IDR   S. Previdi, Ed.
Internet-Draft   C. Filsfils
Intended status: Standards Track   A. Lindem
Expires: April 20, 2018   A. Sreekantiah
                                                       Cisco Systems
                                                          H. Gredler
                                                         RtBrick Inc.
                                                    October 17, 2017

Segment Routing Prefix SID extensions for BGP
draft-ietf-idr-bgp-prefix-sid-07

Abstract

   Segment Routing (SR) architecture allows a node to steer a packet
   flow through any topological path and service chain by leveraging
   source routing. The ingress node prepends a 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 at the ingress node of the SR domain.

   This document defines a new optional, transitive BGP attribute for
   announcing BGP Prefix Segment Identifiers (BGP Prefix-SID)
   information.

Requirements Language

   The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
   "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this
   document are to be interpreted as described in RFC 2119 [RFC2119]
   only when they appear in all upper case. They may also appear in
   lower or mixed case as English words, without any normative meaning.

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 April 20, 2018.

Copyright Notice

Table of Contents

1. Introduction

   Segment Routing (SR) architecture leverages the source routing
   paradigm. A group of inter-connected nodes that use SR forms a SR
   domain. A segment represents either a topological instruction such
   as "go to prefix P following shortest path" or a service instruction
   (e.g.: "pass through deep packet inspection"). Other types of
   segments may be defined in the future.

   A segment is identified through a Segment Identifier (SID).
   Typically, the ingress node of the SR domain prepends a 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 while when SR is applied to the IPv6
   dataplane the SID consists of an IPv6 address.

   A BGP-Prefix Segment (and its BGP Prefix-SID), is a BGP segment
   attached to a BGP prefix. A BGP Prefix-SID is always a global SID
   ([I-D.ietf-spring-segment-routing]) within the SR/BGP domain (i.e.,
   the set of Autonomous Systems under a common administration and
   control and where SR is used) and identifies an instruction to
   forward the packet over the ECMP-aware 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 Segment
   by the BGP Prefix-SID.

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

   As described in [I-D.ietf-spring-segment-routing-msdc], the BGP
   Prefix-SID attribute defined in this document can be attached to
   prefixes from AFI/SAFI:

      Multiprotocol BGP labeled IPv4/IPv6 Unicast ([RFC3107]).

      Multiprotocol BGP ([RFC4760]) unlabeled IPv6 Unicast.

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

   It has to be noted that:

   o A BGP Prefix-SID MAY be global between domains when the
      interconnected domains agree on the SID allocation scheme.

Alternatively, when interconnecting domains, 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 As described in [I-D.ietf-spring-segment-routing-msdc], a BGP
   Prefix-SID MAY be attached to a prefix. In addition, each prefix
   will likely have a different as_path attribute. This implies that
   each prefix is advertised individually, reducing the ability to
   pack BGP advertisements (when sharing common attributes).

2. BGP-Prefix-SID

The BGP Prefix-SID attached to a BGP prefix P represents the
instruction "go to Prefix P" along its BGP bestpath (potentially
ECMP-enabled).

2.1. 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:

   As described in [I-D.ietf-spring-segment-routing-msdc] the
   operator assigns a globally unique "index", L_I, to a locally
   sourced 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
   to use 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 SID's for each of its links and peers. This information
   is required in order to perform the explicit path computation and
   to express any explicit path into a list of SIDs. The
   advertisement of topological information and Peer segments (Peer
   SIDs) is assumed to be done through
   [I-D.ietf-idr-bgpls-segment-routing-epe].

   If the BGP speakers are not all configured with the same SRGB, and
   if traffic-engineering within the SR domain is required, each node

        may be required to advertise its local SRGB in addition to the
        topological information.

        This documents assumes that BGP-LS is the preferred method for
        collecting both topological, 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 SID's, hence without
        applicability for TE, the Originator SRGB TLV of the prefix-SID
        attribute, is specified in Section 3.3 of this document.

