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IGP Unreachable Prefix Announcement
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Abstract

Summarization is often used in multi-area or multi-domain networks to improve network efficiency and scalability. With summarization in place, there is a need to signal loss of reachability to an individual prefix covered by the summary. This enables fast convergence by steering traffic away from the node which owns the prefix and is no longer reachable.

This document describes how to use the existing protocol mechanisms in IS-IS and OSPF, together with the two new flags, to advertise such prefix reachability loss.

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.

Status of This Memo

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

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1. Introduction

Link-state IGP protocols like IS-IS [ISO10589], OSPF [RFC2328], and OSPFv3 [RFC5340] are primarily used to distribute routing information between routers belonging to a single Autonomous System (AS) and to calculate the reachability for IPv4 or IPv6 prefixes advertised by the individual nodes inside the AS. Each node advertises the state of its local adjacencies, connected prefixes, capabilities, etc. The collection of these states from all the routers inside the area form a link-state database (LSDB) that describes the topology of the area and holds additional state information about the prefixes, router capabilities, etc.

The growth of networks running a link-state routing protocol results in the addition of more state which leads to scalability and convergence challenges. The organization of networks into levels/areas and IGP domains helps limit the scope of link-state information within certain boundaries. However, the state related to prefix reachability often requires propagation across a multi-area/level and/or multi-domain IGP network. Techniques such as summarization have been used traditionally to address the scale challenges associated with advertising prefix state outside of the local area/domain. However, this results in suppression of the individual prefix state that is useful for triggering fast-convergence mechanisms outside of the IGPs - e.g., BGP PIC Edge [I-D.ietf-rtgwg-bgp-pic].

Similarly, when an egress router needs to be taken out of service for maintenance, the traffic is drained from the node before taking it down. This is typically achieved by setting OVERLOAD bit together with using high metric for all prefixes advertised by the node in IS-IS, or by setting high metric on all-links and prefixes advertised by the node in OSPF. When prefixes from such node are summarized by the Area Border Router (ABR) or Autonomous System Boundary Router (ASBR), nodes outside of the area or domain are unaware of these summarized prefixes becoming unreachable. This document proposes protocol extensions to carry information about such prefixes in a backward compatible manner.

This document does not define how to advertise prefix that is not reachable for routing. That has been defined for IS-IS in [RFC5305] and [RFC5308], for OSPF in [RFC2328], and for OSPFv3 in [RFC5340].

This document defines a method to signal a specific reason for which the prefix with unreachable metric was advertised. This is done to distinguish it from any other possible cases, where such advertisement may be used.

IGP protocols typically only advertise the reachability of the prefix. Prefix that was previously advertised as reachable is made unreachable just by withdrawing the previous advertisement of the prefix. In our use case, we want to signal unreachability for a prefix for which the reachability was not explicitly signaled previously, because it was covered by the reachability of the summary address.

This document defines two new flags in IS-IS, OSPF, and OSPFv3. These flags, together with the existing protocol mechanisms, provide the support for advertising prefix unreachability, together with the reason for which the unreachability is advertised. The functionality being described is called Unreachable Prefix Announcement (UPA).

This document also defines how the UPA is propagated across ISIS levels and OSPF areas.

2. Generation of the UPA

UPA MAY be generated by the ABR or ASBR for a prefix that is summarized by the summary address originated by the ABR or ASBR in the following cases:

1. Reachability of a prefix that was reachable earlier was lost.

2. For any of the planned maintenance cases:

   - if the node originating the prefix is signalling the overload state in ISIS.

   - the metric to reach the prefix from the ABR or ASBR crosses the configured threshold.

Implementations MAY limit the UPA generation to specific prefixes, e.g. host prefixes, SRv6 locators, or similar. Such filtering is optional and MAY be controlled via configuration.

The intent of UPA is to provide an event driven signal of the transition of a destination from reachable to unreachable. It is not intended to advertise a persistent state. UPA advertisements SHOULD therefore be withdrawn after some amount of time, that would provides sufficient time for UPA to be flooded network-wide and acted upon by receiving nodes, but limits the presence of UPA in the network. The time the UPA is kept in the network SHOULD also reflect the intended use-case for which the UPA was advertised.

Implementation MAY provide a configuration option to specify the UPA lifetime at the originating ABR or ASBR.

