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Segment Routing Prefix SID extensions for BGP
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Abstract

Segment Routing (SR) leverages the source routing paradigm. A node steers a packet through an ordered list of instructions, called segments. A segment can represent any instruction, topological or service-based. The ingress node prepends an SR header to a packet containing a set of segment identifiers (SID). Each SID represents a topological or a service-based instruction. Per-flow state is maintained only on the ingress node of the SR domain. An SR domain is defined as a single administrative domain for global SID assignment.

This document defines an optional, transitive BGP attribute for announcing BGP Prefix Segment Identifiers (BGP Prefix-SID) information and the specification for SR-MPLS SIDs.

Requirements Language

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

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1. Introduction

The Segment Routing (SR) architecture leverages the source routing paradigm. A segment represents either a topological instruction such as "go to prefix P following shortest path" or a service instruction. Other types of segments may be defined in the future.

A segment is identified through a Segment Identifier (SID). An SR domain is defined as a single administrative domain for global SID assignment. It may be comprised of a single Autonomous System (AS) or multiple ASes under consolidated global SID administration. Typically, the ingress node of the SR domain prepends an SR header containing segments identifiers (SIDs) to an incoming packet.

As described in [I-D.ietf-spring-segment-routing], when SR is applied to the MPLS dataplane ([I-D.ietf-spring-segment-routing-mpls]), the SID consists of a label.

[I-D.ietf-spring-segment-routing] also describes how segment routing can be applied to an IPv6 dataplane (SRv6) using an IPv6 routing header containing a stack of SR SIDs encoded as IPv6 addresses [I-D.ietf-6man-segment-routing-header]. The applicability and support for Segment Routing over IPv6 is beyond the scope of this document.

A BGP-Prefix Segment is a BGP prefix with a Prefix-SID attached. A BGP Prefix-SID is always a global SID ([I-D.ietf-spring-segment-routing]) within the SR domain and identifies an instruction to forward the packet over the Equal-Cost Multi-Path (ECMP) best-path computed by BGP to the related prefix. The BGP Prefix-SID is the identifier of the BGP prefix segment. In this document, we always refer to the BGP-Prefix segment by the BGP Prefix-SID.

This document describes the BGP extension to signal the BGP Prefix-SID. Specifically, this document defines a BGP attribute known as the BGP Prefix-SID attribute and specifies the rules to originate, receive, and handle error conditions for the attribute.

The BGP Prefix-SID attribute defined in this document can be attached to prefixes from Multiprotocol BGP IPv4/IPv6 Labeled Unicast ([RFC4760], [RFC8277]). Usage of the BGP Prefix-SID attribute for other Address Family Identifier (AFI)/ Subsequent Address Family Identifier (SAFI) combinations is not defined herein but may be specified in future specifications.

[I-D.ietf-spring-segment-routing-msdc] describes example use cases where the BGP Prefix-SID is used for the above AFI/SAFI combinations.

It should be noted that:

- o A BGP Prefix-SID will be global across ASes when the interconnected ASes are part of the same SR domain. Alternatively, when interconnecting ASes, the ASBRs of each domain will have to handle the advertisement of unique SIDs. The mechanisms for such interconnection are outside the scope of the protocol extensions defined in this document.

- o A BGP Prefix-SID MAY be attached to a BGP prefix. This implies that each prefix is advertised individually, reducing the ability to pack BGP advertisements (when sharing common attributes).

2. MPLS BGP Prefix SID

The BGP Prefix-SID is realized on the MPLS dataplane ([I-D.ietf-spring-segment-routing-mpls]) in the following way:

The operator assigns a globally unique label index, L_I, to a locally originated prefix of a BGP speaker N which is advertised to all other BGP speakers in the SR domain.

According to [I-D.ietf-spring-segment-routing], each BGP speaker is configured with a label block called the Segment Routing Global Block (SRGB). While [I-D.ietf-spring-segment-routing] recommends using the same SRGB across all the nodes within the SR domain, the SRGB of a node is a local property and could be different on different speakers. The drawbacks of the use case where BGP speakers have different SRGBs are documented in [I-D.ietf-spring-segment-routing] and [I-D.ietf-spring-segment-routing-msdc].