        As defined in [I-D.ietf-spring-segment-routing-mpls], the index
        L_I is an offset in the SRGB. Each BGP speaker derives its local
        MPLS label, L, by adding L_I to the start value of its own SRGB,
        and programs L in its MPLS dataplane as its incoming/local label
        for the prefix. It has to be noted that while SRGBs and SIDs are
        advertised using 32 bit values, the derived label is to be
        considered as the 20 right-most bits. See Section 4.1 for more
        details.

        The outgoing label for the prefix is found in the NLRI of the
        Multiprotocol BGP labeled IPv4/IPv6 Unicast prefix advertisement.
        The 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 of a given prefix.

     In order to advertise the label index of a given prefix P and,
     optionally, the SRGB, a new extension to BGP is needed: the BGP
     Prefix-SID attribute. This extension is described in subsequent
     sections.

2.2. IPv6 Prefix Segment

     As illustrated in [I-D.ietf-spring-segment-routing-msdc], when SR is
     used over an IPv6 dataplane, the BGP Prefix-SID consists of an IPv6
     address assigned to the BGP speaker.

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" (i.e., a set of TLVs). The following
TLVs are defined:

o Label-Index TLV

o IPv6 SID TLV

o Originator SRGB TLV

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

IPv6 SID TLV is used only when SR is applied to the IPv6 dataplane.

3.1. Label-Index TLV

The Label-Index TLV MUST be present in the Prefix-SID attribute
attached to Labeled IPv4/IPv6 unicast prefixes ([RFC3107]) 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               |   RESERVED    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            Flags              |          Label Index          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Label Index           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
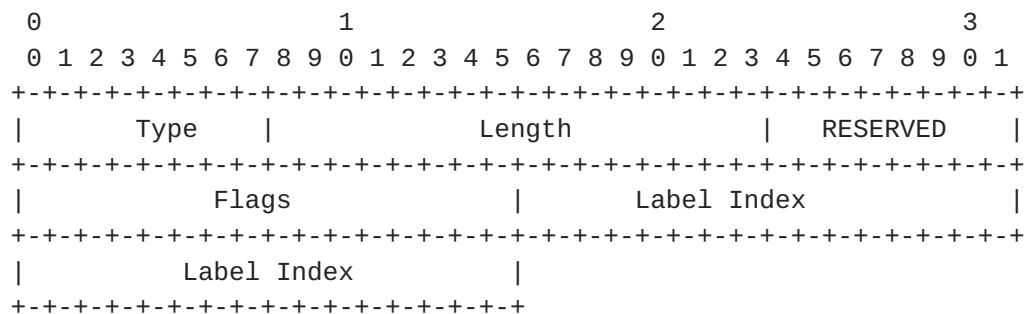
where:

o Type is 1.

o Length: is 7, the total length of the value portion of the TLV.

o RESERVED: 8 bit field. MUST be clear on transmission an MUST be
   ignored at reception..

o Flags: 16 bits of flags. None is defined by this document. The
   flag field MUST be clear on transmission and MUST be ignored at
   reception.

o Label Index: 32 bit value representing the index value in the SRGB
   space.

