the inter-area prefix reachability advertisement would not be available for these intra-area destinations within the area. It is RECOMMENDED

to avoid such partitioning by providing enough redundancy inside the area for each Flex-Algorithm being used.

14. Flex-Algorithm and Forwarding Plane

This section describes how Flex-Algorithm paths are used in forwarding.

14.1. Segment Routing MPLS Forwarding for Flex-Algorithm

This section describes how Flex-Algorithm paths are used with SR MPLS forwarding.

Prefix SID advertisements include an SR-Algorithm value and, as such, are associated with the specified SR-Algorithm. Prefix-SIDs are also associated with a specific topology which is inherited from the associated prefix reachability advertisement. When the algorithm value advertised is a Flex-Algorithm value, the Prefix SID is associated with paths calculated using that Flex-Algorithm in the associated topology.

A Flex-Algorithm path **MUST** be installed in the MPLS forwarding plane using the MPLS label that corresponds to the Prefix-SID that was advertised for that Flex-algorithm. If the Prefix SID for a given Flex-algorithm is not known, the Flex-Algorithm specific path cannot be installed in the MPLS forwarding plane.

Traffic that is supposed to be routed via Flex-Algorithm specific paths, **MUST** be dropped when there are no such paths available.

Loop Free Alternate (LFA) paths for a given Flex-Algorithm **MUST** be computed using the same constraints as the calculation of the primary paths for that Flex-Algorithm. LFA paths **MUST** only use Prefix-SIDs advertised specifically for the given algorithm. LFA paths **MUST NOT** use an Adjacency-SID that belongs to a link that has been pruned from the Flex-Algorithm computation.

If LFA protection is being used to protect a given Flex-Algorithm paths, all routers in the area participating in the given Flex-Algorithm **SHOULD** advertise at least one Flex-Algorithm specific Node-SID. These Node-SIDs are used to steer traffic over the LFA computed backup path.

14.2. SRv6 Forwarding for Flex-Algorithm

This section describes how Flex-Algorithm paths are used with SRv6 forwarding.

In SRv6 a node is provisioned with topology/algorithm specific locators for each of the topology/algorithm pairs supported by that node. Each locator is an aggregate prefix for all SIDs provisioned on that node which have the matching topology/algorithm.

The SRv6 locator advertisement in IS-IS [[I-D.ietf-lsr-isis-srv6-extensions](#)] includes the MTID value that associates the locator with a specific topology. SRv6 locator advertisements also includes an Algorithm value that explicitly associates the locator with a specific algorithm. When the algorithm value advertised with a locator represents a Flex-Algorithm, the paths to the locator prefix MUST be calculated using the specified Flex-Algorithm in the associated topology.

Forwarding entries for the locator prefixes advertised in IS-IS MUST be installed in the forwarding plane of the receiving SRv6 capable routers when the associated topology/algorithm is participating in them. Forwarding entries for locators associated with Flex-Algorithms in which the node is not participating MUST NOT be installed in the forwarding plane.

When the locator is associated with a Flex-Algorithm, LFA paths to the locator prefix MUST be calculated using such Flex-Algorithm in the associated topology, to guarantee that they follow the same constraints as the calculation of the primary paths. LFA paths MUST only use SRv6 SIDs advertised specifically for the given Flex-Algorithm.

If LFA protection is being used to protect locators associated with a given Flex-Algorithm, all routers in the area participating in the given Flex-Algorithm SHOULD advertise at least one Flex-Algorithm specific locator and END SID per node and one END.X SID for every link that has not been pruned from such Flex-Algorithm computation. These locators and SIDs are used to steer traffic over the LFA-computed backup path.

[14.3.](#) Other Data-planes' Forwarding for Flex-Algorithm

Any data-plane that wants to use Flex-Algorithm specific forwarding needs to install some form of Flex-Algorithm specific forwarding entries.

