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Distribution of Traffic Engineering (TE) Policies and State using BGP-LS

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Abstract

This document describes a mechanism to collect the Traffic Engineering and Policy information that is locally available in a router and advertise it into BGP-LS updates. Such information can be used by external components for path computation, re-optimization, service placement, network visualization, etc.

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].

Status of This Memo

Table of Contents

1. Introduction

In many network environments, traffic engineering policies are instantiated into various forms:

o MPLS Traffic Engineering Label Switched Paths (TE-LSPs).

- o IP based tunnels (IP in IP, GRE, etc).
- o Segment Routing Traffic Engineering Policies (SR TE Policy) as defined in [I-D.previdi-idr-segment-routing-te-policy]
- o Local cross-connect configuration

All this information can be grouped into the same term: TE Policies. In the rest of this document we refer to TE Policies as the set of information related to the various instantiation of polices: MPLS TE LSPs, IP tunnels (IPv4 or IPv6), SR TE Policies, etc.

TE Polices are generally instantiated by the head-end and are based on either local configuration or controller based programming of the node using various protocols and APIs, e.g., PCEP or BGP.

In many network environments, the configuration and state of each TE Policy that is available in the network is required by a controller which allows the network operator to optimize several functions and operations through the use of a controller aware of both topology and state information.

One example of a controller is the stateful Path Computation Element (PCE) [I-D.ietf-pce-stateful-pce], which could provide benefits in path reoptimization. While some extensions are proposed in Path Computation Element Communication Protocol (PCEP) for the Path Computation Clients (PCCs) to report the LSP states to the PCE, this mechanism may not be applicable in a management-based PCE architecture as specified in section 5.5 of [RFC4655]. As illustrated in the figure below, the PCC is not an LSR in the routing domain, thus the head-end nodes of the TE-LSPs may not implement the PCEP protocol. In this case a general mechanism to collect the TE-LSP states from the ingress LERs is needed. This document proposes an TE Policy state collection mechanism complementary to the mechanism defined in [I-D.ietf-pce-stateful-pce].

```
                                   -----------
                                  |   -----   |
              Service             |  | TED |<-+----------->
              Request             |   -----   |  TED synchronization
                 |                |     |     |  mechanism (for example,
                 v                |     |     |  routing protocol)
           ------------- Request/ |     v     |
          |             | Response|   -----   |
          |     NMS     |<--------+> | PCE |  |
          |             |         |   -----   |
           -------------           -----------
         Service |
         Request |
                 v
            ----------  Signaling   ----------
           | Head-End | Protocol   | Adjacent |
           |  Node    |<---------->|   Node   |
            ----------              ----------
```

                 Figure 1. Management-Based PCE Usage

In networks with composite PCE nodes as specified in section 5.1 of [RFC4655], PCE is implemented on several routers in the network, and the PCCs in the network can use the mechanism described in [I-D.ietf-pce-stateful-pce] to report the TE Policy information to the PCE nodes. An external component may also need to collect the TE Policy information from all the PCEs in the network to obtain a global view of the LSP state in the network.

In multi-area or multi-AS scenarios, each area or AS can have a child PCE to collect the TE Policies in its own domain, in addition, a parent PCE needs to collect TE Policy information from multiple child PCEs to obtain a global view of LSPs inside and across the domains involved.

In another network scenario, a centralized controller is used for service placement. Obtaining the TE Policy state information is quite important for making appropriate service placement decisions with the purpose to both meet the application's requirements and utilize network resources efficiently.

The Network Management System (NMS) may need to provide global visibility of the TE Policies in the network as part of the network visualization function.

BGP has been extended to distribute link-state and traffic engineering information to external components [RFC7752]. Using the same protocol to collect Traffic Engineering and Policy information

is desirable for these external components since this avoids introducing multiple protocols for network information collection. This document describes a mechanism to distribute traffic engineering and policy information (MPLS, IPv4 and IPv6) to external components using BGP-LS.

2. Carrying TE Policy Information in BGP

2.1. TE Policy Information

TE Policy information is advertised in BGP UPDATE messages using the MP_REACH_NLRI and MP_UNREACH_NLRI attributes [RFC4760]. The "Link-State NLRI" defined in [RFC7752] is extended to carry the TE Policy information. BGP speakers that wish to exchange TE Policy information MUST use the BGP Multiprotocol Extensions Capability Code (1) to advertise the corresponding (AFI, SAFI) pair, as specified in [RFC4760]. A new TLV carried in the Link_State Attribute defined in [RFC7752] is also defined in order to carry the attributes of a TE Policy (Section 2.3).