3.2. IPv6 SID

   The IPv6-SID TLV MAY be present in the Prefix-SID attribute attached
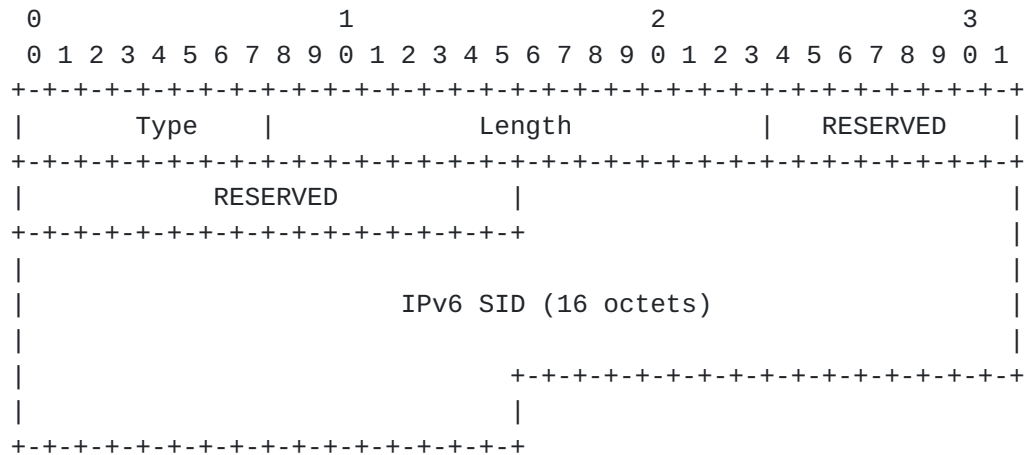   to MP-BGP unlabeled IPv6 unicast prefixes ([RFC4760]) and has the
   following format:

```
 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             |   RESERVED    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          RESERVED            |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               |
|                                                              |
|                     IPv6 SID (16 octets)                     |
|                                                              |
|                              +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
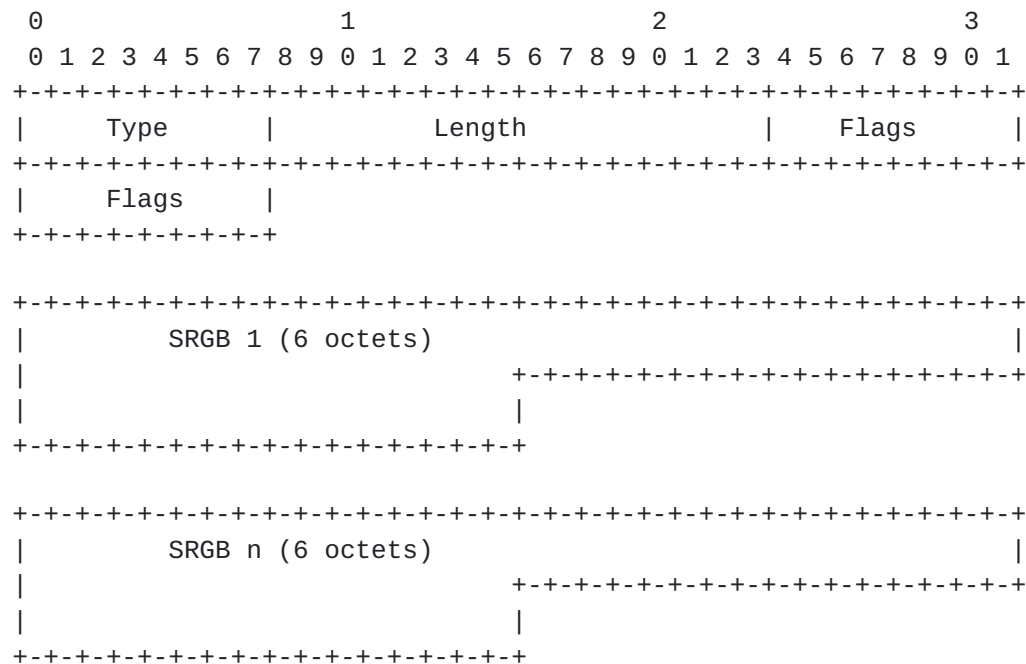
   where:

   o Type is 2.

   o Length: is 19, the total length of the value portion of the TLV.

   o RESERVED: 24 bit field for future use. MUST be clear on
      transmission an MUST be ignored at reception.

   o IPv6 SID: 16 octets.

3.3. 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 of the value portion of the TLV: 2 +
   multiple of 6.

o Flags: 16 bits of flags. None is defined in this document. Flags
   MUST be clear on transmission an MUST be ignored at reception.

o SRGB: 3 octets of base followed by 3 octets of range. Note that
   the SRGB field MAY appear multiple times. If the SRGB field
   appears multiple times, the SRGB consists of multiple ranges.

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.

The originator SRGB describes the SRGB of the node where the BGP
Prefix SID is attached. It is used to build segment routing policies
when different SRGB's are used in the fabric
([I-D.ietf-spring-segment-routing-msdc]).

The originator SRGB may only appear on Prefix-SID attribute attached
to prefixes of SAFI 4 (labeled unicast, [RFC3107]).

4. Receiving BGP-Prefix-SID Attribute

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

4.1. MPLS Dataplane: Labeled Unicast

   A Multiprotocol BGP labeled IPv4/IPv6 Unicast ([RFC3107]) session
   type is required.

   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.

   Given a label_index L_I, we call L = L_I + SRGB_Start as the derived
   label. A BGP Prefix-SID attribute is called "unacceptable" for a
   speaker M if the derived label value L lies outside the SRGB
   configured on M. Otherwise the Label Index attribute is called
   "acceptable" to speaker M.

   The mechanisms through which a given label_index value is assigned to