Data-plane specific forwarding for Flex-Algorithm MUST be defined for each data-plane and is outside of the scope of this document.

15. Operational Considerations

15.1. Inter-area Considerations

The scope of the Flex-Algorithm computation is an area, so is the scope of the FAD. In IS-IS, the Router Capability TLV in which the FAD Sub-TLV is advertised MUST have the S-bit clear, which prevents it to be flooded outside of the level in which it was originated. Even though in OSPF the FAD Sub-TLV can be flooded in an RI LSA that has AS flooding scope, the FAD selection is performed for each individual area in which it is being used.

There is no requirement for the FAD for a particular Flex-Algorithm to be identical in all areas in the network. For example, traffic for the same Flex-Algorithm may be optimized for minimal delay (e.g., using delay metric) in one area or level, while being optimized for available bandwidth (e.g., using IGP metric) in another area or level.

As described in [Section 5.1](#), IS-IS allows the re-generation of the winning FAD from level 2, without any modification to it, into a level 1 area. This allows the operator to configure the FAD in one or multiple routers in the level 2, without the need to repeat the same task in each level 1 area, if the intent is to have the same FAD for the particular Flex-Algorithm across all levels. This can similarly be achieved in OSPF by using the AS flooding scope of the RI LSA in which the FAD Sub-TLV for the particular Flex-Algorithm is advertised.

Re-generation of FAD from a level 1 area to the level 2 area is not supported in IS-IS, so if the intent is to regenerate the FAD between IS-IS levels, the FAD MUST be defined on router(s) that are in level 2. In OSPF, the FAD definition can be done in any area and be propagated to all routers in the OSPF routing domain by using the AS flooding scope of the RI LSA.

15.2. Usage of SRLG Exclude Rule with Flex-Algorithm

There are two different ways in which SRLG information can be used with Flex-Algorithm:

In a context of a single Flex-Algorithm, it can be used for computation of backup paths, as described in [\[I-D.ietf-rtgwg-segment-routing-ti-lfa\]](#). This usage does not require association of any specific SRLG constraint with the given Flex-Algorithm definition.

In the context of multiple Flex-Algorithms, it can be used for creating disjoint sets of paths by pruning the links belonging to a specific SRLG from the topology on which a specific Flex-Algorithm computes its paths. This usage:

Facilitates the usage of already deployed SRLG configurations for setup of disjoint paths between two or more Flex-Algorithms.

Requires explicit association of a given Flex-Algorithm with a specific set of SRLG constraints as defined in [Section 6.5](#) and [Section 7.5](#).

The two usages mentioned above are orthogonal.

[15.3.](#) Max-metric consideration

Both IS-IS and OSPF have a mechanism to set the IGP metric on a link to a value that would make the link either non-reachable or to serve as the link of last resort. Similar functionality would be needed for the Min Unidirectional Link Delay and TE metric, as these can be used to compute Flex-Algorithm paths.

The link can be made un-reachable for all Flex-Algorithms that use Min Unidirectional Link Delay as metric, as described in [Section 5.1](#), by removing the Flex-Algorithm ASLA Min Unidirectional Link Delay advertisement for the link. The link can be made the link of last resort by setting the delay value in the Flex-Algorithm ASLA delay advertisement for the link to the value of 16,777,215 ($2^{24} - 1$).

The link can be made un-reachable for all Flex-Algorithms that use TE metric, as described in [Section 5.1](#), by removing the Flex-Algorithm ASLA TE metric advertisement for the link. The link can be made the link of last resort by setting the TE metric value in the Flex-Algorithm ASLA delay advertisement for the link to the value of ($2^{24} - 1$) in IS-IS and ($2^{32} - 1$) in OSPF.

[16.](#) Backward Compatibility

This extension brings no new backward compatibility issues. IS-IS, OSPFv2 and OSPFv3 all have well defined handling of unrecognized TLVs and sub-TLVs that allows the introduction of the new extensions, similar to those defined here, without introducing any interoperability issues.