The format of "Link-State NLRI" is defined in [RFC7752]. A new "NLRI Type" is defined for TE Policy Information as following:

o NLRI Type: TE Policy NLRI (suggested codepoint value 5, to be assigned by IANA).

[RFC7752] defines the BGP-LS NLRI as follows:

```
   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
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |            NLRI Type          |     Total NLRI Length         |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |                                                               |
  //                  Link-State NLRI (variable)                 //
  |                                                               |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

This document defines a new NLRI-Type and its format: the TE Policy NLRI defined in the following section.

2.2. TE Policy NLRI

The TE Policy NLRI (NLRI Type 5. Suggested value, to be assigned by IANA) is shown in the following figure:

```
      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
     +-+-+-+-+-+-+-+-+-+
     |  Protocol-ID  |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                        Identifier                             |
     |                        (64 bits)                              |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     //                Headend (Node Descriptors)                   //
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     //                TE Policy Descriptors (variable)             //
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

where:

- o Protocol-ID field specifies the component that owns the TE Policy state in the advertising node. The following Protocol-IDs are defined (suggested values, to be assigned by IANA) and apply to the TE Policy NLRI:

Protocol-ID	NLRI information source protocol
8	RSVP-TE
9	Segment Routing

- o "Identifier" is an 8 octet value as defined in [RFC7752].

- o "Headend" consists of a Node Descriptor defined in [RFC7752].

- o "TE Policy Descriptors" consists of:

Codepoint	Descriptor TLV
267	Tunnel ID
268	LSP ID
269	IPv4/6 Tunnel Head-end address
270	IPv4/6 Tunnel Tail-end address
271	SR TE Policy
272	Local Cross Connect

2.2.1. TE Policy Descriptors

This sections defines the TE Policy Descriptors TLVs.

2.2.1.1. Tunnel Identifier (Tunnel ID)

The Tunnel Identifier TLV contains the Tunnel ID defined in [RFC3209] 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               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Tunnel ID             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

where:

o Type: To be assigned by IANA (suggested value: 267)

o Length: 2 octets.

o Tunnel ID: 2 octets as defined in [RFC3209].

2.2.1.2. LSP Identifier (LSP ID)

The LSP Identifier TLV contains the LSP ID defined in [RFC3209] 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               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            LSP ID             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

where:

o Type: To be assigned by IANA (suggested value: 268)

o Length: 2 octets.

o LSP ID: 2 octets as defined in [RFC3209].

2.2.1.3. IPv4/IPv6 Tunnel Head-End Address

The IPv4/IPv6 Tunnel Head-End Address TLV contains the Tunnel Head-End Address defined in [RFC3209] and has 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            |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  //        IPv4/IPv6 Tunnel Head-End Address (variable)         //
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

where:

- Type: To be assigned by IANA (suggested value: 269)

- Length: 4 or 16 octets.

When the IPv4/IPv6 Tunnel Head-end Address TLV contains an IPv4 address, its length is 4 (octets).

When the IPv4/IPv6 Tunnel Head-end Address TLV contains an IPv6 address, its length is 16 (octets).

2.2.1.4. IPv4/IPv6 Tunnel Tail-End Address

The IPv4/IPv6 Tunnel Tail-End Address TLV contains the Tunnel Tail-End Address defined in [RFC3209] and has 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            |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  //        IPv4/IPv6 Tunnel Tail-End Address (variable)         //
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

where:

- Type: To be assigned by IANA (suggested value: 270)

- Length: 4 or 16 octets.

When the IPv4/IPv6 Tunnel Tail-end Address TLV contains an IPv4 address, its length is 4 (octets).

When the IPv4/IPv6 Tunnel Tail-end Address TLV contains an IPv6 address, its length is 16 (octets).

2.2.1.5. SR TE Policy TLV

The SR TE Policy TLV identifies a SR TE Policy as defined in [I-D.previdi-idr-segment-routing-te-policy] 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               |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |                     Distinguisher (4 octets)                  |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |                     Policy Color (4 octets)                   |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |                     Endpoint (4 or 16 octets)                 |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

where:

- o Type: To be assigned by IANA (suggested value: 271)
- o Length: 12 octets.
- o Distinguisher, Policy Color and Endpoint are defined in [I-D.previdi-idr-segment-routing-te-policy].