   a given prefix are outside the scope of this document. The label-
   index value associated with a prefix is locally configured at the BGP
   node originating the prefix.

   The Prefix-SID attribute 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 "unacceptable" by the
   receiving speaker.

   If multiple prefixes are received with the same label_index value,
   all these prefixes MUST have their BGP Prefix-SID attribute
   considered as "unacceptable" by the receiving speaker.

   When a BGP speaker receives a path from a neighbor with an acceptable
   BGP Prefix-SID attribute, it MUST program the derived label as the
   local label for the prefix in its MPLS dataplane. In case of any
   error, a BGP speaker MUST resort to the error handling rules
   specified in Section 6. A BGP speaker MAY log an error for further
   analysis.

   When a BGP speaker receives a path from a neighbor with an
   unacceptable 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 (it does not have the capability or local policy

   disables the capability), it MUST treat the path as if it came
   without a Prefix-SID attribute. For the purposes of local label
   allocation, a BGP speaker MUST assign a local (also called dynamic)
   label (non-SRGB) for such a prefix as per classic Multiprotocol BGP
   labeled IPv4/IPv6 Unicast ([RFC3107]) operation. A BGP speaker MAY
   log an error for further analysis.

   The outgoing label is always programmed as per classic Multiprotocol
   BGP labeled IPv4/IPv6 Unicast (RFC3107 [RFC3107]) operation.

   Specifically, a BGP speaker receiving a prefix with a Prefix-SID
   attribute and a label NLRI field of implicit-null 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. The Label Index gives the information to the receiving node on
   which local/incoming label the BGP speaker SHOULD use.

4.2. IPv6 Dataplane

   When an SR IPv6 BGP speaker receives a IPv6 Unicast BGP Update with a
   prefix having the BGP Prefix-SID attribute attached, it checks
   whether the IPv6 SID TLV is present. If present, then the receiver
   assumes that the originator supports SR on the IPv6 dataplane.

   The Originator SRGB MUST be ignored on reception.

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

5. Announcing BGP-Prefix-SID Attribute

   The BGP Prefix-SID attribute MAY be attached to labeled BGP prefixes
   (IPv4/IPv6) [RFC3107] or to IPv6 prefixes [RFC4760]. In order to
   prevent distribution of the BGP Prefix-SID attribute beyond its
   intended scope of applicability, attribute filtering SHOULD be