ABR or ASBR MUST withdraw the previously advertised UPA when the reason for which the UPA was generated ceases - e.g. prefix reachability was restored or its metric has changed such that it is below the configured threshold value.

As UPA advertisements in IS-IS are advertised in existing Link State PDUs (LSPs) and the unit of flooding in IS-IS is an LSP, it is RECOMMENDED that, when possible, UPAs are advertised in LSPs dedicated to this type of advertisement. This will minimize the number of LSPs which need to be updated when UPAs are advertised and withdrawn.

In OSPF and OSPFv3, each inter-area and external prefix is advertised in it’s own LSA, so the above optimisation does not apply to OSPF.

It is also RECOMMENDED that implementations limit the number of UPA advertisements which can be originated at a given time.

3. Supporting UPA in IS-IS

[RFC5305] defines the encoding for advertising IPv4 prefixes using 4 octets of metric information. Section 4 specifies:

"If a prefix is advertised with a metric larger then MAX_PATH_METRIC (0xFE000000, see paragraph 3.0), this prefix MUST NOT be considered during the normal SPF computation. This allows advertisement of a prefix for purposes other than building the normal IP routing table."

Similarly, [RFC5308] defines the encoding for advertising IPv6 prefixes using 4 octets of metric information. Section 2 states:

"...if a prefix is advertised with a metric larger than MAX_V6_PATH_METRIC (0xFE000000), this prefix MUST NOT be considered during the normal Shortest Path First (SPF) computation. This will allow advertisement of a prefix for purposes other than building the normal IPv6 routing table."

This functionality can be used to advertise a prefix (IPv4 or IPv6) in a manner which indicates that reachability has been lost - and to do so without requiring all nodes in the network to be upgraded to support the functionality.

3.1. Advertisement of UPA in IS-IS

Existing nodes in a network that do not suport UPA will not use UPAs during the route calculation, but will continue to flood them. This allows flooding of such advertisements to occur without the need to upgrade all nodes in a network.

Recognition of the advertisement as UPA is only required on routers which have a valid use case for this information. Those ABRs or ASBRs, which are responsible for propagating UPA advertisements into other areas or domains MUST also recognize UPA advertisements.

As per the definitions referenced in the preceding section, any prefix advertisement with a metric value greater than 0xFE000000 can be used for purposes other than normal routing calculations. Such metric MUST be used when advertising UPA in IS-IS.

UPA in IS-IS is supported for all IS-IS Sub-TLVs registered in the IS-IS Sub-TLVs Advertising Prefix Reachability registry, which was initially defined in [RFC7370], e.g.,:

- SRv6 Locator [RFC9352]
- Extended IP reachability [RFC5305]
- MT IP Reach [RFC5120]
- IPv6 IP Reach [RFC5308]
- MT IPv6 IP Reach [RFC5120]
- IPv4 Algorithm Prefix Reachability TLV [RFC9502]
- IPv6 Algorithm Prefix Reachability TLV [RFC9502]

3.2. Propagation of UPA in IS-IS

IS-IS allows propagation of IP prefixes in both directions between level 1 and level 2. Propagation is only done if the prefix is reachable in the source level, e.g., prefix is only propagated from a level in which the prefix is reachable. Such requirement of reachability MUST NOT be applied for UPAs, as they are propagating unreachability.

IS-IS L1/L2 routers may wish to advertise received UPAs into other areas (upwards and/or downwards). When propagating UPAs the original metric value MUST be preserved. The cost to reach the originator of the received UPA MUST NOT be considered when readvertising the UPA.

4. Supporting UPA in OSPF

[RFC2328] Appendix B defines the following architectural constant for OSPF:

"LSInfinity The metric value indicating that the destination described by an LSA is unreachable. Used in summary-LSAs and AS-external-LSAs as an alternative to premature aging (see Section 14.1). It is defined to be the 24-bit binary value of all ones: 0xffffff."

[RFC5340] Appendix B states:

"Architectural constants for the OSPF protocol are defined in Appendix B of OSPFV2."

indicating that these same constants are applicable to OSPFv3.