2.2.1.6. MPLS Cross Connect

The MPLS Cross Connect TLV identifies a local MPLS state in the form of incoming label and interface followed by an outgoing label and interface. Outgoing interface may appear multiple times (for multicast states).

The Local Cross Connect 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              |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Incoming label (4 octets)                 |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Outgoing label (4 octets)                 |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    //                          Sub-TLVs (variable)                //
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

where:

- o Type: To be assigned by IANA (suggested value: 271)
- o Length: variable.
- o Incoming and Outgoing labels: 4 octets each.
- o Sub-TLVs: following Sub-TLVs are defined:
  - * Interface Sub-TLV
  - * Forwarding Equivalent Class (FEC)

The MPLS Cross Connect TLV:

MUST have an incoming label.

MUST have an outgoing label.

MAY contain an Interface Sub-TLV having the I-flag set.

MUST contain at least one Interface Sub-TLV having the I-flag unset.

MAY contain multiple Interface Sub-TLV having the I-flag unset. This is the case of a multicast MPLS cross connect.

MAY contain a FEC Sub-TLV.

2.2.1.6.1. MPLS Cross Connect Sub-TLVs

2.2.1.6.1.1. Interface Sub-TLV

The Interface sub-TLV is optional and contains the identifier of the interface (incoming or outgoing) in the form of an IPv4 address or an IPv6 address.

The Interface sub-TLV has the following format:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              Type             |          Length               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

+-+-+-+-+-+-+-+-+
|     Flags     |
+-+-+-+-+-+-+-+-+

+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Local Interface Identifier (4 octets)                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
//         Interface Address (4 or 16 octets)                  //
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

where:

- o Type: To be assigned by IANA (suggested value: 1)

- o Length: 9 or 21.

- o Flags: 1 octet of flags defined as follows:

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

where:

  * I-Flag is the Interface flag. When set, the Interface Sub-TLV describes an incoming interface. If the I-flag is not set, then the Interface Sub-TLV describes an outgoing interface.

- o Local Interface Identifier: a 4 octet identifier.

- o Interface address: a 4 octet IPv4 address or a 16 octet IPv6 address.

2.2.1.6.1.2. Forwarding Equivalent Class (FEC) Sub-TLV

The FEC sub-TLV is optional and contains the FEC associated to the incoming label.

The FEC sub-TLV has the following format:

```
  0                   1                   2                   3
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |             Type              |          Length               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |   Flags       |  Masklength   |   Prefix (variable)          //
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 //                      Prefix (variable)                       //
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

where:

o Type: To be assigned by IANA (suggested value: 2)

o Length: variable.

o Flags: 1 octet of flags defined as follows:

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

where:

* 4-Flag is the IPv4 flag. When set, the FEC Sub-TLV describes an IPv4 FEC. If the 4-flag is not set, then the FEC Sub-TLV describes an IPv6 FEC.

o Mask Length: 1 octet of prefix length.

o Prefix: an IPv4 or IPv6 prefix whose mask length is given by the " Mask Length" field.

2.3. TE Policy State

A new TLV called "TE Policy State TLV" (codepoint to be assigned by IANA), is used to describe the characteristics of the TE Policy, which is carried in the optional non-transitive BGP Attribute "LINK_STATE Attribute" defined in [RFC7752]. These TE Policy characteristics include the characteristics and attributes of the

policy, it's dataplane, explicit path, Quality of Service (QoS) parameters, route information, the protection mechanisms, etc.

```
 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            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Path-origin  |   Dataplane   |            RESERVED           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
//            TE Policy State Sub-TLVs (variable)              //
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

where:

TE Policy State TLV

o Type: Suggested value 1158 (to be assigned by IANA)

o Length: the total length of the TE Policy State TLV not including Type and Length fields.

o Path-origin: identifies the component (or protocol) from which the contained object originated. This allows for objects defined in different components to be collected while avoiding the possible code collisions among these components. Following path-origin codepoints are defined in this document (suggested values, to be assigned by IANA).

Code Point	Path Origin
1	RSVP-TE
2	PCE
3	BGP SR TE Policy
4	NETCONF
5	Static

o Dataplane: describes to which dataplane the policy is applied to. The following dataplane values are defined:

Code Point	Dataplane
1	MPLS-IPv4
2	MPLS-IPv6
3	IPv6

- o RESERVED: 16-bit field field. SHOULD be set to 0 on transmission and MUST be ignored on receipt.

