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IGP Flexible Algorithms (Flex-Algorithm) In IP Networks
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Abstract

An IGP Flexible Algorithm (Flex-Algorithm) allows IGP to compute constraint-based paths. As currently defined, IGP Flex-Algorithm is used with Segment Routing (SR) data planes - SR MPLS and SRv6. Therefore, Flex-Algorithm cannot be deployed in the absence of SR.

This document extends IGP Flex-Algorithm, so that it can be used for regular IPv4 and IPv6 prefixes. This allows Flex-Algorithm to be deployed in any IP network, even in the absence of SR.

Status of This Memo

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1. Introduction

An IGP Flex-Algorithm as specified in [I-D.ietf-lsr-flex-algo] computes a constraint-based path to:

- o All Flex-Algorithm specific Prefix Segment Identifiers (SIDs) [RFC8402].

o All Flex-Algorityhm specific SRv6 Locators [I-D.ietf-spring-srv6-network-programming].

Therefore, Flex-Algorithm cannot be deployed in the absence of SR and SRv6.

This document extends Flex-Algorithm, allowing it to compute paths to:

o An IPv4 [RFC0791] address.

o An IPv6 [RFC8200] address.

This allows Flex-Algorithm to be deployed in any IP network, even in the absence of SR and SRv6.

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. Egress Node Procedures

Network operators configure multiple loopback interfaces on an egress node. They associate one or more IP addresses with each loopback interface and one Flex-Algorithm with each IP address.

If a packet is sent to a loopback address, and the loopback address is not associated with a Flex-Algorithm, the packet follows the IGP least-cost path to the egress node. If a packet is sent to a loopback address, and the loopback address is associated with a Flex-Algorithm, the packet follows the constraint-base path that the Flex-Algorithm calculated.

4. Advertising Flex-Algorithm Definitions (FAD)

To guarantee loop free forwarding, all routers that participate in a Flex-Algorithm MUST agree on the Flex-Algorithm Definition (FAD).

Selected nodes within the IGP domain MUST advertise FADs as described in Sections 5, 6 and 7 of [I-D.ietf-lsr-flex-algo].

5. Advertising IP Flex-Algorithm Participation

A node may use various algorithms when calculating paths to nodes and prefixes. Algorithm values are defined in the IGP Algorithm Type Registry [IANA-ALG].

A node MUST participate in a Flex-Algorithm to be:

- o able to compute path for such Flex-Algorithm

- o be part of the topology for such Flex-Algorithm

Flex-Algorithm participation MUST be advertised for each Flex-Algorithm application independently, as specified in Section 10.2 of [I-D.ietf-lsr-flex-algo]. Using Flex-Algorithm for regular IPv4 and IPv6 prefixes represents a new Flex-Algorithm application (IP Flex-Algorithm), and as such the Flex-Algorithm participation for the IP Flex-Algorithm application MUST be signalled independently of any other Flex-Algorithm applications (e.g. SR).

Following sections describe how the IP Flex-Algorithm participation is advertised in IGP protocols.

5.1. The ISIS IP Algorithm Sub-TLV

The ISIS IP Algorithm Sub-TLV is a sub-TLV of the ISIS Router Capability TLV [RFC7981] 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    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Algorithm 1   | Algorithm 2   | Algorithm ... |  Algorithm n  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 1: ISIS IP Algorithm Sub-TLV

o Type: IP Algorithm Sub-TLV (Value TBD by IANA)

o Length: Variable

o Algorithm (1 octet): value from 1 to 255.

The IP Algorithm Sub-TLV MUST be propagated throughout the level and MUST NOT be advertised across level boundaries. Therefore, the S bit in the Router Capability TLV, in which the IP Algorithm Sub-TLV is advertised, MUST NOT be set.

The IP Algorithm Sub-TLV is optional. It MUST NOT be advertised more than once at a given level. A router receiving multiple IP Algorithm sub-TLVs from the same originator SHOULD select the first advertisement in the lowest-numbered LSP and subsequent instances of the IP Algorithm Sub-TLV MUST be ignored.

The IP Algorithm Sub-TLV advertises the participation in Flex-Algorithms, and MUST NOT impact the router participation in default

algorithm 0. The IP Algorithm Sub-TLV could be used to advertise support for non-zero standard algorithms, but that is outside the scope of this document.

The IP Flex-Algorithm participation advertised in ISIS IP Algorithm Sub-TLV is topology independent. When a router advertises participation in ISIS IP Algorithm Sub-TLV, the participation applies to all topologies in which the advertising node participates.