17. Security Considerations

This draft adds two new ways to disrupt IGP networks:

An attacker can hijack a particular Flex-Algorithm by advertising a FAD with a priority of 255 (or any priority higher than that of the legitimate nodes).

An attacker could make it look like a router supports a particular Flex-Algorithm when it actually doesn't, or vice versa.

Both of these attacks can be addressed by the existing security extensions as described in [[RFC5304](#)] and [[RFC5310](#)] for IS-IS, in [[RFC2328](#)] and [[RFC7474](#)] for OSPFv2, and in [[RFC5340](#)] and [[RFC4552](#)] for OSPFv3.

18. IANA Considerations

18.1. IGP IANA Considerations

18.1.1. IGP Algorithm Types Registry

This document makes the following registrations in the "IGP Algorithm Types" registry:

Type: 128-255.

Description: Flexible Algorithms.

Reference: This document ([Section 4](#)).

18.1.2. IGP Metric-Type Registry

IANA is requested to set up a registry called "IGP Metric-Type Registry" under an "Interior Gateway Protocol (IGP) Parameters" IANA registries. The registration policy for this registry is "Standards Action" ([[RFC8126](#)] and [[RFC7120](#)]).

Values in this registry come from the range 0-255.

This document registers following values in the "IGP Metric-Type Registry":

Type: 0

Description: IGP metric

Reference: This document ([Section 5.1](#))

Type: 1

Description: Min Unidirectional Link Delay as defined in [\[RFC8570\], section 4.2](#), and [\[RFC7471\], section 4.2](#).

Reference: This document ([Section 5.1](#))

Type: 2

Description: Traffic Engineering Default Metric as defined in [\[RFC5305\], section 3.7](#), and Traffic engineering metric as defined in [\[RFC3630\], section 2.5.5](#)

Reference: This document ([Section 5.1](#))

[18.2.](#) Flexible Algorithm Definition Flags Registry

IANA is requested to set up a registry called "IS-IS Flexible Algorithm Definition Flags Registry" under an "Interior Gateway Protocol (IGP) Parameters" IANA registries. The registration policy for this registry is "Standards Action" ([\[RFC8126\]](#) and [\[RFC7120\]](#)).

This document defines the following single bit in Flexible Algorithm Definition Flags registry:

Bit #	Name
-----	-----
0	Prefix Metric Flag (M-flag)

Reference: This document ([Section 6.4](#), [Section 7.4](#)).

[18.3.](#) IS-IS IANA Considerations

[18.3.1.](#) Sub TLVs for Type 242

This document makes the following registrations in the "sub-TLVs for TLV 242" registry.

Type: 26.

Description: Flexible Algorithm Definition.

Reference: This document ([Section 5.1](#)).

18.3.2. Sub TLVs for for TLVs 135, 235, 236, and 237

This document makes the following registrations in the "Sub-TLVs for for TLVs 135, 235, 236, and 237" registry.

Type: 6

Description: Flexible Algorithm Prefix Metric.

Reference: This document ([Section 8](#)).

18.3.3. Sub-Sub-TLVs for Flexible Algorithm Definition Sub-TLV

This document creates the following Sub-Sub-TLV Registry:

Registry: Sub-Sub-TLVs for Flexible Algorithm Definition Sub-TLV

Registration Procedure: Expert review

Reference: This document ([Section 5.1](#))

This document defines the following Sub-Sub-TLVs in the "Sub-Sub-TLVs for Flexible Algorithm Definition Sub-TLV" registry:

Type: 1

Description: Flexible Algorithm Exclude Admin Group

Reference: This document ([Section 6.1](#)).

Type: 2

Description: Flexible Algorithm Include-Any Admin Group

Reference: This document ([Section 6.2](#)).

Type: 3

Description: Flexible Algorithm Include-All Admin Group

Reference: This document ([Section 6.3](#)).