TE Policy State sub-TLVs: objects as defined in [RFC3209],[RFC3473], [RFC5440] and [I-D.previdi-idr-segment-routing-te-policy]. Rather than replicating all these objects in this document, the semantics and encodings of the objects are reused. These objects are carried in the "TE Policy State Information" with the following format.

2.3.1. RSVP Objects

RSVP-TE objects are encoded in the "Value" field of the LSP State TLV and consists of MPLS TE LSP objects defined in RSVP-TE [RFC3209] [RFC3473]. Rather than replicating all MPLS TE LSP related objects in this document, the semantics and encodings of the MPLS TE LSP objects are re-used. These MPLS TE LSP objects are carried in the LSP State TLV.

When carrying RSVP-TE objects, the "Path-Origin" field is set to "RSVP-TE".

The following RSVP-TE Objects are defined:

- o SENDER_TSPEC and FLOW_SPEC [RFC2205]

- o SESSION_ATTRIBUTE [RFC3209]

- o EXPLICIT_ROUTE Object (ERO) [RFC3209]

- o ROUTE_RECORD Object (RRO) [RFC3209]

- o FAST_REROUTE Object [RFC4090]

- o DETOUR Object [RFC4090]

- o EXCLUDE_ROUTE Object (XRO) [RFC4874]

- o SECONDARY_EXPLICIT_ROUTE Object (SERO) [RFC4873]

- o SECONDARY_RECORD_ROUTE (SRRO) [RFC4873]
- o LSP_ATTRIBUTES Object [RFC5420]
- o LSP_REQUIRED_ATTRIBUTES Object [RFC5420]
- o PROTECTION Object [RFC3473][RFC4872][RFC4873]
- o ASSOCIATION Object [RFC4872]
- o PRIMARY_PATH_ROUTE Object [RFC4872]
- o ADMIN_STATUS Object [RFC3473]
- o LABEL_REQUEST Object [RFC3209][RFC3473]

For the MPLS TE LSP Objects listed above, the corresponding sub-objects are also applicable to this mechanism. Note that this list is not exhaustive, other MPLS TE LSP objects which reflect specific characteristics of the MPLS TE LSP can also be carried in the LSP state TLV.

2.3.2. PCE Objects

PCE objects are encoded in the "Value" field of the MPLS TE LSP State TLV and consists of PCE objects defined in [RFC5440]. Rather than replicating all MPLS TE LSP related objects in this document, the semantics and encodings of the MPLS TE LSP objects are re-used. These MPLS TE LSP objects are carried in the LSP State TLV.

When carrying PCE objects, the "Path-Origin" field is set to "PCE".

The following PCE Objects are defined:

- o METRIC Object [RFC5440]
- o BANDWIDTH Object [RFC5440]

For the MPLS TE LSP Objects listed above, the corresponding sub-objects are also applicable to this mechanism. Note that this list is not exhaustive, other MPLS TE LSP objects which reflect specific characteristics of the MPLS TE LSP can also be carried in the LSP state TLV.

2.3.3. SR TE Policy Sub-TLVs

Segment Routing Traffic Engineering Policy (SR TE Policy) as described in [I-D.previdi-idr-segment-routing-te-policy]makes use of the Tunnel Encapsulation Attribute defined in [I-D.ietf-idr-tunnel-encaps] and defines following sub-TLVs:

o Preference

o Binding SID

o Weight

o Segment List

o Segment

The equivalent sub-TLVs are defined hereafter and carried in the TE Policy State TLV. When carrying SR TE Policy objects, the "Path-Origin" field is set to "BGP SR TE Policy".

2.3.3.1. Preference Object

The Preference sub-TLV has the following format:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |   Length      |     Flags     |   RESERVED    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Preference (4 octets)                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

All fields, including type and length, are defined in [I-D.previdi-idr-segment-routing-te-policy].

2.3.3.2. SR TE Binding SID Sub-TLV

The Binding SID sub-TLV has the following format:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |   Length      |     Flags     |   RESERVED    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              Binding SID (variable, optional)                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

All fields, including type and length, are defined in [I-D.previdi-idr-segment-routing-te-policy].

[I-D.previdi-idr-segment-routing-te-policy] specifies the Binding SID sub-TLV which carries an indication of which value to allocate as Binding SID to the SR TE Policy. In the context of the BGP-LS extensions defined in this document, the Binding SID sub-TLV to the reciever of the , the Binding SID TLThe Binding SID sub-TLV contains the Binding SID the originator of the BGP-LS update has allocated to the corresponding SR TE Policy.