[RFC2328] section 14.1. also describes the usage of LSInfinity as a way to indicate loss of prefix reachability:

"Premature aging can also be used when, for example, one of the router's previously advertised external routes is no longer reachable. In this circumstance, the router can flush its AS-external-LSA from the routing domain via premature aging. This procedure is preferable to the alternative, which is to originate a new LSA for the destination specifying a metric of LSInfinity."

In addition, NU-bit is defined for OSPFv3 [RFC5340]. Prefixes having the NU-bit set in their PrefixOptions field SHOULD NOT be included in the routing calculation.

UPA in OSPFv2 is supported for OSPFv2 Summary-LSA [RFC2328], AS-external-LSAs [RFC2328], NSSA AS-external LSA [RFC3101], and OSPFv2 IP Algorithm Prefix Reachability Sub-TLV [RFC9502].

UPA in OSPFv3 is supported for Inter-Area-Prefix-LSA [RFC5340], AS-External-LSA [RFC5340], NSSA-LSA [RFC5340], E-Inter-Area-Prefix-LSA [RFC8362], E-AS-External-LSA [RFC8362], E-Type-7-LSA [RFC8362], and SRv6 Locator LSA [RFC9513].

4.1. Advertisement of UPA in OSPF

If an ABR or ASBR advertises UPA in an advertisement of an inter-area or external prefix inside OSPFv2 or OSPFv3 then it MUST set the age to a value lower than MaxAge and set the metric to LSInfinity.

UPA flooding inside the area follows the existing standard procedures defined by OSPF [RFC2328] and OSPFv3 [RFC5340].

4.2. Propagation of UPA in OSPF

OSPF ABRs or ASBRs, which would be responsible for propagating UPA advertisements into other areas MUST recognize such advertisements.

Advertising prefix reachability between OSPF areas assumes prefix reachability in a source area. Such requirement of reachability MUST NOT be applied for UPAs, as they are propagating unreachability.

OSPF ABRs or ASBRs MAY advertise received UPAs between connected areas or domains. When doing so, the original LSInfinity metric value in UPA MUST be preserved. The cost to reach the originator of the received UPA MUST NOT be considered when readvertising the UPA to connected areas.

5. Signaling UPA

In IS-IS a prefix can be advertised with metric higher than 0xFE000000, in OSPF with metric LSInfinity, or in OSPFv3 with NU-bit set in PrefixOptions, for various reasons. Even though in all cases the treatment of such metric, or NU-bit, is specified for IS-IS, OSPF and OSPFv3, having an explicit way to signal that the prefix was advertised in order to signal unreachability is required to distinguish it from other cases where the prefix with such metric is advertised.

5.1. Signaling UPA in IS-IS

Two new bits in the IPv4/IPv6 Extended Reachability Attribute Flags [RFC7794] are defined:

U-Flag: - Unreachable Prefix Flag (Bit 5). When set, it indicates that the prefix is unreachable.

UP-Flag: - Unreachable Planned Prefix Flag (Bit 6). When set, this flag indicates that the prefix is unreachable due to a planned event (e.g., planned maintenance).

Originating node MUST NOT set the UP-flag without setting the U-fag.

Receiving node MUST ignore the UP-flag in the advertisement if the U-flag is not set.

The prefix that is advertised with U-Flag or UP-Flag MUST have the metric set to a value larger than 0xFE000000. If the prefix metric is less than or equal 0xFE000000, both of these flags MUST be ignored.

5.2. Signaling UPA in OSPF

A new Prefix Attributes Sub-TLV has been defined in [I-D.ietf-lsr-ospf-prefix-extended-flags] for advertising additional prefix attribute flags in OSPFv2 and OSPFv3.

Two new bits in Prefix Attributes Sub-TLV are defined:

U-Flag: - Unreachable Prefix Flag (Bit 0). When set, it indicates that the prefix is unreachable.

UP-Flag: - Unreachable Planned Prefix Flag (Bit 1). When set, this flag indicates that the prefix is unreachable due to a planned event (e.g., planned maintenance).

Originating node MUST NOT set the UP-flag without setting the U-fag.

Receiving node MUST ignore the UP-flag in the advertisement if the U-flag is not set.

5.2.1. Signaling UPA in OSPFv2

In OSPFv2 the Prefix Attributes Sub-TLV is a Sub-TLV of the OSPFv2 Extended Prefix TLV [RFC7684].