Type: 4

Description: Flexible Algorithm Definition Flags

Reference: This document ([Section 6.4](#)).

Type: 5

Description: Flexible Algorithm Exclude SRLG

Reference: This document ([Section 6.5](#)).

[18.4.](#) OSPF IANA Considerations

[18.4.1.](#) OSPF Router Information (RI) TLVs Registry

This specification updates the OSPF Router Information (RI) TLVs Registry.

Type: 16

Description: Flexible Algorithm Definition TLV.

Reference: This document ([Section 5.2](#)).

[18.4.2.](#) OSPFv2 Extended Prefix TLV Sub-TLVs

This document makes the following registrations in the "OSPFv2 Extended Prefix TLV Sub-TLVs" registry.

Type: 3

Description: Flexible Algorithm Prefix Metric.

Reference: This document ([Section 9](#)).

[18.4.3.](#) OSPFv3 Extended-LSA Sub-TLVs

This document makes the following registrations in the "OSPFv3 Extended-LSA Sub-TLVs" registry.

Type: 26

Description: Flexible Algorithm Prefix Metric.

Reference: This document ([Section 9](#)).

Type: TBD (suggested value 30)

Description: OSPF Flexible Algorithm ASBR Metric Sub-TLV

Reference: This document ([Section 10.2](#)).

18.4.4. OSPF Flex-Algorithm Prefix Metric Bits

This specification requests creation of "OSPF Flex-Algorithm Prefix Metric Bits" registry under the OSPF Parameters Registry with the following initial values.

Bit Number: 0

Description: E bit - External Type

Reference: this document.

The bits 1-7 are unassigned and the registration procedure to be followed for this registry is IETF Review.

18.4.5. OSPF Opaque LSA Option Types

This document makes the following registrations in the "OSPF Opaque LSA Option Types" registry.

Value: TBD (suggested value 11)

Description: OSPFv2 Extended Inter-Area ASBR LSA

Reference: This document ([Section 10.1](#)).

18.4.6. OSPFv2 Extended Inter-Area ASBR TLVs

This specification requests creation of "OSPFv2 Extended Inter-Area ASBR TLVs" registry under the OSPFv2 Parameters Registry with the following initial values.

Value: 1

Description : Extended Inter-Area ASBR TLV

Reference: this document

The values 2 to 32767 are unassigned, values 32768 to 33023 are reserved for experimental use while the values 0 and 33024 to 65535 are reserved. The registration procedure to be followed for this registry is IETF Review or IESG Approval.

18.4.7. OSPFv2 Inter-Area ASBR Sub-TLVs

This specification requests creation of "OSPFv2 Extended Inter-Area ASBR Sub-TLVs" registry under the OSPFv2 Parameters Registry with the following initial values.

Value: 1

Description : OSPF Flexible Algorithm ASBR Metric Sub-TLV

Reference: this document

The values 2 to 32767 are unassigned, values 32768 to 33023 are reserved for experimental use while the values 0 and 33024 to 65535 are reserved. The registration procedure to be followed for this registry is IETF Review or IESG Approval.

18.4.8. OSPF Flexible Algorithm Definition TLV Sub-TLV Registry

This document creates the following registry:

Registry: OSPF Flexible Algorithm Definition TLV sub-TLV

Registration Procedure: Expert review

Reference: This document ([Section 5.2](#))

The "OSPF Flexible Algorithm Definition TLV sub-TLV" registry will define sub-TLVs at any level of nesting for the Flexible Algorithm TLV and should be added to the "Open Shortest Path First (OSPF) Parameters" registries group. New values can be allocated via IETF Review or IESG Approval.

This document registers following Sub-TLVs in the "TLVs for Flexible Algorithm Definition TLV" registry:

Type: 1

Description: Flexible Algorithm Exclude Admin Group

Reference: This document ([Section 7.1](#)).

Type: 2

Description: Flexible Algorithm Include-Any Admin Group

Reference: This document ([Section 7.2](#)).