5.2. The OSPF IP Algorithm TLV

The OSPF IP Algorithm TLV is a top-level TLV of the Router Information Opaque LSA [RFC7770] 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            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Algorithm 1 | Algorithm...  |   Algorithm n |               |
+-                                                             -+
|                                                               |
```

+ +

Figure 2: OSPF IP Algorithm TLV

- o Type: IP Algorithm TLV (Value TBD by IANA)
- o Length: Variable
- o Algorithm (1 octet): value from 1 to 255.

The IP Algorithm TLV is optional. It SHOULD only be advertised once in the Router Information Opaque LSA.

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

The IP Algorithm TLV advertises the participation in Flex-Algorithms, and MUST NOT impact the router participation in default algorithm 0. The IP Algorithm TLV could be used to advertise support for non-zero standard algorithms, but that is outside the scope of this document.

The IP Flex-Algorithm participation advertised in OSPF IP Algorithm TLV is topology independent. When a router advertises participation in OSPF IP Algorithm TLV, the participation applies to all topologies in which the advertising node participates.

6. Advertising IP Flex-Algorthm Reachability

To be able to associate the prefix with the Flex-Algorithm, the existing prefix reachability advertisements can not be used, because they advertise the prefix reachability in default algorithm 0. Instead, a new IP Flex-Algorithm reachability advertisements are defined in ISIS and OSPF.

Two new top-level TLVs are defined in ISIS [ISO10589] to advertise prefix reachability associated with a Flex-Algorithm.

o The IPv4 Algorithm Prefix Reachability TLV

o The IPv6 Algorithm Prefix Reachability TLV

New top-level TLV of OSPFv2 Extended Prefix Opaque LSA [RFC7684] is defined to advertise prefix reachability associated with a Flex-Algorithm in OSPFv2.

6.1. The ISIS IPv4 Algorithm Prefix Reachability TLV

A new top level TLV is defined for advertising IPv4 Flex-Algorithm Prefix Reachability in ISIS - IPv4 Algorithm Prefix Reachability TLV.

This new TLV shares the sub-TLV space defined for TLVs 135, 235, 236 and 237.

The ISIS IPv4 Algorithm Prefix Reachability 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     |R|R|R|R|    MTID             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

ISIS IPv4 Algorithm Prefix Reachability TLV o Type: IPv4 Algorithm Prefix Reachability TLV (Value TBD by IANA).

o Length: variable.

o R bits (4 bits): reserved for future use. They MUST be set to zero on transmission and MUST be ignored on receipt.

o MTID (12 bits): Multitopology Identifier as defined in [RFC5120]. Note that the value 0 is legal.

Followed by one or more prefix entries of the form:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            Metric                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Flags       |  Algorithm    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Pfx Length   |  Prefix (variable)...
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Sub-tlv-len  |         Sub-TLVs (variable) . . .             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

ISIS IPv4 Algorithm Prefix Reachability TLV

o Metric (4 octets): Metric information.

o Flags (1 octet):