   deployed.

5.1. MPLS Dataplane: Labeled Unicast

   A BGP speaker that originates a prefix attaches the Prefix-SID
   attribute when it advertises the prefix to its neighbors via
   Multiprotocol BGP labeled IPv4/IPv6 Unicast ([RFC3107]). The value
   of the Label-Index in the Label-Index TLV is determined by
   configuration.

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

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

In all cases, the label field of the advertised NLRI ([RFC3107],
[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 speakers interfaces, this label is the
usual MPLS label (such as the implicit or explicit NULL label).

5.2. IPv6 Dataplane

A BGP speaker that originates an IPv6 prefix with the Prefix-SID
attribute, MAY include the IPv6 SID TLV.

A BGP speaker that advertises a path received from one of its
neighbors SHOULD advertise the Prefix-SID received with the path
without modification regardless of whether the Prefix-SID was
acceptable. If the path did not come with a Prefix-SID attribute,
the speaker MAY attach a Prefix-SID to the path if configured to do
so.

6. Error Handling of BGP-Prefix-SID Attribute

When a BGP Speaker receives a BGP Update message containing a
malformed BGP Prefix-SID attribute, it MUST ignore the received BGP
Prefix-SID attributes and not pass it to other BGP peers. This is
equivalent to the -attribute discard- action specified in [RFC7606].
When discarding an attribute, a BGP speaker MAY log an error for
further analysis.

If the BGP Prefix-SID attribute appears more than once in an BGP
Update message, then, according to [RFC7606], all the occurrences of

the attribute other than the first one SHALL be discarded and the BGP
Update message SHALL continue to be processed.

When a BGP speaker receives an unacceptable Prefix-SID attribute, it
MAY log an error for further analysis.

7. IANA Considerations

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

Currently, IANA temporarily assigned the following:

   40 BGP Prefix-SID (TEMPORARY - registered 2015-09-30, expires
   2016-09-30) [draft-ietf-idr-bgp-prefix-sid]

This document defines 3 new TLVs for BGP Prefix-SID attribute. These
TLVs need to be registered with IANA. We request IANA to create a
new registry for BGP Prefix-SID Attribute TLVs as follows:

Under "Border Gateway Protocol (BGP) Parameters" registry, "BGP
Prefix-SID attribute Types" Reference: draft-ietf-idr-bgp-prefix-sid
Registration Procedure(s): Values 1-254 First Come, First Served,
Value 0 and 255 reserved