Type: 3

Description: Flexible Algorithm Include-All Admin Group

Reference: This document ([Section 7.3](#)).

Type: 4

Description: Flexible Algorithm Definition Flags

Reference: This document ([Section 7.4](#)).

Type: 5

Description: Flexible Algorithm Exclude SRLG

Reference: This document ([Section 7.5](#)).

Types in the range 32768-33023 are for experimental use; these will not be registered with IANA, and MUST NOT be mentioned by RFCs.

Types in the range 33024-65535 are not to be assigned at this time. Before any assignments can be made in the 33024-65535 range, there MUST be an IETF specification that specifies IANA Considerations that covers the range being assigned.

[18.4.9](#). Link Attribute Applications Registry

This document registers following bit in the Link Attribute Applications Registry:

Bit-3

Description: Flexible Algorithm (X-bit)

Reference: This document ([Section 12](#)).

[19](#). Acknowledgements

This draft, among other things, is also addressing the problem that the [[I-D.gulkohegde-routing-planes-using-sr](#)] was trying to solve. All authors of that draft agreed to join this draft.

Thanks to Eric Rosen, Tony Przygienda, William Britto A J, Gunter Van De Velde, Dirk Goethals, Manju Sivaji and, Baalajee S for their detailed review and excellent comments.

Thanks to Cengiz Halit for his review and feedback during initial phase of the solution definition.

Thanks to Kenji Kumaki for his comments.

Thanks to Acee Lindem for editorial comments.

20. References

20.1. Normative References

- [I-D.ietf-lsr-isis-srv6-extensions]
Psenak, P., Filsfils, C., Bashandy, A., Decraene, B., and Z. Hu, "IS-IS Extensions to Support Segment Routing over IPv6 Dataplane", [draft-ietf-lsr-isis-srv6-extensions-18](#) (work in progress), October 2021.
- [ISO10589]
International Organization for Standardization, "Intermediate system to Intermediate system intra-domain routing information exchange protocol for use in conjunction with the protocol for providing the connectionless-mode Network Service (ISO 8473)", ISO/IEC 10589:2002, Second Edition, Nov 2002.
- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", [BCP 14](#), [RFC 2119](#), DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/info/rfc2119>>.
- [RFC4203] Kompella, K., Ed. and Y. Rekhter, Ed., "OSPF Extensions in Support of Generalized Multi-Protocol Label Switching (GMPLS)", [RFC 4203](#), DOI 10.17487/RFC4203, October 2005, <<https://www.rfc-editor.org/info/rfc4203>>.
- [RFC5250] Berger, L., Bryskin, I., Zinin, A., and R. Coltun, "The OSPF Opaque LSA Option", [RFC 5250](#), DOI 10.17487/RFC5250, July 2008, <<https://www.rfc-editor.org/info/rfc5250>>.
- [RFC5307] Kompella, K., Ed. and Y. Rekhter, Ed., "IS-IS Extensions in Support of Generalized Multi-Protocol Label Switching (GMPLS)", [RFC 5307](#), DOI 10.17487/RFC5307, October 2008, <<https://www.rfc-editor.org/info/rfc5307>>.
- [RFC7308] Osborne, E., "Extended Administrative Groups in MPLS Traffic Engineering (MPLS-TE)", [RFC 7308](#), DOI 10.17487/RFC7308, July 2014, <<https://www.rfc-editor.org/info/rfc7308>>.
- [RFC7684] Psenak, P., Gredler, H., Shakir, R., Henderickx, W., Tantsura, J., and A. Lindem, "OSPFv2 Prefix/Link Attribute Advertisement", [RFC 7684](#), DOI 10.17487/RFC7684, November 2015, <<https://www.rfc-editor.org/info/rfc7684>>.