```
 0 1 2 3 4 5 6 7
+-+-+-+-+-+-+-+-+
|D|S|           |
+-+-+-+-+-+-+-+-+
```

D-flag: When the Prefix is leaked from level-2 to level-1, the D bit MUST be set. Otherwise, this bit MUST be clear. Prefixes with the D bit set MUST NOT be leaked from level-1 to level-2. This is to prevent looping.

S-flag: Set when Sub-TLVs are present for the prefix entry.

- o Algorithm (1 octet): Associated Algorithm from 1 to 255.

- o Prefix Len (1 octet): Prefix length measured in bits.

- o Prefix (variable length): Prefix mapped to Flex-Algorithm.

- o Optional Sub-TLV-length (1 octet): Number of octets used by sub-TLVs

- o Optional sub-TLVs (variable length).

A router receiving multiple IPv4 Algorithm Prefix Reachability advertisements for the same prefix, from the same originator, each with a different Algorithm, MUST select the first advertisement in the lowest-numbered LSP and ignore any subsequent IPv4 Algorithm Prefix Reachability advertisements for the same prefix for any other Algorithm.

A router receiving multiple IPv4 Algorithm Prefix Reachability advertisements for the same prefix, from different originators, each with a different Algorithm, MUST ignore all of them and MUST NOT install any forwarding entries based on these advertisements.

In cases where a prefix advertisement is received in both a IPv4 Prefix Reachability TLV and an IPv4 Algorithm Prefix Reachability TLV, the IPv4 Prefix Reachability advertisement MUST be preferred when installing entries in the forwarding plane.

6.2. The ISIS IPv6 Algorithm Prefix Reachability TLV

The ISIS IPv6 Algorithm Prefix Reachability TLV is identical to the ISIS IPv4 Algorithm Prefix Reachability TLV, except that it has a unique type. The type is TBD by IANA.

A router receiving multiple IPv6 Algorithm Prefix Reachability advertisements for the same prefix, from the same originator, each with a different Algorithm, MUST select the first advertisement in the lowest-numbered LSP and ignore any subsequent IPv6 Algorithm Prefix Reachability advertisements for the same prefix for any other Algorithm.

A router receiving multiple IPv6 Algorithm Prefix Reachability advertisements for the same prefix, from different originators, each with a different Algorithm, MUST ignore all of them and MUST NOT install any forwarding entries based on these advertisements.

In cases where a prefix advertisement is received in both a IPv6 Prefix Reachability TLV and an IPv6 Algorithm Prefix Reachability TLV, the IPv6 Prefix Reachability advertisement MUST be preferred when installing entries in the forwarding plane.

6.3. The OSPFv2 Algorithm Prefix Reachability TLV

A new top level TLV of OSPFv2 Extended Prefix Opaque LSA is defined for advertising IPv4 Algorithm Prefix Reachability in OSPFv2 - OSPF Algorithm Prefix Reachability TLV

Multiple Algorithm Prefix Reachability TLV MAY be advertised in each OSPFv2 Extended Prefix Opaque LSA. However, since the opaque LSA type defines the flooding scope, the LSA flooding scope MUST satisfy the application specific requirements for all the prefixes included in a single OSPFv2 Extended Prefix Opaque LSA. The Algorithm Prefix Reachability 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            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Route Type   | Prefix Length |     AF        |      Flags    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       MT-ID   |  Algorithm    |             Reserved          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Address Prefix (variable)                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Metric                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Sub-TLVs (variable)                      |
+-                                                             -+
|                                                               |
```

OSPFv2 Algorithm Prefix Reachability TLV

Type: Algorithm Prefix Reachability TLV (Value TBD by IANA).

Length: Variable dependent on sub-TLVs.

Route Type (1 octet): type of the OSPF route. Supported types are:

1 - Intra-Area

2 - Inter-Area

3 - AS External with Type-1 Metric

4 - AS External with Type-2 Metric

5 - NSSA External with Type-1 Metric

6 - NSSA External with Type-2 Metric

Prefix Length (1 octet): Length of prefix in bits.

AF (1 octet): Address family for the prefix. Currently, the only supported value is 0 for IPv4 unicast. The inclusion of address family in this TLV allows for future extension.

Flags (1 octet): Flags applicable to the prefix. Supported Flags include:

0x80 - A-Flag (Attach flag): An Area Border Router (ABR) generating an Extended Prefix TLV for inter-area prefix that is locally connected or attached in other connected area SHOULD set this flag.

0x40 - N-Flag (Node Flag): Set when the prefix identifies the advertising router i.e., the prefix is a host prefix advertising a globally reachable address typically associated with a loopback address. The advertising router MAY choose to not set this flag even when the above conditions are met. If the flag is set and the prefix length is not a host prefix then the flag MUST be ignored. The flag is preserved when the OSPFv2 Extended Prefix Opaque LSA is propagated between areas.

MT-ID (1 octet): Multi-Topology ID as defined in [RFC8402]

Algorithm: (1 octet). Associated Algorithm from 1 to 255.

Adress Prefix: For the address family IPv4 unicast, the prefix itself encoded as a 32-bit value. The default route is represented by a prefix of length 0. Prefix encoding for other address families is beyond the scope of this specification.

Metric (4 octets): Metric information.

If this TLV is advertised multiple times for the same prefix in the same OSPFv2 Extended Prefix Opaque LSA, only the first instance of the TLV is used by receiving OSPFv2 Routers. This situation SHOULD be logged as an error.

If this TLV is advertised multiple times for the same prefix in different OSPFv2 Extended Prefix Opaque LSAs originated by the same OSPF router, the OSPF advertising router is re-originating Extended Prefix Opaque LSAs for multiple prefixes and is most likely repacking Algorithm Prefix Reachability TLVs in Extended Prefix Opaque LSAs. In this case, the Algorithm Prefix Reachability TLV in the Extended Prefix Opaque LSA with the smallest Opaque ID is used by receiving OSPFv2 Routers. This situation may be logged as a warning.

It is RECOMMENDED that OSPF routers advertising Algorithm Prefix Reachability TLVs in different Extended Prefix Opaque LSAs re-originate these LSAs in ascending order of Opaque ID to minimize the disruption.