If traffic-engineering within the SR domain is required, each node may also be required to advertise topological information and Peering SIDs for each of its links and peers. This information is required to perform the explicit path computation and to express an explicit path as a list of SIDs. The advertisement of topological information and peer segments (Peer SIDs) is done through [I-D.ietf-idr-bgpls-segment-routing-epe].

If a prefix segment is to be included in an MPLS label stack, e.g., for traffic engineering purposes, the knowledge of the SRGB of the originator of the prefix is required in order to compute the local label used by the originator.

This document assumes that BGP-LS is the preferred method for collecting both peer segments (Peer SIDs) and SRGB information through [RFC7752], [I-D.ietf-idr-bgpls-segment-routing-epe], and

[I-D.ietf-idr-bgp-ls-segment-routing-ext]. However, as an optional alternative for the advertisement of the local SRGB without the topology nor the peer SIDs, hence without applicability for TE, the Originator SRGB TLV of the BGP Prefix-SID attribute is specified in Section 3.2 of this document.

A BGP speaker will derive its local MPLS label L from the label index L_I and its local SRGB as described in [I-D.ietf-spring-segment-routing-mpls]. The BGP speaker then programs the MPLS label L in its MPLS dataplane as its incoming/local label for the prefix. See Section 4.1 for more details.

The outgoing label for the prefix is found in the Network Layer Reachability Information (NLRI) of the Multiprotocol BGP IPv4/IPv6 Labeled Unicast prefix advertisement as defined in [RFC8277]. The label index L_I is only used as a hint to derive the local/incoming label.

Section 3.1 of this document specifies the Label-Index TLV of the BGP Prefix-SID attribute; this TLV can be used to advertise the label index for a given prefix.

3. BGP Prefix-SID Attribute

The BGP Prefix-SID attribute is an optional, transitive BGP path attribute. The attribute type code 40 has been assigned by IANA (see Section 7).

The BGP Prefix-SID attribute is defined here to be a set of elements encoded as "Type/Length/Value" tuples (i.e., a set of TLVs). All BGP Prefix-SID attribute TLVs will start with a 1-octet type and a 2-octet length. The following TLVs are defined in this document:

o Label-Index TLV

o Originator SRGB TLV

The Label-Index and Originator SRGB TLVs are used only when SR is applied to the MPLS dataplane.

For future extensibility, unknown TLVs MUST be ignored and propagated unmodified.

3.1. Label-Index TLV

The Label-Index TLV MUST be present in the BGP Prefix-SID attribute attached to IPv4/IPv6 Labeled Unicast prefixes ([RFC8277]). It MUST

be ignored when received for other BGP AFI/SAFI combinations. The Label-Index 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            |   RESERVED    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            Flags              |       Label Index             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Label Index          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

where:

- o Type is 1.
- o Length: is 7, the total length in octets of the value portion of the TLV.
- o RESERVED: 8-bit field. MUST be clear on transmission and MUST be ignored on reception.
- o Flags: 16 bits of flags. None are defined by this document. The flag field MUST be clear on transmission and MUST be ignored on reception.
- o Label Index: 32-bit value representing the index value in the SRGB space.

3.2. Originator SRGB TLV

The Originator SRGB TLV is an optional TLV 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               |    Flags      |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |     Flags     |
 +-+-+-+-+-+-+-+-+

 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |         SRGB 1 (6 octets)                                     |
 |                               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |         SRGB n (6 octets)                                     |
 |                               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

where:

- o Type is 3.

- o Length is the total length in octets of the value portion of the TLV: 2 + (non-zero multiple of 6).

- o Flags: 16 bits of flags. None are defined in this document. Flags MUST be clear on transmission and MUST be ignored on reception.

- o SRGB: 3 octets specifying the first label in the range followed by 3 octets specifying the number of labels in the range. Note that the SRGB field MAY appear multiple times. If the SRGB field appears multiple times, the SRGB consists of multiple ranges that are concatenated.

The Originator SRGB TLV contains the SRGB of the node originating the prefix to which the BGP Prefix-SID is attached. The Originator SRGB TLV MUST NOT be changed during the propagation of the BGP update. It is used to build segment routing policies when different SRGBs are used in the fabric, for example ([I-D.ietf-spring-segment-routing-msdc]).