In the context of BGP-LS, the Binding SID sub-TLV defined in this document, contains the effective value of the Binding SID that the router allocated to the SR TE Policy. The router is the SR TE Policy receiver (as described in [I-D.previdi-idr-segment-routing-te-policy]) and it is also the originator of the corresponding BGP-LS update with the extensions defined in this document.

2.3.3.3. Weight Sub-TLV

The Weight sub-TLV has the following format:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |   Length      |     Flags     |   RESERVED    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                              Weight                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

All fields, including type and length, are defined in [I-D.previdi-idr-segment-routing-te-policy].

2.3.3.4. Segment List Sub-TLV

The Segment List object contains sub-TLVs (which in fact are sub-sub-TLVs) and has 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    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
//                            sub-TLVs                         //
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

o All fields, including type and length, are defined in [I-D.previdi-idr-segment-routing-te-policy].

o Length is the total length (not including the Type and Length fields) of the sub-TLVs encoded within the Segment List sub-TLV.

o sub-objects:

   * An optional single Weight sub-TLV.

   * One or more Segment sub-TLVs.

The Segment List sub-TLV is mandatory.

Multiple occurrences of the Segment List sub-TLV MAY appear in the SR TE Policy.

2.3.3.5. Segment Sub-TLV

The Segment sub-TLV describes a single segment in a segment list (i.e.: a single element of the explicit path). Multiple Segment sub-TLVs constitute an explicit path of the SR TE Policy.

[I-D.previdi-idr-segment-routing-te-policy] defines 8 different types of Segment Sub-TLVs:

Type 1: SID only, in the form of MPLS Label
Type 2: SID only, in the form of IPv6 address
Type 3: IPv4 Node Address with optional SID
Type 4: IPv6 Node Address with optional SID
Type 5: IPv4 Address + index with optional SID
Type 6: IPv4 Local and Remote addresses with optional SID
Type 7: IPv6 Address + index with optional SID
Type 8: IPv6 Local and Remote addresses with optional SID

2.3.3.5.1. Type 1: SID only, in the form of MPLS Label

The Type-1 Segment Sub-TLV encodes a single SID in the form of an MPLS label. The format is as follows:

```
 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     |   RESERVED    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Label                        | TC  |S|       TTL     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type, Length and values are defined in
[I-D.previdi-idr-segment-routing-te-policy].

2.3.3.5.2. Type 2: SID only, in the form of IPv6 address

The Type-2 Segment Sub-TLV encodes a single SID in the form of an
IPv6 address. The format is as follows:

```
 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     |   RESERVED    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
//                      IPv6 SID (16 octets)                   //
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type, Length and values are defined in
[I-D.previdi-idr-segment-routing-te-policy].

2.3.3.5.3. Type 3: IPv4 Node Address with optional SID

The Type-3 Segment Sub-TLV encodes an IPv4 node address and an
optional SID in the form of either an MPLS label or an IPv6 address.
The format is as follows:

```
 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     |   RESERVED    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 IPv4 Node Address (4 octets)                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
//                SID (optional, 4 or 16 octets)               //
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type, Length and values are defined in
[I-D.previdi-idr-segment-routing-te-policy].

2.3.3.5.4. Type 4: IPv6 Node Address with optional SID

The Type-4 Segment Sub-TLV encodes an IPv6 node address and an
optional SID in the form of either an MPLS label or an IPv6 address.
The format is as follows:

```
     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     |   RESERVED    |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    //               IPv6 Node Address (16 octets)                 //
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    //               SID (optional, 4 or 16 octets)                //
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type, Length and values are defined in [I-D.previdi-idr-segment-routing-te-policy].

2.3.3.5.5. Type 5: IPv4 Address + index with optional SID

The Type-5 Segment Sub-TLV encodes an IPv4 node address, an interface index and an optional SID in the form of either an MPLS label or an IPv6 address. The format is as follows:

```
     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     |   RESERVED    |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                IfIndex (4 octets)                             |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                IPv4 Node Address (4 octets)                   |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    //               SID (optional, 4 or 16 octets)                //
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type, Length and values are defined in [I-D.previdi-idr-segment-routing-te-policy].

2.3.3.5.6. Type 6: IPv4 Local and Remote addresses with optional SID

The Type-6 Segment Sub-TLV encodes an IPv4 node address, an adjacency local address, an adjacency remote address and an optional SID in the form of either an MPLS label or an IPv6 address. The format is as follows:

```
     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     |   RESERVED    |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                Local IPv4 Address (4 octets)                  |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                Remote IPv4 Address  (4 octets)                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    //                      SID (4 or 16 octets)                   //
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type, Length and values are defined in
[I-D.previdi-idr-segment-routing-te-policy].