The prefix that is advertised with U-Flag or UP-Flag MUST have the metric set to a value LSInfinity. If the prefix metric is not equal to LSInfinity, both of these flags MUST be ignored. For default algorithm 0 prefixes with U-Flag or UP-Flag, it is therefore REQUIRED to advertise the unreachable prefix in the base OSPFv2 LSA - e.g., OSPFv2 Summary-LSA [RFC2328], or AS-external-LSAs [RFC2328], or NSSA AS-external LSA [RFC3101].

5.2.2. Signaling UPA in OSPFv3

In OSPFv3 the Prefix Attribute Flags Sub-TLV is defined as a Sub-TLV of the following OSPFv3 TLVs that are defined in [RFC8362]:

Intra-Area Prefix TLV

Inter-Area Prefix TLV

External Prefix TLV

The prefix that is advertised with U-Flag or UP-flag MUST have the metric set to a value LSInfinity. For default algorithm 0 prefixes, the LSInfinity MUST be set in the parent TLV. For IP Algorithm

Prefixes [RFC9502], the LSInfinity MUST be set in OSPFv3 IP Algorithm Prefix Reachability sub-TLV. If the prefix metric is not equal to LSInfinity, both of these flags MUST be ignored.

The prefix that is advertised with U-Flag or UP-Flag MUST have the NU-bit set in the PrefixOptions of the parent TLV. If the NU-bit in PrefixOptions of the parent TLV is not set, both of these flags MUST be ignored.

6. Area and Domain Partition

UPA is not meant to address an area/domain partition. When an area or domain partitions, while multiple ABRs or ASBRs advertise the same summary, each of them can only reach portion of the summarized prefix. As a result, depending on which ABR or ASBR the traffic is using to enter a partitioned area, the traffic could be dropped or be delivered to its final destination. UPA does not make the problem of an area partition any worse. In case of an area partition each of the ABRs or ASBRs will generate UPAs for the destinations for which the reachability was lost locally. As the UPA propagates to the nodes outside of a partitioned area, it may result in such nodes picking an alternative egress node for the traffic, if such alternate egress node exists. If such alternate egress node resides outside of a partitioned area, traffic will be restored. If such alternate egress node resides in a partitioned area and is covered by the summary, the trafic will be dropped if it enters a partitioned area via the ABR or ASBR that can not reach the alternate egress node - resulting in similar behavior as without the UPA. Above is similarly applicable to a domain partition.

7. Processing of the UPA

The setting of the U-Flag signals that the prefix is unreachable. If the U flag is set, the setting of the UP flag signals that the unreachability is due to a planned event.

Processing of the received UPAs is optional and SHOULD be controlled by the configuration at the receiver. The receiver itself, based on its configuration, decides what the UPA will be used for and what applications, if any, will be notified when UPA is received. Usage of the UPA at the receiver is outside of the scope of this document

As an example, UPA may be used to trigger BGP PIC Edge at the receiving router [I-D.ietf-rtgwg-bgp-pic].

8. IANA Considerations

8.1. IS-IS Prefix Attribute Flags Sub-TLV

This document adds two new bits in the "IS-IS Bit Values for Prefix Attribute Flags Sub-TLV" registry:

Bit #: 5

Description: U-Flag

Reference: This document (Section 5.1).

Bit #: 6

Description: UP-Flag

Reference: This document (Section 5.1).

8.2. OSPFv2 and OSPFv3 OSPFv2 Prefix Extended Flags

This document adds two new bits in the "OSPFv2 Prefix Extended Flags" and "OSPFv3 Prefix Extended Flags" registres:

Bit #: 0

Description: U-Flag

Reference: This document (Section 5.2).

Bit #: 1

Description: UP-Flag

Reference: This document (Section 5.2).

9. Security Considerations

The use of UPAs introduces the possibility that an attacker could inject a false, but apparently valid, UPA. However, the risk of this occurring is no greater than the risk today of an attacker injecting any other type of false advertisement.

The risks can be reduced by the use of existing security extensions as described in:

- [RFC5304], [RFC5310], and [RFC7794] for IS-IS.

- [RFC2328], [RFC7474] and [RFC7684] for OSPFv2.

- [RFC5340], [RFC4552] and [RFC8362] for OSPFv3.

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