- [RFC7770] Lindem, A., Ed., Shen, N., Vasseur, JP., Aggarwal, R., and S. Shaffer, "Extensions to OSPF for Advertising Optional Router Capabilities", [RFC 7770](#), DOI 10.17487/RFC7770, February 2016, <<https://www.rfc-editor.org/info/rfc7770>>.
- [RFC7981] Ginsberg, L., Previdi, S., and M. Chen, "IS-IS Extensions for Advertising Router Information", [RFC 7981](#), DOI 10.17487/RFC7981, October 2016, <<https://www.rfc-editor.org/info/rfc7981>>.
- [RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in [RFC 2119](#) Key Words", [BCP 14](#), [RFC 8174](#), DOI 10.17487/RFC8174, May 2017, <<https://www.rfc-editor.org/info/rfc8174>>.
- [RFC8362] Lindem, A., Roy, A., Goethals, D., Reddy Vallem, V., and F. Baker, "OSPFv3 Link State Advertisement (LSA) Extensibility", [RFC 8362](#), DOI 10.17487/RFC8362, April 2018, <<https://www.rfc-editor.org/info/rfc8362>>.
- [RFC8665] Psenak, P., Ed., Previdi, S., Ed., Filsfils, C., Gredler, H., Shakir, R., Henderickx, W., and J. Tantsura, "OSPF Extensions for Segment Routing", [RFC 8665](#), DOI 10.17487/RFC8665, December 2019, <<https://www.rfc-editor.org/info/rfc8665>>.
- [RFC8666] Psenak, P., Ed. and S. Previdi, Ed., "OSPFv3 Extensions for Segment Routing", [RFC 8666](#), DOI 10.17487/RFC8666, December 2019, <<https://www.rfc-editor.org/info/rfc8666>>.
- [RFC8667] Previdi, S., Ed., Ginsberg, L., Ed., Filsfils, C., Bashandy, A., Gredler, H., and B. Decraene, "IS-IS Extensions for Segment Routing", [RFC 8667](#), DOI 10.17487/RFC8667, December 2019, <<https://www.rfc-editor.org/info/rfc8667>>.
- [RFC8919] Ginsberg, L., Psenak, P., Previdi, S., Henderickx, W., and J. Drake, "IS-IS Application-Specific Link Attributes", [RFC 8919](#), DOI 10.17487/RFC8919, October 2020, <<https://www.rfc-editor.org/info/rfc8919>>.
- [RFC8920] Psenak, P., Ed., Ginsberg, L., Henderickx, W., Tantsura, J., and J. Drake, "OSPF Application-Specific Link Attributes", [RFC 8920](#), DOI 10.17487/RFC8920, October 2020, <<https://www.rfc-editor.org/info/rfc8920>>.