2.3.3.5.7. Type 7: IPv6 Address + index with optional SID

The Type-7 Segment Sub-TLV encodes an IPv6 node address, an interface index and an optional SID in the form of either an MPLS label or an IPv6 address. The format is as follows:

```
     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     |   RESERVED    |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                 IfIndex (4 octets)                            |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    //                IPv6 Node Address (16 octets)                //
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    //                SID (optional, 4 or 16 octets)               //
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type, Length and values are defined in
[I-D.previdi-idr-segment-routing-te-policy].

2.3.3.5.8. Type 8: IPv6 Local and Remote addresses with optional SID

The Type-8 Segment Sub-TLV encodes an IPv6 node address, an adjacency local address, an adjacency remote address and an optional SID in the form of either an MPLS label or an IPv6 address. The format is as follows:

```
     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     |   RESERVED    |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    //              Local IPv6 Address (16 octets)                 //
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    //              Remote IPv6 Address  (16 octets)               //
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    //                    SID (4 or 16 octets)                     //
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type, Length and values are defined in [I-D.previdi-idr-segment-routing-te-policy].

3. Operational Considerations

The Existing BGP operational procedures apply to this document. No new operation procedures are defined in this document. The operational considerations as specified in [RFC7752] apply to this document.

In general, it is assumed that the TE Policy head-end nodes are responsible for the distribution of TE Policy state information, while other nodes, e.g. the nodes in the path of a policy, MAY report the TE Policy information (if available) when needed. For example, the border routers in the inter-domain case will also distribute LSP state information since the ingress node may not have the complete information for the end-to-end path.

4. IANA Considerations

This document requires new IANA assigned codepoints.

4.1. BGP-LS NLRI-Types

IANA maintains a registry called "Border Gateway Protocol - Link State (BGP-LS) Parameters" with a sub-registry called "BGP-LS NLRI-Types".

The following codepoints is suggested (to be assigned by IANA):

Type	NLRI Type	Reference
5	TE Policy NLRI type	this document

4.2. BGP-LS Protocol-IDs

IANA maintains a registry called "Border Gateway Protocol - Link State (BGP-LS) Parameters" with a sub-registry called "BGP-LS Protocol-IDs".

The following Protocol-ID codepoints are suggested (to be assigned by IANA):

Protocol-ID	NLRI information source protocol	Reference
8	RSVP-TE	this document
9	Segment Routing	this document

4.3. BGP-LS Descriptors TLVs

IANA maintains a registry called "Border Gateway Protocol - Link State (BGP-LS) Parameters" with a sub-registry called "Node Anchor, Link Descriptor and Link Attribute TLVs".

The following TLV codepoints are suggested (to be assigned by IANA):

TLV Code Point	Description	Value defined in
1158	TE Policy State TLV	this document
267	Tunnel ID TLV	this document
268	LSP ID TLV	this document
269	IPv4/6 Tunnel Head-end address TLV	this document
270	IPv4/6 Tunnel Tail-end address TLV	this document
271	SR TE Policy Identifier TLV	this document

4.4. BGP-LS LSP-State TLV Path Origin

This document requests IANA to maintain a new sub-registry under "Border Gateway Protocol - Link State (BGP-LS) Parameters". The new registry is called "Path Origin" and contains the codepoints allocated to the "Path Origin" field defined in Section 2.3. The registry contains the following codepoints (suggested values, to be assigned by IANA):

Code Point	Path Origin
1	RSVP-TE
2	PCE
3	BGP SR TE Policy
4	NETCONF
5	Static

4.5. BGP-LS LSP-State TLV Dataplane

This document requests IANA to maintain a new sub-registry under "Border Gateway Protocol - Link State (BGP-LS) Parameters". The new registry is called "Dataplane" and contains the codepoints allocated to the "dataplane" field defined in Section 2.3. The registry contains the following codepoints (suggested values, to be assigned by IANA):

Code Point	Dataplane
1	MPLS-IPv4
2	MPLS-IPv6
3	IPv6

5. Security Considerations

Procedures and protocol extensions defined in this document do not affect the BGP security model. See [RFC6952] for details.

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