Examples of how the receiving routers concatenate the ranges and build their neighbor's Segment Routing Global Block (SRGB) are included in [I-D.ietf-spring-segment-routing-mpls]).

The Originator SRGB TLV may only appear in a BGP Prefix-SID attribute attached to IPv4/IPv6 Labeled Unicast prefixes ([RFC8277]). It MUST be ignored when received for other BGP AFI/SAFI combinations. Since the Label-Index TLV is required for IPv4/IPv6 prefix applicability, the Originator SRGB TLV will be ignored if it is not specified consistent with Section 6.

If a BGP speaker receives a node's SRGB as an attribute of the BGP-LS Node NLRI and the BGP speaker also receives the same node's SRGB in a BGP Prefix-SID attribute, then the received values should be the same. If the values are different, the values advertised in the BGP-LS NLRI SHOULD be preferred and an error should be logged.

4. Receiving BGP Prefix-SID Attribute

A BGP speaker receiving a BGP Prefix-SID attribute from an External BGP (EBGP) neighbor residing outside the boundaries of the SR domain MUST discard the attribute unless it is configured to accept the attribute from the EBGP neighbor. A BGP speaker SHOULD log an error for further analysis when discarding an attribute.

4.1. MPLS Dataplane: Labeled Unicast

A BGP session supporting the Multiprotocol BGP labeled IPv4 or IPv6 Unicast ([RFC8277]) AFI/SAFI is required.

When the BGP Prefix-SID attribute is attached to a BGP labeled IPv4 or IPv6 Unicast [RFC8277] AFI/SAFI, it MUST contain the Label-Index TLV and MAY contain the Originator SRGB TLV. A BGP Prefix-SID attribute received without a Label-Index TLV MUST be considered as "invalid" by the receiving speaker.

The label index provides guidance to the receiving BGP speaker as to the incoming label that SHOULD be allocated to the prefix.

A BGP speaker may be locally configured with an SRGB=[SRGB_Start, SRGB_End]. The preferred method for deriving the SRGB is a matter of local node configuration.

The mechanisms through which a given label index value is assigned to a given prefix are outside the scope of this document.

Given a label index L_I, we refer to (L = L_I + SRGB_Start) as the derived label. A BGP Prefix-SID attribute is designated "conflicting" for a speaker M if the derived label value L lies outside the SRGB configured on M. Otherwise the Label-Index TLV is designated "acceptable" to speaker M.

If multiple different prefixes are received with the same label index, all of the different prefixes MUST have their BGP Prefix-SID attribute considered as "conflicting".

If multiple valid paths for the same prefix are received from multiple BGP speakers or, in the case of [RFC7911], from the same BGP speaker, and the BGP Prefix-SID attributes do not contain the same label index, then the label index from the best path BGP Prefix-SID attribute SHOULD be chosen with a notable exception being when [RFC5004] is being used to dampen route changes.

When a BGP speaker receives a path from a neighbor with an "acceptable" BGP Prefix-SID attribute and that path is selected as the best path, it SHOULD program the derived label as the label for the prefix in its local MPLS dataplane.

When a BGP speaker receives a path from a neighbor with an "invalid" or "conflicting" BGP Prefix-SID attribute or when a BGP speaker receives a path from a neighbor with a BGP Prefix-SID attribute but is unable to process it (e.g., local policy disables the functionality), it MUST ignore the BGP Prefix-SID attribute. For the purposes of label allocation, a BGP speaker MUST assign a local (also called dynamic) label (non-SRGB) for such a prefix as per classic Multiprotocol BGP IPv4/IPv6 Labeled Unicast ([RFC8277]) operation.

In the case of an "invalid" BGP Prefix-SID attribute, a BGP speaker MUST follow the error handling rules specified in Section 6. A BGP speaker SHOULD log an error for further analysis. In the case of a "conflicting" BGP Prefix-SID attribute, a BGP speaker SHOULD NOT treat it as error and SHOULD propagate the attribute unchanged. A BGP Speaker SHOULD log a warning for further analysis, i.e., in the case the conflict is not due to a label index transition.

When a BGP Prefix-SID attribute changes and transitions from "conflicting" to "acceptable", the BGP Prefix-SID attributes for other prefixes may also transition to "acceptable" as well. Implementations SHOULD assure all impacted prefixes revert to using the label indices corresponding to these newly "acceptable" BGP Prefix-SID attributes.