20.2. Informative References

- [I-D.gulkohegde-routing-planes-using-sr]
Hegde, S. and A. Gulko, "Separating Routing Planes using Segment Routing", [draft-gulkohegde-routing-planes-using-sr-00](#) (work in progress), March 2017.
- [I-D.ietf-rtgwg-segment-routing-ti-lfa]
Litkowski, S., Bashandy, A., Filsfils, C., Francois, P., Decraene, B., and D. Voyer, "Topology Independent Fast Reroute using Segment Routing", [draft-ietf-rtgwg-segment-routing-ti-lfa-08](#) (work in progress), January 2022.
- [RFC2328] Moy, J., "OSPF Version 2", STD 54, [RFC 2328](#), DOI 10.17487/RFC2328, April 1998, <<https://www.rfc-editor.org/info/rfc2328>>.
- [RFC3101] Murphy, P., "The OSPF Not-So-Stubby Area (NSSA) Option", [RFC 3101](#), DOI 10.17487/RFC3101, January 2003, <<https://www.rfc-editor.org/info/rfc3101>>.
- [RFC3630] Katz, D., Kompella, K., and D. Yeung, "Traffic Engineering (TE) Extensions to OSPF Version 2", [RFC 3630](#), DOI 10.17487/RFC3630, September 2003, <<https://www.rfc-editor.org/info/rfc3630>>.
- [RFC3906] Shen, N. and H. Smit, "Calculating Interior Gateway Protocol (IGP) Routes Over Traffic Engineering Tunnels", [RFC 3906](#), DOI 10.17487/RFC3906, October 2004, <<https://www.rfc-editor.org/info/rfc3906>>.
- [RFC4552] Gupta, M. and N. Melam, "Authentication/Confidentiality for OSPFv3", [RFC 4552](#), DOI 10.17487/RFC4552, June 2006, <<https://www.rfc-editor.org/info/rfc4552>>.
- [RFC5304] Li, T. and R. Atkinson, "IS-IS Cryptographic Authentication", [RFC 5304](#), DOI 10.17487/RFC5304, October 2008, <<https://www.rfc-editor.org/info/rfc5304>>.
- [RFC5305] Li, T. and H. Smit, "IS-IS Extensions for Traffic Engineering", [RFC 5305](#), DOI 10.17487/RFC5305, October 2008, <<https://www.rfc-editor.org/info/rfc5305>>.
- [RFC5310] Bhatia, M., Manral, V., Li, T., Atkinson, R., White, R., and M. Fanto, "IS-IS Generic Cryptographic Authentication", [RFC 5310](#), DOI 10.17487/RFC5310, February 2009, <<https://www.rfc-editor.org/info/rfc5310>>.

- [RFC5340] Coltun, R., Ferguson, D., Moy, J., and A. Lindem, "OSPF for IPv6", [RFC 5340](#), DOI 10.17487/RFC5340, July 2008, <<https://www.rfc-editor.org/info/rfc5340>>.
- [RFC7120] Cotton, M., "Early IANA Allocation of Standards Track Code Points", [BCP 100](#), [RFC 7120](#), DOI 10.17487/RFC7120, January 2014, <<https://www.rfc-editor.org/info/rfc7120>>.
- [RFC7471] Giacalone, S., Ward, D., Drake, J., Atlas, A., and S. Previdi, "OSPF Traffic Engineering (TE) Metric Extensions", [RFC 7471](#), DOI 10.17487/RFC7471, March 2015, <<https://www.rfc-editor.org/info/rfc7471>>.
- [RFC7474] Bhatia, M., Hartman, S., Zhang, D., and A. Lindem, Ed., "Security Extension for OSPFv2 When Using Manual Key Management", [RFC 7474](#), DOI 10.17487/RFC7474, April 2015, <<https://www.rfc-editor.org/info/rfc7474>>.
- [RFC8126] Cotton, M., Leiba, B., and T. Narten, "Guidelines for Writing an IANA Considerations Section in RFCs", [BCP 26](#), [RFC 8126](#), DOI 10.17487/RFC8126, June 2017, <<https://www.rfc-editor.org/info/rfc8126>>.
- [RFC8570] Ginsberg, L., Ed., Previdi, S., Ed., Giacalone, S., Ward, D., Drake, J., and Q. Wu, "IS-IS Traffic Engineering (TE) Metric Extensions", [RFC 8570](#), DOI 10.17487/RFC8570, March 2019, <<https://www.rfc-editor.org/info/rfc8570>>.

Authors' Addresses

Peter Psenak (editor)
Cisco Systems
Apollo Business Center
Mlynske nivy 43
Bratislava, 82109
Slovakia

Email: ppsenak@cisco.com

Shraddha Hegde
Juniper Networks, Inc.
Embassy Business Park
Bangalore, KA, 560093
India

Email: shraddha@juniper.net

Clarence Filsfils
Cisco Systems, Inc.
Brussels
Belgium

Email: cfilsfil@cisco.com

Ketan Talaulikar
Arcus, Inc
India

Email: ketant.ietf@gmail.com

Arkadiy Gulko
Edward Jones

Email: arkadiy.gulko@edwardjones.com