A router receiving multiple Algorithm Prefix Reachability TLVs for the same prefix, from different originators, each with a different Algorithm, MUST ignore all of them and MUST NOT install any forwarding entries based on these advertisements.

In cases where a prefix advertisement is received in any of the LSAs advertising the prefix reachability for algorithm 0 (Router-LSA, Summary-LSA, AS-external-LSA or NSSA AS-external LSA) and in an IPv4 Algorithm Prefix Reachability TLV, the prefix reachability advertisement for algorithm 0 MUST be preferred when installing entries in the forwarding plane, regardless of the Route Type advertised in IPv4 Algorithm Prefix Reachability TLV.

6.4. The OSPFv3 Flex-Algorithm IP Prefix Opaque LSA

TBD.

7. Calculating of IP Flex-Algorthm Paths

IP Flex-Algorthm is considered as yet another application of the Flex-Algorithm as described in Section 10 and Section 12 of the [I-D.ietf-lsr-flex-algo].

Participation for the IP Flex-Algorithm is signalled as described in Section 5 and is specific to the IP Flex-Algorithm application.

Calculation of IP Flex-Algorithm paths follows the Section 12 of [I-D.ietf-lsr-flex-algo]. This computation uses the IP Flex-Algorithm participation and is independent of the Flex-Algorithm calculation done for any other Flex-Algorithm applications (e.g. SR, SRv6).

IP Flex-Algorithm application only considers participating nodes during the Flex-Algorithm calculation. When computing paths for a

given Flex-Algorithm, all nodes that do not advertise participation for IP Flex-Algorithm, as described in Section 5, MUST be pruned from the topology.

8. IP Flex-Algorthm Forwarding

IP Algorithm Prefix Reachability advertisement as described in Section 5 includes the MTID value that associates the prefix with a specific topology. Algorithm Prefix Reachability advertisement also includes an Algorithm value that explicitly associates the prefix with a specific Flex-Algorithm. The paths to the prefix MUST be calculated using the specified Flex-Algorithm in the associated topology.

Forwarding entries for the IP Flex-Algorithm prefixes advertised in IGPs MUST be installed in the forwarding plane of the receiving IP Flex-Algorithm prefix capable routers when they participate in the associated topology and algorithm. Forwarding entries for IP Flex-Algorithm prefixes associated with Flex-Algorithms in which the node is not participating MUST NOT be installed in the forwarding plane.

When the IP Flex-Algorithm prefix is associated with a Flex-Algorithm, LFA paths to the 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.

9. Deployment Considerations

IGP Flex-Algorithm can be used by many applications. Original specification was done for SR and SRv6, this specification adds IP as another application that can use IGP Flex-Algorithm. Other applications may be defined in the future. This section provides some details about the coexistence of the various applications of the IGP Flex-Algorithm.

Flex-Algorithm definition (FAD), as described in [I-D.ietf-lsr-flex-algo], is application independent and is used by all Flex-Algorithm applications.

Participation in the Flex-Algorithm, as described in [I-D.ietf-lsr-flex-algo], is application specific.

Calculation of the flex-algo paths is application specific and uses application specific participation advertisements.

Application specific participation and calculation guarantee that the forwarding of the traffic over the Flex-Algorithm application

specific paths is consistent between all nodes over which the traffic is being forwarded.

Multiple application can use the same Flex-Algorithm value at the same time and and as such share the FAD for it. For example SR-MPLS and IP can both use such common Flex-Algorithm. Traffic for SR-MPLS will be forwarded based on Flex-algorithm specific SR SIDs. Traffic for IP Flex-Algorithm will be forwarded based on Flex-Algorithm specific prefix reachability announcements.

10. IANA Considerations

This specification updates the OSPF Router Information (RI) TLVs Registry as follows:

Value	TLV Name	Reference

TBD	IP Algorithm TLV	This Document Section 5.2

This document also updates the "Sub-TLVs for TLV 242" registry as follows:

Value	TLV Name	Reference
TBD	IP Algorithm Sub-TLV	This Document Section 5.1

This document also updates the "ISIS TLV Codepoints Registry" registry as follows:

Value	TLV Name	Reference
TBD	IPv4 Algorithm Prefix Reachability TLV	This document, Section 6.1
TBD	IPv6 Algorithm Prefix Reachability TLV	This document, Section 6.2
TBD		

This document updates the "OSPFv2 Extended Prefix Opaque LSA TLVs" registry as follows::

Value	TLV Name	Reference
TBD	OSPFv2 Algorithm Prefix Reachability TLV	This Document, Section 6.1

11. Security Considerations

TBD

12. Acknowledgements

TBD.

13. References

13.1. Normative References

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