The outgoing label is always programmed as per classic Multiprotocol BGP IPv4/IPv6 Labeled Unicast ([RFC8277]) operation. Specifically, a BGP speaker receiving a prefix with a BGP Prefix-SID attribute and a label NLRI field of Implicit NULL [RFC3032] from a neighbor MUST adhere to standard behavior and program its MPLS dataplane to pop the top label when forwarding traffic to the prefix. The label NLRI defines the outbound label that MUST be used by the receiving node.

5. Advertising BGP Prefix-SID Attribute

The BGP Prefix-SID attribute MAY be attached to BGP IPv4/IPv6 Label Unicast prefixes [RFC8277]. In order to prevent distribution of the BGP Prefix-SID attribute beyond its intended scope of applicability, attribute filtering SHOULD be deployed to remove the BGP Prefix-SID attribute at the administrative boundary of the segment routing domain.

A BGP speaker that advertises a path received from one of its neighbors SHOULD advertise the BGP Prefix-SID received with the path without modification, as long as the BGP Prefix-SID was acceptable. If the path did not come with a BGP Prefix-SID attribute, the speaker MAY attach a BGP Prefix-SID to the path if configured to do so. The content of the TLVs present in the BGP Prefix-SID is determined by the configuration.

5.1. MPLS Dataplane: Labeled Unicast

A BGP speaker that originates a prefix attaches the BGP Prefix-SID attribute when it advertises the prefix to its neighbors via Multiprotocol BGP IPv4/IPv6 Labeled Unicast ([RFC8277]). The value of the label index in the Label-Index TLV is determined by configuration.

A BGP speaker that originates a BGP Prefix-SID attribute MAY optionally announce the Originator SRGB TLV along with the mandatory Label-Index TLV. The content of the Originator SRGB TLV is determined by configuration.

Since the label index value must be unique within an SR domain, by default an implementation SHOULD NOT advertise the BGP Prefix-SID attribute outside an Autonomous System unless it is explicitly configured to do so.

In all cases, the label field of the advertised NLRI ([RFC8277], [RFC4364]) MUST be set to the local/incoming label programmed in the MPLS dataplane for the given advertised prefix. If the prefix is associated with one of the BGP speaker's interfaces, this is the usual MPLS label (such as the Implicit or Explicit NULL label [RFC3032]).

6. Error Handling of BGP Prefix-SID Attribute

When a BGP Speaker receives a BGP Update message containing a malformed or invalid BGP Prefix-SID attribute attached to a IPv4/IPv6 Labeled Unicast prefix [RFC8277], it MUST ignore the received BGP Prefix-SID attributes and not advertise it to other BGP peers. In

this context, a malformed BGP Prefix-SID attribute is one that cannot be parsed due to not meeting the minimum attribute length requirement, contains a TLV length that doesn't conform to the length constraints for the TLV, or a contains TLV length that would extend beyond the end of the attribute (as defined by the attribute length). This is equivalent to the "Attribute discard" action specified in [RFC7606]. When discarding an attribute, a BGP speaker SHOULD log an error for further analysis.

As per with [RFC7606], if the BGP Prefix-SID attribute appears more than once in an UPDATE message, then all the occurrences of the attribute other than the first one SHALL be discarded and the UPDATE message will continue to be processed. Similarly, if a recognized TLV appears more than once in an BGP Prefix-SID attribute while the specification only allows for a single occurrence, then all the occurrences of the TLV other than the first one SHALL be discarded and the Prefix-SID attribute will continue to be processed.

For future extensibility, unknown TLVs MUST be ignored and propagated unmodified.

7. IANA Considerations

This document defines a BGP path attribute known as the BGP Prefix-SID attribute. This document requests IANA to assign an attribute code type (suggested value: 40) to the BGP Prefix-SID attribute from the BGP Path Attributes registry.