```
Value Type            Reference
0     Reserved        this document
1     Label-Index     this document
2     IPv6 SID        this document
3     Originator SRGB this document
4-254 Unassigned
255   Reserved        this document
```

8. Manageability Considerations

This document defines a new BGP attribute in order to address the use
case described in [I-D.ietf-spring-segment-routing-msdc]. It i
assumed that the new attribute (BGP Prefix-SID) advertisement 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
   originated and attached to a prefix. The operator MUST be capable
   of explicitly enabling the BGP Prefix-SID origination.

   o Prevent any undesired propagation of the BGP Prefix-SID attribute.
      By default the BGP Prefix-SID is not advertised outside the
      boundary of an AS. The propagation to other ASs MUST be
      explicitly configured.

   The deployment model described in
   [I-D.ietf-spring-segment-routing-msdc] assumes multiple Autonomous
   Systems (AS) under a common administration. The BGP Prefix-SID
   advertisement is therefore applicable to inter-AS context while it is
   confined within a single SR Domain.

9. Security Considerations

   This document introduces a new BGP attribute (BGP Prefix-SID) which
   inherits the security considerations expressed in: [RFC4271] and
   [RFC3107].

   The BGP Prefix-SID attribute addresses the requirements introduced in
   [I-D.ietf-spring-segment-routing-msdc] and It has to be noted, as
   described in Section 8, that this document refer to a deployment
   model where all nodes are under the same administration. In this
   context, we assume that the operator doesn't want to leak outside of
   the domain any information related to internal prefixes and topology.
   The internal information includes the BGP Prefix-SID. In order to
   prevent such leaking, the standard BGP mechanisms (filters) are
   applied on the boundary of the SR domain.

10. Contributors

   Keyur Patel
   Arrcus, Inc.
   US

   Email: Keyur@arrcus.com

   Saikat Ray
   Unaffiliated
   US

   Email: raysaikat@gmail.com

11. Acknowledgements

   The authors would like to thanks Satya Mohanty for his contribution
   to this document.

12. References

12.1. Normative References

   [I-D.ietf-spring-segment-routing]
              Filsfils, C., Previdi, S., Decraene, B., Litkowski, S.,
              and R. Shakir, "Segment Routing Architecture", draft-ietf-
              spring-segment-routing-12 (work in progress), June 2017.

   [I-D.ietf-spring-segment-routing-mpls]
              Filsfils, C., Previdi, S., Bashandy, A., Decraene, B.,
              Litkowski, S., and R. Shakir, "Segment Routing with MPLS
              data plane", draft-ietf-spring-segment-routing-mpls-10
              (work in progress), June 2017.

   [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>.

   [RFC3107] Rekhter, Y. and E. Rosen, "Carrying Label Information in
              BGP-4", RFC 3107, DOI 10.17487/RFC3107, May 2001,
              <https://www.rfc-editor.org/info/rfc3107>.

   [RFC4271] Rekhter, Y., Ed., Li, T., Ed., and S. Hares, Ed., "A
              Border Gateway Protocol 4 (BGP-4)", RFC 4271,
              DOI 10.17487/RFC4271, January 2006,
              <https://www.rfc-editor.org/info/rfc4271>.

   [RFC4364] Rosen, E. and Y. Rekhter, "BGP/MPLS IP Virtual Private
              Networks (VPNs)", RFC 4364, DOI 10.17487/RFC4364, February
              2006, <https://www.rfc-editor.org/info/rfc4364>.

   [RFC7606] Chen, E., Ed., Scudder, J., Ed., Mohapatra, P., and K.
              Patel, "Revised Error Handling for BGP UPDATE Messages",
              RFC 7606, DOI 10.17487/RFC7606, August 2015,
              <https://www.rfc-editor.org/info/rfc7606>.

12.2. Informative References

   [I-D.ietf-idr-bgp-ls-segment-routing-ext]
              Previdi, S., Psenak, P., Filsfils, C., Gredler, H., and M.
              Chen, "BGP Link-State extensions for Segment Routing",
              draft-ietf-idr-bgp-ls-segment-routing-ext-03 (work in
              progress), July 2017.

   [I-D.ietf-idr-bgpls-segment-routing-epe]
              Previdi, S., Filsfils, C., Patel, K., Ray, S., and J.
              Dong, "BGP-LS extensions for Segment Routing BGP Egress
              Peer Engineering", draft-ietf-idr-bgpls-segment-routing-
              epe-13 (work in progress), June 2017.

   [I-D.ietf-spring-segment-routing-msdc]
              Filsfils, C., Previdi, S., Mitchell, J., Aries, E., and P.
              Lapukhov, "BGP-Prefix Segment in large-scale data
              centers", draft-ietf-spring-segment-routing-msdc-05 (work
              in progress), June 2017.

   [RFC4760] Bates, T., Chandra, R., Katz, D., and Y. Rekhter,
              "Multiprotocol Extensions for BGP-4", RFC 4760,
              DOI 10.17487/RFC4760, January 2007,
              <https://www.rfc-editor.org/info/rfc4760>.

   [RFC7752] Gredler, H., Ed., Medved, J., Previdi, S., Farrel, A., and
              S. Ray, "North-Bound Distribution of Link-State and
              Traffic Engineering (TE) Information Using BGP", RFC 7752,
              DOI 10.17487/RFC7752, March 2016,
              <https://www.rfc-editor.org/info/rfc7752>.

Authors' Addresses

   Stefano Previdi (editor)
   Cisco Systems
   IT

   Email: stefano@previdi.net

   Clarence Filsfils
   Cisco Systems
   Brussels
   Belgium

   Email: cfilsfils@cisco.com

   Acee Lindem
   Cisco Systems
   170 W. Tasman Drive
   San Jose, CA 95124 95134
   USA

   Email: acee@cisco.com

      Arjun Sreekantiah
      Cisco Systems
      170 W. Tasman Drive
      San Jose, CA 95124 95134
      USA

      Email: asreekan@cisco.com

      Hannes Gredler
      RtBrick Inc.

      Email: hannes@rtbrick.com