IANA temporarily assigned the following:

40 BGP Prefix-SID (TEMPORARY - registered 2015-09-30, expires 2018-09-30) [draft-ietf-idr-bgp-prefix-sid]

This document defines two TLVs for the BGP Prefix-SID attribute. These TLVs need to be registered with IANA. We request IANA to create a registry for BGP Prefix-SID Attribute TLVs as follows:

Under "Border Gateway Protocol (BGP) Parameters" registry, "BGP Prefix-SID TLV Types" Reference: draft-ietf-idr-bgp-prefix-sid
Registration Procedure(s): Values 1-254 - Expert Review as defined in [RFC8126], Value 0 and 255 reserved

Value	Type	Reference
0	Reserved	this document
1	Label-Index	this document
2	Deprecated	this document
3	Originator SRGB	this document
4-254	Unassigned	
255	Reserved	this document

The value 2 previously corresponded to the IPv6 SID TLV which was specified in previous versions of this document. It was removed and usage of the BGP Prefix-SID for Segment Routing over the IPv6 dataplane [I-D.ietf-spring-segment-routing] has been deferred to future specifications.

This document also requests creation of the "BGP Prefix-SID Label-Index TLV Flags" registry under the "Border Gateway Protocol (BGP) Parameters" registry, Reference: draft-ietf-idr-bgp-prefix-sid. Initially, this 16-bit flags registry will be empty. The registration policy for flag bits will Expert Review [RFC8126] consistent with the BGP Prefix-SID TLV Types registry.

Finally, this document requests creation of the "BGP Prefix-SID Originator SRGB TLV Flags" registry under the "Border Gateway Protocol (BGP) Parameters" registry, Reference: draft-ietf-idr-bgp-prefix-sid. Initially, this 16-bit flags registry will be empty. The registration policy for flag bits will Expert Review [RFC8126] consistent with the BGP Prefix-SID TLV Types registry.

The designated experts must be good and faithful stewards of the above registries, assuring that each request is legitimate and corresponds to a viable use case. Given the limited number of bits in the flags registries and the applicability to a single TLV, additional scrutiny should be afforded to flag bit allocation requests. In general, no single use case should require more than one flag bit and, should the use case require more, alternate encodings using new TLVs should be considered.

8. Manageability Considerations

This document defines a BGP attribute to address use cases such as the one described in [I-D.ietf-spring-segment-routing-msdc]. It is assumed that advertisement of the BGP Prefix-SID attribute is controlled by the operator in order to:

o Prevent undesired origination/advertisement of the BGP Prefix-SID attribute. By default, a BGP Prefix-SID attribute SHOULD NOT be attached to a prefix and advertised. Hence, BGP Prefix-SID advertisement SHOULD require explicit enablement.

o Prevent any undesired propagation of the BGP Prefix-SID attribute. By default, the BGP Prefix-SID is not advertised outside the boundary of a single SR/administrative domain which may include one or more ASes. The propagation to other ASes MUST be explicitly configured.

The deployment model described in [I-D.ietf-spring-segment-routing-msdc] assumes multiple Autonomous Systems (ASes) under a common administrative domain. For this use case, the BGP Prefix-SID advertisement is applicable to the inter-AS context, i.e., EBGP, while it is confined to a single administrative domain.

9. Security Considerations

This document introduces a BGP attribute (BGP Prefix-SID) which inherits the security considerations expressed in: [RFC4271], [RFC8277], and [I-D.ietf-spring-segment-routing].

When advertised using BGPsec as described in [RFC8205], the BGP Prefix-SID attribute doesn't impose any unique security considerations. It should be noted that the BGP Prefix-SID attribute is not protected by the BGPsec signatures.

It should be noted that, as described in Section 8, this document refers to a deployment model where all nodes are under the single administrative domain. In this context, we assume that the operator doesn't want to leak any information related to internal prefixes and topology outside of the administrative domain. The internal information includes the BGP Prefix-SID. In order to prevent such leaking, the common BGP mechanisms (filters) are applied at the boundary of the SR/administrative domain. Local BGP attribute filtering policies and mechanisms are not standardized and, consequently, beyond the scope of this document.

To prevent a Denial-of-Service (DoS) or Distributed-Denial-of-Service (DDoS) attack due to excessive BGP updates with an invalid or conflicting BGP Prefix-SID attribute, error log message rate-limiting as well as suppression of duplicate error log messages SHOULD be deployed.

Since BGP-LS is the preferred method for advertising SRGB information, the BGP speaker SHOULD log an error if a BGP Prefix-SID attribute is received with SRGB information different from that received as an attribute of the same node's BGP-LS Node NLRI.

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